



(51) International Patent Classification:

C22C 21/02 (2006.01) C22C 1/02 (2006.01)

C25D 11/02 (2006.01) C22C 1/06 (2006.01)

C25D 11/04 (2006.01) G01J 5/53 (2022.01)

(21) International Application Number:

PCT/CN2023/107381

(22) International Filing Date:

14 July 2023 (14.07.2023)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

202210847707.0 19 July 2022 (19.07.2022) CN

202221871034.4 20 July 2022 (20.07.2022) CN

202221863336.7 20 July 2022 (20.07.2022) CN

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: PLANE SURFACE BLACKBODY, PREPARATION METHOD, AND DEVICE THEREOF

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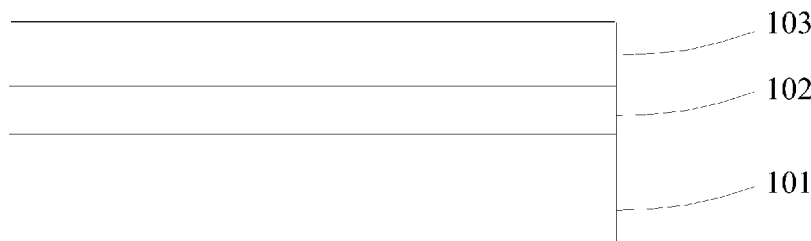


FIG. 1

(57) Abstract: A plane source blackbody. The plane source blackbody may include an aluminum alloy substrate, wherein the aluminum alloy substrate includes Mn with a mass fraction of 0.04%-0.07%, Cr with a mass fraction of 0.07%-0.12%, Er with a mass fraction of 0.09%-0.11%, and Pr with a mass fraction of 0.04%-0.06%.



**Published:**

— *with international search report (Art. 21(3))*

**PLANE SURFACE BLACKBODY, PREPARATION METHOD, AND DEVICE THEREOF****CROSS-REFERENCE TO RELATED APPLICATIONS**

**[0001]** This application claims priority to Chinese Patent Application No. 202210847707.0, filed on July 19, 2022, Chinese Patent Application No. 202221871034.4, filed on July 20, 2022, and Chinese Patent Application No. 202221863336.7, filed on July 20, 2022, the entire contents of each of which are incorporated herein by reference.

**TECHNICAL FIELD**

**[0002]** The present disclosure relates to the field of an infrared technology, in particular to a plane source blackbody, a preparation method and a device thereof.

**BACKGROUND**

**[0003]** As a standard radiation source of an infrared spectrum, a plane source blackbody is widely used in a calibration of plane source blackbody devices such as an infrared remote sensor and a thermal imager. With the development of the infrared technology, an application field of an infrared technology is becoming more and more extensive. The plane source blackbody includes an aluminum substrate and a coating coated on a surface of the aluminum substrate. A temperature uniformity, a stability and an emissivity are key performance for evaluating a quality of the plane source blackbody. Among them, a material and a surface roughness of the coating determine the emissivity of the plane source blackbody, and a performance of the aluminum substrate directly affects the temperature uniformity and the stability of the plane source blackbody. Therefore, it is expected to prepare a plane source blackbody with excellent temperature uniformity, stability and high emissivity by improving the aluminum substrate and the coating, so as to meet application scenarios with higher requirements for emissivity.

**SUMMARY**

**[0004]** One of the embodiments of the present disclosure provides a plane source blackbody. The plane source blackbody includes: an aluminum alloy substrate. The aluminum alloy substrate includes Mn with a mass fraction of 0.04%-0.07%, Cr with a mass fraction of 0.07%-0.12%, Er with a mass fraction of 0.09%-0.11%, and Pr with a mass fraction of 0.04%-0.06%.

**[0005]** In some embodiments, the aluminum alloy substrate may further include Si with a mass fraction of 6% -8%.

**[0006]** In some embodiments, the aluminum alloy substrate may further include Fe with a mass fraction of 0.4% -0.6%.

**[0007]** In some embodiments, the aluminum alloy substrate may further include Mg with a mass fraction of 0.2% -0.3%.

**[0008]** In some embodiments, a mass ratio of Fe to Mg in the aluminum alloy substrate may be 1.7:1 ~ 2.3:1.

**[0009]** In some embodiments, a mass ratio of Fe to Cr in the aluminum alloy substrate may be 4.8:1 ~ 5.8:1.

**[0010]** In some embodiments, a mass ratio of Fe to Mn in the aluminum alloy substrate may be 8.8:1 ~ 10.2:1.

**[0011]** In some embodiments, the plane source blackbody may further include an alumina layer arranged on the aluminum alloy substrate; and a radiation layer arranged on the alumina layer.

- [0012] In some embodiments, the aluminum alloy substrate and the alumina layer may be integrated as a whole.
- [0013] In some embodiments, a plurality of cavities may be arranged on a surface of the radiation layer away from the alumina layer. For each of the plurality of cavities, a size ratio of a depth of the cavity to a size of an opening of the cavity may be greater than or equal to 6; and the depths of the plurality of cavities may be less than a thickness of the radiation layer.
- [0014] In some embodiments, the size ratio of the depth of the cavity to the size of the opening of the cavity may be 6-10.
- [0015] In some embodiments, the depths of the plurality of cavities may be 54  $\mu\text{m}$  - 70  $\mu\text{m}$ .
- [0016] In some embodiments, a distance between adjacent two cavities of the plurality of cavities may be greater than or equal to 3  $\mu\text{m}$ .
- [0017] In some embodiments, the distance between the adjacent two cavities may be 3  $\mu\text{m}$  - 5  $\mu\text{m}$ .
- [0018] In some embodiments, the plurality of cavities may be arranged in an array.
- [0019] In some embodiments, the plurality of cavities may be cylinder cavities or cuboid cavities.
- [0020] In some embodiments, the plane source blackbody may further include a rare-earth fluoride layer arranged on a surface of the radiation layer away from the alumina layer.
- [0021] In some embodiments, the rare-earth fluoride layer may include a lanthanum trifluoride layer or an yttrium fluoride layer.
- [0022] In some embodiments, a thickness of the rare-earth fluoride layer may be 1200 nm - 1400 nm.
- [0023] In some embodiments, the rare-earth fluoride layer may include at least two sub-layers.
- [0024] In some embodiments, a thickness of each of the at least two sub-layers may be 320 nm-380 nm.
- [0025] In some embodiments, thicknesses of the at least two sub-layers may be the same.
- [0026] In some embodiments, materials of the at least two sub-layers may be the same.
- [0027] In some embodiments, a roughness of a surface of the alumina layer away from the aluminum alloy substrate may be  $R_{a1}$ , a roughness of a surface of the rare-earth fluoride layer away from the radiation layer may be  $R_{a2}$ , and  $R_{a1} > R_{a2}$ .
- [0028] One of the embodiments of the present disclosure provides a method for preparing an area-source blackbody. The method includes: preparing an aluminum alloy substrate, wherein the aluminum alloy substrate includes Mn with a mass fraction of 0.04%-0.07%, Cr with a mass fraction of 0.07%-0.12%, Er with a mass fraction of 0.09%-0.11%, and Pr with a mass fraction of 0.04%-0.06%; preparing an alumina layer on the aluminum alloy substrate; and preparing a radiation layer on the alumina layer to obtain the plane source blackbody.
- [0029] In some embodiments, preparing the aluminum alloy substrate may include: melting raw materials into an alloy liquid; refining the alloy liquid for degassing; pouring the refined alloy liquid into an ingot; obtaining a prefabricated member by performing a die-casting operation on the ingot; and obtaining the aluminum alloy substrate by performing an aging treatment on the prefabricated member.
- [0030] In some embodiments, a temperature of refining the alloy liquid for degassing may be 700°C - 710°C, and a duration time of refining the alloy liquid for degassing may be 10 minutes - 20 minutes.
- [0031] In some embodiments, in an operation of refining the alloy liquid for degassing, a nitrogen gas may be introduced, and an amount of refining agent may be 0.05% -0.15% with respect to a mass of the alloy

liquid.

**[0032]** In some embodiments, a temperature of the aging treatment may be 120°C - 160°C, and a duration time of the aging treatment may be 2h - 12h.

**[0033]** In some embodiments, the method may further include obtaining a plurality of cavities by performing a laser etching or a chemical etching on a surface of the radiation layer away from the alumina layer, wherein for each of the plurality of cavities, a size ratio of a depth of the cavity to a size of an opening of the cavity is greater than or equal to 6.

**[0034]** In some embodiments, the method may further include preparing a rare-earth fluoride layer on a surface of the radiation layer away from the alumina layer using at least one of sputtering, chemical vapor deposition, or evaporation.

**[0035]** One of the embodiments of the present disclosure provides a device for preparing the plane source blackbody. The device includes the aforementioned plane source blackbody.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0036]** The present disclosure is further described in terms of exemplary embodiments. These exemplary embodiments are described in detail with reference to the drawings. These embodiments are non-limiting exemplary embodiments, in which like reference numerals represent similar structures throughout the several views of the drawings, and wherein:

**[0037]** FIG. 1 is a schematic diagram illustrating an exemplary structure of a plane source blackbody according to some embodiments of the present disclosure;

**[0038]** FIG. 2 is another schematic diagram illustrating an exemplary structure of a plane source blackbody according to some embodiments of the present disclosure;

**[0039]** FIG. 3 is another schematic diagram illustrating an exemplary structure of a plane source blackbody according to some embodiments of the present disclosure;

**[0040]** FIG. 4 is another schematic diagram illustrating an exemplary structure of a plane source blackbody according to some embodiments of the present disclosure; and

**[0041]** FIG. 5 is a flowchart illustrating an exemplary process for preparing a plane source blackbody according to some embodiments of the present disclosure.

### DETAILED DESCRIPTION

**[0042]** In order to more clearly illustrate the technical solutions of the embodiments of the present disclosure, the following will briefly introduce the drawings that need to be used in the description of the embodiments. Obviously, drawings described below are only some examples or embodiments of the present disclosure. Those skilled in the art, without further creative efforts, may apply the present disclosure to other similar scenarios according to these drawings. It should be understood that the purposes of these illustrated embodiments are only provided to those skilled in the art to practice the application, and not intended to limit the scope of the present disclosure. Unless obviously obtained from the context or the context illustrates otherwise, the same numeral in the drawings refers to the same structure or operation.

**[0043]** It will be understood that the terms “system,” “device,” “unit,” and/or “module” used herein are one method to distinguish different components, elements, parts, sections, or assemblies of different levels. However, if other words may achieve the same purpose, the words may be replaced by other expressions.

**[0044]** As used herein, the singular forms "a," "an," "one," and/or "the" may be intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "include" and/or "comprise," when used in this disclosure, specify the presence of integers, devices, behaviors, stated features, steps, elements, operations, and/or components, but do not exclude the presence or addition of one or more other integers, devices, behaviors, features, steps, elements, operations, components, and/or groups thereof.

**[0045]** The flowcharts used in the present disclosure illustrate operations that systems implement according to some embodiments of the present disclosure. It should be understood that the preceding or following operations are not necessarily performed in the exact order. Instead, various operations may be processed in reverse order or simultaneously. Moreover, one or more other operations may be added to the flowcharts. One or more operations may be removed from the flowcharts.

**[0046]** FIG. 1 is a schematic diagram illustrating an exemplary structure of a plane source blackbody according to some embodiments of the present disclosure.

**[0047]** In some embodiments, the plane source blackbody includes an aluminum substrate. In some embodiments, the plane source blackbody further comprises an alumina layer arranged on any surface of the aluminum substrate, and a radiation layer arranged on the alumina layer. In some embodiments, the radiation layer is disposed on a surface of the alumina layer away from the aluminum substrate. In some embodiments, the aluminum substrate may be an aluminum alloy substrate or a pure aluminum substrate. In the present disclosure, an aluminum alloy substrate may be taken as an example for description.

**[0048]** As shown in FIG. 1, a plane source blackbody 100 includes an aluminum alloy substrate 101. In some embodiments, the plane source blackbody 100 may further include an alumina layer 102 and a radiation layer 103. In some embodiments, the alumina layer 102 may be arranged on any surface of the aluminum alloy substrate 101, and the radiation layer 103 may be arranged on any surface of the alumina layer 102 away from the aluminum alloy substrate 101.

**[0049]** The plane source blackbody may be a standard radiation source used for an infrared radiation detection.

**[0050]** The aluminum alloy substrate refers to an alloy substrate based on aluminum with a certain amount of other alloying elements added. For example, the other alloying elements may include at least one of Si, Fe, Mg, Mn, Cr, Er, and Pr, etc.

**[0051]** In some embodiments, the aluminum alloy substrate 101 may include Mn with a mass fraction of 0.04%-0.07%, Cr with a mass fraction of 0.07%-0.12%, Er with a mass fraction of 0.09%-0.11%, and Pr with a mass fraction of 0.04%-0.06%. In some embodiments, the aluminum alloy substrate 101 may further include Si with a mass fraction of 6%-8%. In some embodiments, the aluminum alloy substrate 101 may further include Fe with a mass fraction of 0.4%-0.6%. In some embodiments, the aluminum alloy substrate 101 may further include Mg with a mass fraction of 0.2%-0.3%.

**[0052]** In some embodiments, the aluminum alloy substrate 101 may be composed of Si with a mass fraction of 6%-8%, Fe with a mass fraction of 0.4%-0.6%, Mg with a mass fraction of 0.2%-0.3%, Mn with a mass fraction of 0.04%-0.07%, Cr with a mass fraction of 0.07%-0.12%, Er with a mass fraction of 0.09%-0.11%, Pr with a mass fraction of 0.04%-0.06%, unavoidable impurities, and the balance of aluminum. In some embodiments, the mass fraction of Si in the aluminum alloy substrate 101 may be 6%, 6.2%, 6.5%, 6.7%, 7%,

7.2%, 7.5%, 7.8%, 8%, etc. In some embodiments, the mass fraction of Si in the aluminum alloy substrate 101 may be 6%-7%, 7%-8%, 6.2%-7.8%, 6.5%-7.5%, 6.7%-7.2%, etc.

**[0053]** In some embodiments, the mass fraction of Fe in the aluminum alloy substrate 101 may be 0.4%, 0.42%, 0.45%, 0.47%, 0.5%, 0.52%, 0.55%, 0.57%, 0.6%, etc. In some embodiments, the mass fraction of Fe in the aluminum alloy substrate 101 may be 0.4%-0.5%, 0.5%-0.6%, 0.45%-0.55%, 0.42%-0.57%, 0.47%-0.52%, etc.

**[0054]** In some embodiments, the mass fraction of Mg in the aluminum alloy substrate 101 may be 0.2%, 0.22%, 0.25%, 0.28%, 0.3%, etc. In some embodiments, the mass fraction of Mg in the aluminum alloy substrate 101 may be 0.2%-0.25%, 0.25%-0.3%, 0.22%-0.28%, etc.

**[0055]** In some embodiments, the mass fraction of Mn in the aluminum alloy substrate 101 may be 0.04%, 0.05%, 0.06%, 0.07%, etc. In some embodiments, the mass fraction of Mn in the aluminum alloy substrate 101 may be 0.04%-0.05%, 0.04%-0.06%, 0.05%-0.06%, 0.05%-0.07%, 0.06%-0.07%, etc.

**[0056]** In some embodiments, the mass fraction of Cr in the aluminum alloy substrate 101 may be 0.07%, 0.08%, 0.09%, 0.10%, 0.11%, 0.12%, etc. In some embodiments, the mass fraction of Cr in the aluminum alloy substrate 101 may be 0.07%-0.08%, 0.07%-0.09%, 0.07%-0.10%, 0.07%-0.11%, 0.08%-0.10%, 0.08%-0.11%, 0.08%-0.12%, 0.09%-0.11%, 0.09%-0.12%, 0.10%-0.12%, etc.

**[0057]** In some embodiments, the mass fraction of Er in the aluminum alloy substrate 101 may be 0.09%, 0.10%, 0.11%, etc. In some embodiments, the mass fraction of Er in the aluminum alloy substrate 101 may be 0.09%-0.10%, 0.10%-0.11%, etc.

**[0058]** In some embodiments, the mass fraction of Pr in the aluminum alloy substrate 101 may be 0.04%, 0.05%, 0.06%, etc. In some embodiments, the mass fraction of Pr in the aluminum alloy substrate 101 may be 0.04%-0.05%, 0.05%-0.06%, etc.

**[0059]** In the aluminum alloy substrate, Fe and Mg exists in a Fe-Al-Si ternary phase and/or a Fe-Al-Si-Mg quaternary phase. The Fe-Al-Si ternary phase has an excellent thermal conductivity, and reduces a solid solubility of other materials while reducing a lattice distortion, thereby improving the thermal conductivity of the aluminum alloy substrate. However, electrode potentials of iron-rich phases such as the Fe-Al-Si ternary phase and the Fe-Al-Si-Mg quaternary phase are much higher than the electrode potential of the aluminum substrate, which increases an intergranular corrosion of the aluminum substrate. Therefore, it is difficult for the aluminum alloy substrate to have both the thermal conductivity and a corrosion resistance.

**[0060]** By designing the composition of the aluminum alloy substrate, for example, designing a type and content (mass fraction) of other alloying elements added to the aluminum alloy substrate, in the aluminum alloy substrate, Cr forms intermetallic compounds with the iron-rich phase to hinder a nucleation and growth process of a recrystallization, which plays a role in strengthening the alloy, reduces the intergranular corrosion of the alloy, and improves the corrosion resistance. At the same time, the thermal conductivity of the aluminum alloy substrate is hardly affected. Similarly, Mn forms intermetallic compounds with the iron-rich phase, which reduces the electrode potential of the iron-rich phase, reduces the intergranular corrosion of the alloy, and improves the corrosion resistance. At the same time, the thermal conductivity of the aluminum alloy substrate is hardly affected.

**[0061]** Er exists in an Er-Al binary phase, which increases a distance of a grain boundary precipitated phase, increases a discontinuity of the grain boundary precipitated phase, and further improves a stress corrosion

resistance and an intergranular corrosion resistance of the aluminum alloy substrate. In addition, a precipitated disperse strengthening phase hinders a dislocation movement on the one hand, and nucleates heterogeneously to refine grains on the other hand, thereby improving a toughness and a tensile strength of the alloy and ensuring basic performance requirements of the aluminum alloy substrate.

**[0062]** Pr reduces a hindrance of the binary phase to a phonon transmission, thereby improving the tensile strength and the thermal conductivity of the aluminum alloy substrate. At the same time, an influence of hydrogen is eliminated, so as to avoid embrittlement caused by hydrogen, and improve the stress corrosion resistance.

**[0063]** Therefore, the aluminum alloy substrate prepared in the present disclosure has excellent thermal conductivity, corrosion resistance, and tensile strength.

**[0064]** In a traditional aluminum alloy die casting, the mass fraction of silicon in an aluminum alloy ingot needs to reach 9.6%-12% to improve a fluidity of the aluminum alloy ingot in a molten state, so that the aluminum alloy substrate can be obtained by die-casting the aluminum alloy ingot. In the composition of the aluminum alloy substrate of the present disclosure, a relatively small amount of Si (e.g., with a mass fraction of 6%-8%) can improve a fluidity of the aluminum alloy ingot in a molten state so that the aluminum alloy substrate can be obtained by die-casting the aluminum alloy ingot, thereby not only reducing the amount of Si, but also simplifying a preparation process of the aluminum alloy substrate, so as to realize an industrial production of the aluminum alloy substrate, and reduce a production cost.

**[0065]** In some embodiments, a mass ratio of Fe to Mg in the aluminum alloy substrate 101 may be 1.7:1-2.3:1. In some embodiments, the mass ratio of Fe to Mg in the aluminum alloy substrate 101 may be 2:1. The mass ratio refers to the mass ratio of different elements in the aluminum alloy substrate. For example, the mass ratio of Fe to Mg of 1.7:1 may indicate that the mass of Fe is 1.7 grams or a multiple of 1.7 grams, and the mass of Mg is 1 gram or the same multiple of 1 gram, etc. The following mass ratios all indicate the mass ratios of different elements.

**[0066]** In some embodiments, the mass ratio of Fe to Cr in the aluminum alloy substrate 101 may be 4.8:1-5.2:1. In some embodiments, the mass ratio of Fe to Cr in the aluminum alloy substrate 101 may be 5:1.

**[0067]** In some embodiments, the mass ratio of Fe to Mn in the aluminum alloy substrate 101 may be 9.8:1-10.2:1. In some embodiments, the mass ratio of Fe to Mn in the aluminum alloy substrate 101 may be 10:1.

**[0068]** In some embodiments, the aluminum alloy substrate 101 and the alumina layer 102 may be an integrated structured. In some embodiments, the aluminum alloy substrate 101 and the alumina layer 102 may be separate structures.

**[0069]** In some embodiments, in the aluminum alloy substrate 101, copper and zinc are not included in the balance components other than unavoidable impurities.

**[0070]** Adding copper and zinc to the aluminum alloy substrate may reduce the thermal conductivity of the aluminum alloy substrate (referring to Embodiment 1.1, Comparative embodiment 1.1 and Comparative embodiment 1.2 in Table 1 below). For example, the addition of copper may cause a greater lattice distortion, resulting in a decrease in the thermal conductivity. Zinc added to the aluminum alloy substrate may react with the iron-rich phase (e.g., the Fe-Al-Si ternary phase and/or the Fe-Al-Si-Mg quaternary phase), weaken the high thermal conductivity of the binary phase, resulting in a decrease in the thermal conductivity. Therefore, the aluminum alloy substrate with copper and zinc cannot simultaneously have the thermal conductivity and

corrosion resistance of the aluminum alloy substrate.

**[0071]** In some embodiments, the alumina layer 102 may be obtained by any means on any surface of the aluminum alloy substrate, which is not limited in the present disclosure.

**[0072]** As an example, the alumina layer 102 may be obtained by in situ oxidation on any surface of the aluminum alloy substrate.

**[0073]** An oxidation mode may be selected from any one or more combinations of an anodic oxidation, a hard oxidation, and an arc oxidation, so that the aluminum alloy substrate and the alumina layer in the plane source blackbody have an excellent bonding force. At the same time, a thermal resistance between the alumina layer and the aluminum alloy substrate may be avoided as the thermal resistance may affect a measurement accuracy.

**[0074]** In some embodiments, the surface of the alumina layer 102 away from the aluminum alloy substrate 101 may be a rough surface, which better improves the bonding force between the radiation layer 103 and the alumina layer 102.

**[0075]** The radiation layer 103 may be selected from the materials with high emissivity. For example, the material may be a carbon nanotube, an inorganic coating, etc.

**[0076]** In some embodiments, the radiation layer may be a coating made of a paint including an inorganic powder. The inorganic powder may include: 1%-15% MgO, 35%-55% Cr<sub>2</sub>O<sub>3</sub>, 0.5%-8% MnO<sub>2</sub>, 0.5%-8% NiO, 1%-20% SiC and 1%-15% TiO<sub>2</sub> (by the mass fraction). The paint may also include a certain amount of solvents and conventional additives such as silicone resins, dispersants, and leveling agents. The composition of the radiation layer above is only an example, which is not limited in the present disclosure.

**[0077]** The radiation layer 103 may be made by any manners, for example, spraying, coating, etc., which is not limited in the present disclosure.

**[0078]** In some embodiments, a roughness of the surface of the radiation layer 103 away from the alumina layer 102 may be set as required.

**[0079]** In some embodiments, a thickness of the radiation layer 103 may be 10 μm-100 μm. In some embodiments, the thickness of the radiation layer may be 10 μm-70 μm. In some embodiments, the thickness of the radiation layer may be 60 μm-100 μm.

**[0080]** In the plane source blackbody described in some embodiments of the present disclosure, specific contents of Mn, Cr, Er, and Pr are added to the aluminum alloy substrate. A temperature transmission in the aluminum alloy substrate formed may be fast, so that an internal surface temperature of the plane source blackbody may be the same as the temperature of a temperature control system. At the same time, the temperature of the plane source blackbody may be uniform, which makes a calibration more accurate. At the same time, the aluminum alloy substrate may also have an excellent corrosion resistance, which effectively ensures a stability of the plane source blackbody. While achieving a low cost, the aluminum alloy substrate has the high thermal conductivity and corrosion resistance at the same time, thereby ensuring a temperature response rate and a temperature uniformity of the plane source blackbody, broadening application scenarios of the plane source blackbody, and improving a product competitiveness of the plane source blackbody.

## **Preparation of aluminum alloy substrate**

### **Embodiment 1.1**

[0081] Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.25%, Mn: 0.05%, Cr: 0.1%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

[0082] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

[0083] The refined alloy liquid was poured into an ingot, then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

#### **Embodiment 1.2**

[0084] Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 6%, Fe: 0.4%, Mg: 0.2%, Mn: 0.04%, Cr: 0.08%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

[0085] Then a refining degassing was carried out on the alloy liquid at 700°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After that the refining degassing, the alloy liquid was stand for 15 minutes.

[0086] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

#### **Embodiment 1.3**

[0087] Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 8%, Fe: 0.6%, Mg: 0.3%, Mn: 0.06%, Cr: 0.12%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

[0088] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 20 minutes.

[0089] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

#### **Embodiment 1.4**

[0090] Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added

to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 8%, Fe: 0.4%, Mg: 0.2%, Mn: 0.04%, Cr: 0.08%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

**[0091]** Then a refining degassing was carried out on the alloy liquid at 700°C. In the refining degassing, nitrogen gas was introduced, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 10 minutes.

**[0092]** The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 150°C for 4 h.

#### **Embodiment 1.5**

**[0093]** Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.25%, Mn: 0.05%, Cr: 0.1%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

**[0094]** Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 20 minutes.

**[0095]** The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 130°C for 6 h.

#### **Embodiment 1.6**

**[0096]** Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.25%, Mn: 0.05%, Cr: 0.1%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

**[0097]** Then a refining degassing was carried out at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

**[0098]** The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 150°C for 10 h to obtain an aluminum alloy substrate.

#### **Comparative Example 1.1**

**[0099]** Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, aluminum-copper alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.25%, Mn: 0.05%,

Cr: 0.1%, Er: 0.1%, Pr: 0.05%, Cu: 1%, unavoidable impurities, and the balance of aluminum.

[00100] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

[00101] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

[00102] The only difference between Comparative Example 1.1 and Embodiment 1.1 is that aluminum-copper alloy was further added to the molten aluminum to obtain the alloy liquid. The mass fraction of Cu in the alloy liquid was controlled to be 1%.

### Comparative Example 1.2

[00103] Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, aluminum-zinc alloy, and erbium ingots were added for melting, and then praseodymium ingots were added for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.25%, Mn: 0.05%, Cr: 0.1%, Er: 0.1%, Pr: 0.05%, Zn: 1%, unavoidable impurities, and the balance of aluminum.

[00104] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

[00105] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

[00106] The only difference between Comparative Example Comparative Example 1.2 and Embodiment 1.1 is that aluminum-zinc alloy was further added to the molten aluminum to obtain the alloy liquid. The mass fraction of Zn in the alloy liquid was controlled to be 1%.

### Comparative Example 1.3

[00107] Aluminum ingots was melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, the composition of the alloy liquid was controlled as Si: 7%, Fe: 0.1%, Mg: 0.25%, Mn: 0.05%, Cr: 0.1%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

[00108] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After that, the alloy liquid was stand for 15 minutes.

[00109] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

[00110] The only difference between Comparative Example 1.3 and Embodiment 1.1 is that the mass fraction of Fe in the alloy liquid was controlled to be 0.1%.

### Comparative Example 1.4

[00111] Aluminum ingots was melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 1%, Mg: 0.25%, Mn: 0.05%, Cr: 0.1%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

[00112] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

[00113] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h to obtain an aluminum alloy substrate.

[00114] The only difference between Comparative Example 1.4 and Embodiment 1.1 is that the mass fraction of Fe in the alloy liquid was controlled to be 1%.

#### **Comparative Example 1.5**

[00115] Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 1%, Mn: 0.05%, Cr: 0.1%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

[00116] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

[00117] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

[00118] The only difference between Comparative Example 1.5 and Embodiment 1.1 is that the mass fraction of Mg in the alloy liquid was controlled to be 1%.

#### **Comparative Example 1.6**

[00119] Aluminum ingots was melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.1%, Mn: 0.05%, Cr: 0.1%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

[00120] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

[00121] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated

member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

[00122] The only difference between Comparative Example 1.6 and Embodiment 1.1 is that the mass fraction of Mg in the alloy liquid was controlled to be 0.1%.

#### **Comparative Example 1.7**

[00123] Aluminum ingots was melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 1%, Cr: 0.1%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

[00124] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

[00125] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

[00126] The difference between Comparative Example 1.7 and embodiment 1.1 is that no aluminum-manganese alloy was added to the molten alloy, and there was no manganese in the alloy liquid except for unavoidable impurities.

#### **Comparative Example 1.8**

[00127] Aluminum ingots was melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 1%, Mn: 0.3%, Cr: 0.1%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

[00128] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas may be introduced, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

[00129] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

[00130] The only difference between Comparative Example 1.8 and Embodiment 1.1 is that the mass fraction of Mn in the alloy liquid was controlled to be 0.3%.

#### **Comparative Example 1.9**

[00131] Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.25%, Mn: 0.05%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

[00132] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

[00133] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

[00134] The only difference between Comparative Example 1.9 and Embodiment 1.1 is that no aluminum-chromium alloy was added when melting the alloy liquid, and except for unavoidable impurities, there was no chromium element in the excess component of the alloy liquid.

#### **Comparative Example 1.10**

[00135] Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.25%, Mn: 0.05%, Cr: 0.2%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

[00136] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

[00137] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

[00138] The only difference between Comparative Example 1.10 and embodiment 1.1 is that the mass fraction of Cr in the alloy liquid was controlled to be 0.2%.

#### **Comparative Example 1.11**

[00139] Aluminum ingots were melted at 730°C into molten aluminum liquid, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, and aluminum-chromium alloy were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.25%, Mn: 0.05%, Cr: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

[00140] Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

[00141] The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

[00142] The only difference between Comparative Example 1.11 and Embodiment 1.1 is that no erbium ingot was added to the molten aluminum to obtain the alloy liquid, and except for unavoidable impurities, there was no erbium element in the excess component of the alloy liquid.

#### **Comparative Example 1.12**

[00143] Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy,

aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.25%, Mn: 0.05%, Cr: 0.1%, Er: 0.3%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

**[00144]** Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

**[00145]** The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

**[00146]** The only difference between Comparative Example 1.12 and Embodiment 1.1 is that the mass fraction of Er in the alloy liquid was controlled to be 0.3%.

### **Comparative Example 1.13**

**[00147]** Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.25%, Mn: 0.05%, Cr: 0.1%, Er: 0.1%, unavoidable impurities, and the balance of aluminum.

**[00148]** Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

**[00149]** The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

**[00150]** The only difference between Comparative Example 1.13 and embodiment 1.1 is that no praseodymium ingot was added for modification treatment when preparing the alloy liquid, and except for unavoidable impurities, there was no praseodymium element in the excess component of the alloy liquid.

### **Comparative Example 1.14**

**[00151]** Aluminum ingots were melted at 730°C into molten aluminum liquid, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-manganese alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.25%, Mn: 0.05%, Cr: 0.1%, Er: 0.1%, Pr: 0.1%, unavoidable impurities, and the balance of aluminum.

**[00152]** Then a refining degassing was carried out on the alloy liquid at 710°C. In the refining degassing, nitrogen gas was introduced to the alloy liquid, and 0.1wt% refining agent was added to the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

**[00153]** The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

**[00154]** The only difference between Comparative Example 1.14 and Embodiment 1.1 is that the mass

fraction of Pr in the alloy liquid was controlled to be 0.1%.

#### Comparative Example 1.15

**[00155]** Aluminum ingots were melted at 730°C into molten aluminum, then aluminum-iron alloy, aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-zinc alloy, aluminum-chromium alloy, and erbium ingots were added to the molten aluminum for melting, and then praseodymium ingots were added to the molten aluminum for modification, to obtain an alloy liquid. In terms of mass fraction, a composition of the alloy liquid was controlled as Si: 7%, Fe: 0.5%, Mg: 0.25%, Zn: 0.1%, Cr: 0.1%, Er: 0.1%, Pr: 0.05%, unavoidable impurities, and the balance of aluminum.

**[00156]** Then a refining degassing was carried out on the alloy liquid at 710°C, nitrogen gas was introduced on the alloy liquid, and 0.1wt% refining agent was added on the alloy liquid. After the refining degassing, the alloy liquid was stand for 15 minutes.

**[00157]** The refined alloy liquid was poured into an ingot, and then the ingot was die-cast into a prefabricated member. An aluminum alloy substrate was obtained by aging the prefabricated member at 140°C for 4 h.

**[00158]** The only difference between Comparative Example 1.15 and Embodiment 1.1 is that aluminum-zinc alloy was added while no aluminum-manganese alloy was added when melting the alloy liquid, and except for unavoidable impurities, there was no Mn in the alloy liquid, while the mass fraction of Zn in the alloy liquid was 0.1%.

**[00159]** A performance (such as a thermal conductivity, a neutral salt spray time, a tensile strength) test was performed on the aluminum alloy substrates obtained in Embodiments 1.1-1.8 and Comparative Examples 1.1-1.15, and test results are shown in Table 1.

**[00160]** The thermal conductivity, also known as a thermal coefficient, reflects a heat transfer ability of a substance. Objects with high thermal conductivities are excellent thermal conductors, while objects with small thermal conductivities are poor thermal conductors or thermal insulators. A test standard of the thermal conductivity is a steady state heat flow method: different temperatures are applied on both sides of a sample to be tested, so that a temperature gradient is formed on upper and lower sides of the sample to be tested, making all heat flow passes through the sample to be tested vertically without a side heat spread.

**[00161]** Neutral salt spray test (NSS) refers to spray salt water including (5±0.5) % sodium chloride through a spraying device in a specific test chamber (an electroplating device), so as to make the salt spray settle on the sample to be tested, and observe a surface corrosion state of the sample to be tested after a certain period of time. The pH value of the salt water is 6.5-7.2. The temperature of the test chamber is required to be 35°C ± 2°C, a humidity is greater than 95%, a fog fall is 1-2 mL/(h·cm<sup>2</sup>), and a nozzle pressure is 78.5-137.3 kPa (0.8-1.4 kgf/cm<sup>2</sup>).

**[00162]** A test standard for a tensile strength includes: preparing a standard sample, and then testing the standard sample by a universal testing machine.

Table 1-Performance test results of the aluminum alloy substrates obtained in Embodiments 1.1-1.6 and Comparative Examples 1.1-1.15.

|                | Thermal conductivity(W/m•K) | Neutral salt spray(h) | Tensile strength (MPa) |
|----------------|-----------------------------|-----------------------|------------------------|
| Embodiment 1.1 | 190                         | 72                    | 292                    |

|                          |     |    |     |
|--------------------------|-----|----|-----|
| Embodiment 1.2           | 195 | 68 | 283 |
| Embodiment 1.3           | 185 | 70 | 290 |
| Embodiment 1.4           | 187 | 74 | 285 |
| Embodiment 1.5           | 187 | 72 | 288 |
| Embodiment 1.6           | 182 | 72 | 290 |
| Comparative Example 1.1  | 173 | 62 | 298 |
| Comparative Example 1.2  | 176 | 72 | 280 |
| Comparative Example 1.3  | 170 | 74 | 293 |
| Comparative Example 1.4  | 194 | 60 | 278 |
| Comparative Example 1.5  | 167 | 58 | 299 |
| Comparative Example 1.6  | 181 | 72 | 279 |
| Comparative Example 1.7  | 189 | 64 | 280 |
| Comparative Example 1.8  | 176 | 74 | 289 |
| Comparative Example 1.9  | 193 | 62 | 280 |
| Comparative Example 1.10 | 178 | 77 | 297 |
| Comparative Example 1.11 | 192 | 60 | 275 |
| Comparative Example 1.12 | 179 | 72 | 300 |
| Comparative Example 1.13 | 191 | 61 | 270 |
| Comparative Example 1.14 | 175 | 72 | 298 |
| Comparative Example 1.15 | 183 | 70 | 290 |

**[00163]** It can be seen from Table 1 that the aluminum alloy ingot formed according to the composition (in terms of mass fraction, 6%-8% of Si, 0.4%-0.6% of Fe, 0.2%-0.3% of Mg, 0.04%-0.07% of Mn, 0.07%-0.12% of Cr, 0.09-0.11% of Er, 0.04-0.06% of Pr, unavoidable impurities, and the balance of aluminum) provided in the present disclosure can be made into the aluminum alloy substrate by die casting. The aluminum alloy substrate has both high thermal conductivity (thermal conductivity  $\geq 185\text{W/m}\cdot\text{K}$ ) and corrosion resistance (neutral salt spray > 65 h), and aluminum alloy substrate also has excellent tensile strength ( $> 280\text{MPa}$ ).

**[00164]** When the mass fraction of any element of Si, Fe, Mg, Mn, Cr, Er, and Pr in the alloy liquid is beyond the corresponding numerical range, the aluminum alloy substrate cannot simultaneously achieve the high thermal conductivity and the corrosion resistance. When at least one element of copper and zinc is included in the alloy liquid, the thermal conductivity of the aluminum alloy substrate is reduced, and the high thermal conductivity and the corrosion resistance cannot be simultaneously achieved.

#### **Preparation of plane source blackbody**

##### **Application embodiment 1.1**

**[00165]** The aluminum alloy substrate obtained in Embodiment 1.1 was degreased, alkali washed, pickled, chemically polished, anodized, colored, sealed and dried in sequence. A solution used for anodization was  $\text{H}_2\text{SO}_4$  solution with a concentration of 20 %. The temperature of the solution was controlled at 25C, an anode current density was  $1.5\text{ A/dm}^2$ , a tank voltage was 20 V, and a time of the processing was controlled at 30

minutes. As a result, an alumina layer was prepared in situ on the aluminum alloy substrate.

**[00166]** Then a radiation layer was prepared on the alumina layer with a thickness of 50  $\mu\text{m}$  to obtain the plane source blackbody. In terms of mass fraction, an inorganic powder in a coating for preparing the radiation layer included: 14% MgO, 50%  $\text{Cr}_2\text{O}_3$ , 1%  $\text{MnO}_2$ , 5% NiO, 15% SiC, and 15%  $\text{TiO}_2$ .

#### Application Embodiments 1.2-1.6

**[00167]** A difference between Application Embodiments 1.2-1.6 and Application Embodiment 1.1 was that the aluminum alloy substrates was respectively prepared according to Application Embodiments 1.2-1.6.

#### Application Comparative Examples 1.1-1.15

**[00168]** The only difference between Application Comparative Examples 1.1-1.15 and Application Embodiment 1.1 is that the aluminum alloy substrates were respectively prepared according to Comparative Examples 1.1-1.15.

**[00169]** The surface source blackbodies prepared according to Application Embodiments 1.1-1.6 and according to Application Comparative Examples 1.1-1.15 were tested, and the test results are shown in Table 2. A FLIR E60 (an emissivity tester) was used to test an emissivity of the plane source blackbodies.

Table 2-Emissivity test results of the surface source blackbodies prepared by Application embodiments 1.1-1.6 and Application Comparative Examples 1.1-1.15

|                                     | Emissivity | Emissivity after salt spray for 72h | Change rate |
|-------------------------------------|------------|-------------------------------------|-------------|
| Application embodiment 1.1          | 0.987      | 0.987                               | 0%          |
| Application embodiment 1.2          | 0.988      | 0.985                               | 0.81%       |
| Application embodiment 1.3          | 0.985      | 0.983                               | 0.41%       |
| Application embodiment 1.4          | 0.986      | 0.986                               | 0%          |
| Application embodiment 1.5          | 0.986      | 0.986                               | 0%          |
| Application embodiment 1.6          | 0.986      | 0.985                               | 0.10%       |
| Application Comparative Example 1.1 | 0.98       | 0.965                               | 1.5%        |
| Application Comparative Example 1.2 | 0.982      | 0.982                               | 0%          |
| Application Comparative Example 1.3 | 0.981      | 0.981                               | 0%          |
| Application Comparative Example 1.4 | 0.988      | 0.967                               | 2.1%        |

|                                      |       |       |       |
|--------------------------------------|-------|-------|-------|
| Application Comparative Example 1.5  | 0.979 | 0.959 | 2.1%  |
| Application Comparative Example 1.6  | 0.981 | 0.981 | 0%    |
| Application Comparative Example 1.7  | 0.987 | 0.973 | 1.4%  |
| Application Comparative Example 1.8  | 0.982 | 0.982 | 0%    |
| Application Comparative Example 1.9  | 0.988 | 0.973 | 1.5%  |
| Application Comparative Example 1.10 | 0.983 | 0.983 | 0%    |
| Application Comparative Example 1.11 | 0.987 | 0.968 | 1.9%  |
| Application Comparative Example 1.12 | 0.983 | 0.983 | 0%    |
| Application Comparative Example 1.13 | 0.986 | 0.986 | 2.0%  |
| Application Comparative Example 1.14 | 0.982 | 0.982 | 0%    |
| Application Comparative Example 1.15 | 0.984 | 0.978 | 0.61% |

**[00170]** It can be seen from Tables 1 and 2 that although the aluminum alloy substrates prepared in Comparative Example 1.4, Comparative Example 1.7, Comparative Example 1.9 and Comparative Example 1.11 have excellent thermal conductivity, they cannot achieve the corrosion resistance at the same time. Therefore, a change rate of the emissivity of the surface source blackbodies in Application Comparative Examples 1.4, Application Comparative Example 1.7, Application Comparative Example 1.9, and Application Comparative Example 1.11 after 72 hours of salt spray are obviously greater than the change rate of the emissivity of the surface source blackbodies in application embodiments, which leads to an insufficient stability.

**[00171]** As the aluminum alloy substrates prepared in Comparative Example 1.2, Comparative Example 1.3, Comparative Example 1.8, Comparative Example 1.10, Comparative Example 1.12 and Comparative Example 1.15 have excellent corrosion resistance and poor thermal conductivity, the application of Comparative Example 1.2, Comparative Example 1.3, Comparative Example 1.8, Comparative Example 1.10, Comparative Example 1.12 and Comparative Example 1.15 have insufficient temperature transmission speed and uniformity, and their emissivity are not as good as that of the application embodiments.

**[00172]** As the thermal conductivity and the corrosion resistance of the aluminum alloy substrates made in Comparative Example 1.1 and Comparative Example 1.5 are both poor, the emissivity of the surface source

blackbodies using Comparative Example 1.1 and Comparative Example 1.5 is not as good as the emissivity of the surface source blackbodies using the application embodiments, and the change rate of the emissivity after 72 hours of salt spray is also significantly greater than the change rate of the emissivity of the application embodiments.

**[00173]** As the aluminum alloy substrate prepared in Comparative Example 1.6 had excellent corrosion resistance, and the thermal conductivity and the tensile strength of the aluminum alloy substrate prepared in Comparative Example 1.6 were poor, the basic performance requirements of the aluminum alloy substrate are not guaranteed, so the emissivity of the plane source blackbody of Comparative Example 1.6 is not be as good as the application embodiments.

**[00174]** Although the aluminum alloy substrate prepared in Comparative Example 1.13 has excellent thermal conductivity, the corrosion resistance and the tensile strength of the aluminum alloy substrate prepared in Comparative Example 1.13 are all poor, a change rate of the emissivity after 72 h of salt spray is significantly greater than a change rate of the Application embodiments.

**[00175]** Although the aluminum alloy substrate prepared in Comparative Example 1.14 has excellent corrosion resistance and tensile strength, but the thermal conductivity of the aluminum alloy substrate is relatively poor. As a result, the emissivity of the plane source blackbody applied in Comparative Example 1.14 is not as good as the emissivity of the plane source blackbody in the Application embodiments.

**[00176]** Meanwhile, the aluminum alloy substrate prepared through the application embodiment 1.1-1.8 has more excellent thermal conductivity, so the temperature transmission in the plane source blackbody in the application embodiment 1.1-1.8 is faster. As a result, the temperature of an inner surface of the plane source blackbody is more consistent with the temperature of an actual temperature control system. At the same time, the temperature of the plane source blackbody is more uniform, and the emissivity of the plane source blackbody is higher, making the calibration more accurate. At the same time, as the aluminum alloy substrate prepared in embodiments 1.1-1.8 of the present disclosure also has excellent corrosion resistance, the stability of the plane source blackbody is stronger. In addition, the aluminum alloy substrate prepared in embodiments 1.1-1.8 of the present disclosure also has relatively high tensile strength, thereby ensuring the basic performance requirement of the aluminum alloy substrate, so that the obtained surface source blackbody has relatively high quality.

**[00177]** FIG. 2 is another schematic diagram illustrating an exemplary structure of a plane source blackbody according to some embodiments of the present disclosure.

**[00178]** In some embodiments, in a plane source blackbody, a plurality of cavities may be arranged on a surface of a radiation layer away from an alumina layer. For each of the plurality of cavities, a size ratio of a depth of the cavity to a size of an opening of the cavity may be greater than or equal to 6, and the depths of the plurality of cavities may be less than a thickness of the radiation layer. In some embodiments, the plane source blackbody may include an aluminum substrate, the alumina layer, and the radiation layer, and the surface of the radiation layer away from the alumina layer may have the plurality of cavities. In some embodiments, the aluminum substrate may be an aluminum alloy substrate or a pure aluminum substrate.

**[00179]** As shown in FIG. 2, a plane source blackbody 200 may include an aluminum alloy substrate 201, an alumina layer 202, and a radiation layer 203, the surface of the radiation layer 203 away from the alumina layer may be arranged with a plurality of cavities 204. The aluminum alloy substrate may also be replaced by

a pure aluminum substrate. In some embodiments, the alumina layer 202 may be arranged on any surface of the aluminum alloy substrate 201, and the radiation layer 203 may be arranged on any surface of the alumina layer 202 away from the aluminum alloy substrate 201. In some embodiments, the aluminum alloy substrate 201 may be the aluminum alloy substrate 101 described in FIG. 1. In some embodiments, the aluminum alloy substrate 201 may also be an aluminum alloy substrate of other components, for example, an Al 6063 substrate.

**[00180]** The size ratio of a cavity refers to a ratio of a depth of the cavity to a size of an opening of the cavity. The depth of a cavity refers to a size of the depth of the cavity in a direction perpendicular to the radiation layer (e.g., the thickness direction of the radiation layer). The size of the opening of the cavity refers to the size of the opening of the cavity on the surface of the radiation layer away from the alumina layer. The size of the opening of the cavity may be set according to actual needs based on a geometry of the cavity. For example, if the opening of the cavity is circular (e.g., if the cavity is cylindrical, conical, frustoconical, etc.), the size of the opening of the cavity refers to a diameter of the circle. For another example, if the opening of the cavity is rectangular (e.g., if the cavity is cuboid, pyramidal, prismatic, trapezoidal, etc.), the size of the opening of the cavity refers to a length of a diagonal, a length of a long side, or a length of a short side of the rectangle. For another example, if the opening of the cavity is square (e.g., if the cavity is cuboid, regular pyramidal, etc.), the size of the opening of the cavity refers to a diagonal length or a side length of the square. For another example, if the opening of the cavity is a triangle (e.g., if the cavity is tetrahedral, triangular prism, etc.), the size of the opening of the cavity refers to the side length or a height of the triangle. For another example, if the opening of the cavity is a trapezoid (e.g., if the cavity is a trapezoidal prism, etc.), the size of the opening of the cavity refers to an upper bottom, a lower bottom, a waist, a height, etc. of the trapezoid. For another example, when the cavity is an irregular shape, the opening of the cavity may be an irregular shape, and the size of the opening of the cavity refers to the maximum value of a distance between any two points on a perimeter of the irregular shape, the maximum or minimum value of the distance between any point on the perimeter of the irregular shape and a geometric center of the irregular shape, etc. In some embodiments, the greater the size ratio, the greater an absorption rate of the radiation layer, and the greater an emissivity of the radiation layer. In some embodiments, the size ratio of the cavity may be 6-10.

**[00181]** In some embodiments, the size ratio of the cavity may be 6, 6.5, 7, 8, 9, 10, 11, 12, 13, 14, 15, etc. In some embodiments, the size ratio of the cavity may be greater than or equal to 6.5, greater than or equal to 7, greater than or equal to 8, greater than or equal to 9, greater than or equal to 10, etc. In some embodiments, the size ratio of the cavity may be 6-6.5, 6.5-10, etc.

**[00182]** In some embodiments, the depth of the cavity 204 may be smaller than the thickness of the radiation layer 203 to ensure a continuity of the radiation layer 203, thereby ensuring an emission performance of the radiation layer.

**[00183]** In some embodiments, the cavity may have a depth of 54  $\mu\text{m}$ -70  $\mu\text{m}$ .

**[00184]** The size ratios of the plurality of cavities 204 may be the same or different.

**[00185]** The distance between two adjacent cavities may be set according to actual needs. The distance between two adjacent cavities refers to a shortest distance between points on the openings of two adjacent cavities on the surface of the radiation layer away from the alumina layer. For example, if the openings of two adjacent cavities are two circles, the distance between the two adjacent cavities are the distance between the

centers of the two circles minus a radius sum of the two circles.

[00186] In some embodiments, the distance between two adjacent cavities may be greater than or equal to 3  $\mu\text{m}$ .

[00187] In some embodiments, the distance between two adjacent cavities may be 3  $\mu\text{m}$ -5  $\mu\text{m}$ .

[00188] In some embodiments, the distance between two adjacent cavities may be 3  $\mu\text{m}$ , 4  $\mu\text{m}$ , 5  $\mu\text{m}$ , 6  $\mu\text{m}$ , 7  $\mu\text{m}$ , etc. In some embodiments, the distance between two adjacent cavities may be greater than or equal to 4  $\mu\text{m}$ , greater than or equal to 5  $\mu\text{m}$ , etc. In some embodiments, the distance between two adjacent cavities may be 3  $\mu\text{m}$ -4  $\mu\text{m}$ , 3  $\mu\text{m}$ -5  $\mu\text{m}$ , 3  $\mu\text{m}$ -6  $\mu\text{m}$ , 4  $\mu\text{m}$ -5  $\mu\text{m}$ , 4  $\mu\text{m}$ -6  $\mu\text{m}$ , 4  $\mu\text{m}$ -7  $\mu\text{m}$ , 5  $\mu\text{m}$ -6  $\mu\text{m}$ , 5  $\mu\text{m}$ -7  $\mu\text{m}$ , etc.

[00189] The distance between adjacent cavities of the plurality of cavities may be the same or different.

[00190] If the distance between two adjacent cavities is too close, a mutual interference may occur, thereby affecting the emissivity. In some embodiments, by limiting the distance between two adjacent cavities, a possibility of the mutual interference may be reduced and a reduction of emissivity may be avoided.

[00191] In some embodiments, the arrangement of the plurality of cavities may be arbitrary. In some embodiments, the plurality of cavities may be arranged in an array. The plurality of cavities may also be arranged in a non-array manner.

[00192] In some embodiments, the geometry of the cavity 204 may be a regular geometry or an irregular geometry. In some embodiments, the cavity may be a regular geometric body, for example, a cylindrical cavity, a cuboid cavity, a cube cavity, etc.

[00193] The geometric shapes of the plurality of cavities may be the same or different.

[00194] The cavity may be obtained by laser etching or chemical etching.

[00195] The plane source blackbody provided by some embodiments of the present disclosure may have the plurality of cavities etched with a size ratio greater than or equal to 6 on the radiation layer, which increases an optical path of a photon propagation, reduces a photon scattering, and thereby reducing a photon loss, and increasing the emissivity, so that the emissivity of the plane source blackbody in the 8  $\mu\text{m}$ -14  $\mu\text{m}$  band may reach 0.99 and above.

#### **Embodiment 2.1**

[00196] Preparation of aluminum substrate: an aluminum substrate was obtained by processing Al 6063 substrate to a required size.

[00197] Preparation of alumina layer: the aluminum substrate was degreased, alkali washed, pickled, chemically polished, anodized, colored, sealed and dried in sequence. The solution used for anodize may be  $\text{H}_2\text{SO}_4$  solution with a concentration of 18%- 20%, a solution temperature was controlled at 18°C -25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a tank voltage was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the oxidized aluminum substrate.

[00198] Preparation of the radiation layer: inorganic powder, silicone resin, BYK-163, BYK-306 were performed a ball-milling operation for 12 hours to obtain a mixed slurry, then the mixed slurry and absolute ethanol were added to the container for dispersion to obtain a uniform dispersion. The inorganic powder was composed of the following raw materials: 14% MgO, 50% Cr<sub>2</sub>O<sub>3</sub>, 1% MnO<sub>2</sub>, 5% NiO, 15% SiC and 15% TiO<sub>2</sub>. The homogeneous dispersion obtained may be sprayed and deposited on an anodized aluminum substrate to obtain the radiant layer.

**[00199]** Laser processing: A laser processing was performed on the surface of the radiation layer of the plane source blackbody. The plane source blackbody was fixed on a femtosecond laser workbench. The femtosecond laser was modulated and split by a diffractive optical device (DOE) to form a 20\*20 laser point cloud array with uniform energy. The points were circular, energy diameters of the points were 9  $\mu\text{m}$ , and a distance (e.g., a distance between the centers of two adjacent laser points minus a radius sum of the two adjacent laser points) between two adjacent laser points in the laser point cloud array was 4  $\mu\text{m}$ . The laser point cloud array was directly written by laser. When direct writing, a material vapor was reduced through a side airflow mode, so as to reduce a generation of plasma, avoid a heat accumulation, reduce a heat-affected zone, improve a processing quality and efficiency of a laser drilling, and form a cylindrical cavity array with a size ratio of the depth of the cavity to the size of the opening of the cavity being 6. The size (e.g., the diameter) of the opening of the cavity was 9  $\mu\text{m}$ , and a distance between two adjacent cavities was 4  $\mu\text{m}$ . Then the array of cylinder cavities was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85 °C in a bake oven for 30 minutes.

## **Embodiment 2.2**

**[00200]** Preparation of aluminum substrate: the aluminum substrate was obtained by processing an Al 6063 substrate to a required size.

**[00201]** Preparing the alumina layer: the aluminum substrate was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was  $\text{H}_2\text{SO}_4$  solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1  $\text{A}/\text{dm}^2$ -2  $\text{A}/\text{dm}^2$ , a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum substrate.

**[00202]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials:  $\text{MgO}$  with a proportion of 14% in mass,  $\text{Cr}_2\text{O}_3$  with a proportion of 50% in mass,  $\text{MnO}_2$  with a proportion of 1% in mass,  $\text{NiO}$  with a proportion of 5% in mass,  $\text{SiC}$  with a proportion of 15% in mass, and  $\text{TiO}_2$  with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum substrate to obtain the radiation layer.

**[00203]** A laser processing: a laser processing was performed on a surface of the radiation layer of the plane source blackbody; and the plane source blackbody was fixed on a femtosecond laser workbench. A femtosecond laser was modulated and beamed by a diffractive optical element (DOE) to form a 20\*20 laser point cloud array with uniform energy. A laser point was circular, and an energy diameter of the laser point was 10  $\mu\text{m}$ . A distance between two adjacent laser points in the laser point cloud array was 5  $\mu\text{m}$ . The femtosecond laser was used to perform a transverse etching first, followed by a longitudinal etching, and a material vapor was reduced by a lateral blowing airflow during etching, thus reducing a generation of plasma, avoiding heat accumulation, reducing an area of a heat affected zone, and improving the processing quality and efficiency of laser drilling. And an array of cylinder cavities with a size ratio of a depth of a cavity to a size of an opening of the cavity being 6.5 was formed. The size (e.g., the diameter) of the opening of the cavity was

10  $\mu\text{m}$ . A distance between two adjacent cavities was 5  $\mu\text{m}$ . Then the array of cylinder cavities was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85  $^{\circ}\text{C}$  in a bake oven for 30 minutes.

### Embodiment 2.3

**[00204]** Preparing the alumina layer: the aluminum alloy substrate obtained in Embodiment 1.1 was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was  $\text{H}_2\text{SO}_4$  solution with a concentration of 18% -20%. A solution temperature was 18 $^{\circ}\text{C}$  - 25 $^{\circ}\text{C}$ , an anode current density was 1  $\text{A}/\text{dm}^2$ -2  $\text{A}/\text{dm}^2$ , a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum substrate.

**[00205]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials:  $\text{MgO}$  with a proportion of 14% in mass,  $\text{Cr}_2\text{O}_3$  with a proportion of 50% in mass,  $\text{MnO}_2$  with a proportion of 1% in mass,  $\text{NiO}$  with a proportion of 5% in mass,  $\text{SiC}$  with a proportion of 15% in mass, and  $\text{TiO}_2$  with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum substrate to obtain the radiation layer.

**[00206]** A laser processing: a laser processing was performed on a surface of the radiation layer of the plane source blackbody; and the plane source blackbody was fixed on a femtosecond laser workbench. A femtosecond laser was modulated and beamed by a diffractive optical element (DOE) to form a 20 \* 20 laser point cloud array with uniform energy. A laser point was circular, and an energy diameter of the laser point was 9  $\mu\text{m}$ . A distance between two adjacent laser points in the laser point cloud array was 4  $\mu\text{m}$ . The femtosecond laser was used to perform a laser direct writing, and a material vapor was reduced by a lateral blowing airflow during etching, thus reducing a generation of plasma, avoiding heat accumulation, reducing an area of a heat affected zone, and improving the processing quality and efficiency of laser drilling. And an array of cylinder cavities with a size ratio of a depth of a cavity to a size of an opening of the cavity being 6 was formed. The size (e.g., the diameter) of the opening of the cavity was 9  $\mu\text{m}$ . A distance between two adjacent cavities was 4  $\mu\text{m}$ . Then the array of cylinder cavities was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85  $^{\circ}\text{C}$  in a bake oven for 30 minutes.

### Embodiment 2.4

**[00207]** Preparing the alumina layer: the aluminum alloy substrate obtained in Embodiment 1.1 was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was  $\text{H}_2\text{SO}_4$  solution with a concentration of 18% -20%. A solution temperature was 18 $^{\circ}\text{C}$  - 25 $^{\circ}\text{C}$ , an anode current density was 1  $\text{A}/\text{dm}^2$ -2  $\text{A}/\text{dm}^2$ , a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum substrate.

**[00208]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The

inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass, Cr<sub>2</sub>O<sub>3</sub> with a proportion of 50% in mass, MnO<sub>2</sub> with a proportion of 1% in mass, NiO with a proportion of 5% in mass, SiC with a proportion of 15% in mass, and TiO<sub>2</sub> with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum substrate to obtain the radiation layer.

**[00209]** A laser processing: a laser processing was performed on a surface of the radiation layer of the plane source blackbody; and the plane source blackbody was fixed on a femtosecond laser workbench. A femtosecond laser was modulated and beamed by a diffractive optical element (DOE) to form a 20 \* 20 laser point cloud array with uniform energy. A laser point was circular, and an energy diameter of the laser point was 7 μm. A distance between two adjacent laser points in the laser point cloud array was 3 μm. The femtosecond laser was used to perform a laser direct writing, and a material vapor was reduced by a lateral blowing airflow during etching, thus reducing a generation of plasma, avoiding heat accumulation, reducing an area of a heat affected zone, and improving the processing quality and efficiency of laser drilling. And an array of cylinder cavities with a size ratio of a depth of a cavity to a size of an opening of the cavity being 10 was formed. The size (e.g., the diameter) of the opening of the cavity was 7 μm. A distance between two adjacent cavities was 3 μm. Then the array of cylinder cavities was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85 °C in a bake oven for 30 minutes.

#### **Embodiment 2.5**

**[00210]** Preparing the alumina layer: the aluminum alloy substrate obtained in Embodiment 1.1 was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was H<sub>2</sub>SO<sub>4</sub> solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum substrate.

**[00211]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass, Cr<sub>2</sub>O<sub>3</sub> with a proportion of 50% in mass, MnO<sub>2</sub> with a proportion of 1% in mass, NiO with a proportion of 5% in mass, SiC with a proportion of 15% in mass, and TiO<sub>2</sub> with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum substrate to obtain the radiation layer.

**[00212]** A laser processing: a laser processing was performed on a surface of the radiation layer of the plane source blackbody; and the plane source blackbody was fixed on a femtosecond laser workbench. A femtosecond laser was modulated and beamed by a diffractive optical element (DOE) to form a 20 \* 20 laser point cloud array with uniform energy. A laser point was circular, and an energy diameter of the laser point was 10 μm. A distance between two adjacent laser points in the laser point cloud array was 5 μm. The femtosecond laser was used to perform a laser direct writing, and a material vapor was reduced by a lateral blowing airflow during etching, thus reducing a generation of plasma, avoiding heat accumulation, reducing an area of a heat affected zone, and improving the processing quality and efficiency of laser drilling. And an

array of cylinder cavities with a size ratio of a depth of a cavity to a size of an opening of the cavity being 6.5 was formed. The size (e.g., the diameter) of the opening of the cavity was 10  $\mu\text{m}$ . A distance between two adjacent cavities was 5  $\mu\text{m}$ . Then the array of cylinder cavities was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85 °C in a bake oven for 30 minutes.

#### **Comparative Example 2.1**

**[00213]** Preparing the aluminum substrate: the aluminum substrate was obtained by processing an Al 6063 substrate into the aluminum substrate to a required size.

**[00214]** Preparing the alumina layer: the aluminum substrate was processed by an operation of anodizing. A solution used for anodizing was  $\text{H}_2\text{SO}_4$  solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes.

**[00215]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 15% in mass,  $\text{Cr}_2\text{O}_3$  with a proportion of 53% in mass,  $\text{MnO}_2$  with a proportion of 7% in mass, NiO with a proportion of 7% in mass, SiC with a proportion of 16% in mass, and  $\text{TiO}_2$  with a proportion of 7% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum substrate to obtain the radiation layer, and then a whole of the aluminum substrate, the alumina layer and the radiation layer was dried with a temperature of 180°C to obtain the plane source blackbody.

#### **Comparative Example 2.2**

**[00216]** Preparing the aluminum substrate: the aluminum substrate was obtained by processing an Al 6063 substrate into the aluminum substrate to a required size.

**[00217]** Preparing the alumina layer: the aluminum substrate was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was  $\text{H}_2\text{SO}_4$  solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum substrate.

**[00218]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 15% in mass,  $\text{Cr}_2\text{O}_3$  with a proportion of 53% in mass,  $\text{MnO}_2$  with a proportion of 7% in mass, NiO with a proportion of 7% in mass, SiC with a proportion of 16% in mass, and  $\text{TiO}_2$  with a proportion of 7% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum substrate to obtain the radiation layer, and then a whole of the aluminum substrate, the alumina layer and the radiation layer was dried with a temperature of 180°C to obtain the plane source blackbody.

#### **Comparative Example 2.3**

**[00219]** Preparing the alumina layer: processing the aluminum substrate by operations of degreasing, alkali

washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was  $\text{H}_2\text{SO}_4$  solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum substrate.

**[00220]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass,  $\text{Cr}_2\text{O}_3$  with a proportion of 50% in mass,  $\text{MnO}_2$  with a proportion of 1% in mass, NiO with a proportion of 5% in mass, SiC with a proportion of 15% in mass, and  $\text{TiO}_2$  with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum substrate to obtain the radiation layer.

**[00221]** A laser processing: a laser processing was performed on a surface of the radiation layer of the plane source blackbody; and the plane source blackbody was fixed on a femtosecond laser workbench. A femtosecond laser was modulated and beamed by a diffractive optical element (DOE) to form a 20 \* 20 laser point cloud array with uniform energy. A laser point was circular, and an energy diameter of the laser point was 9  $\mu\text{m}$ . A distance between two adjacent laser points in the laser point cloud array was 4  $\mu\text{m}$ . The femtosecond laser was used to perform a laser direct writing, and a material vapor was reduced by a lateral blowing airflow during etching, thus reducing a generation of plasma, avoiding heat accumulation, reducing an area of a heat affected zone, and improving the processing quality and efficiency of laser drilling. And an array of cylinder cavities with a size ratio of a depth of a cavity to a size of an opening of the cavity being 5 was formed. The size (e.g., the diameter) of the opening of the cavity was 9  $\mu\text{m}$ . A distance between two adjacent cavities was 4  $\mu\text{m}$ . Then the array of cylinder cavities was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85 °C in a bake oven for 30 minutes.

**[00222]** A difference between the Comparative Example 2.3 and the embodiment 2.3 is that the size ratio of the depth of the cavity to the size of the opening of the cavity of the cylinder cavity in the array formed in the Comparative Example 2.3 was 5, but the size ratio of the depth of the cavity to the size of the opening of the cavity of the cylinder cavity in the array formed in the embodiment 2.3 was 6.

#### **Comparative Example 2.4**

**[00223]** Preparing the alumina layer: the aluminum alloy substrate obtained in Embodiment 1.1 was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was  $\text{H}_2\text{SO}_4$  solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum substrate.

**[00224]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass,  $\text{Cr}_2\text{O}_3$

with a proportion of 50% in mass, MnO<sub>2</sub> with a proportion of 1% in mass, NiO with a proportion of 5% in mass, SiC with a proportion of 15% in mass, and TiO<sub>2</sub> with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum substrate to obtain the radiation layer.

**[00225]** A laser processing: a laser processing was performed on a surface of the radiation layer of the plane source blackbody; and the plane source blackbody was fixed on a femtosecond laser workbench. A femtosecond laser was modulated and beamed by a diffractive optical element (DOE) to form a 20 \* 20 laser point cloud array with uniform energy. A laser point was circular, and an energy diameter of the laser point was 9 μm. A distance between two adjacent laser points in the laser point cloud array was 2 μm. The femtosecond laser was used to perform a laser direct writing, and a material vapor was reduced by a lateral blowing airflow during etching, thus reducing a generation of plasma, avoiding heat accumulation, reducing an area of a heat affected zone, and improving the processing quality and efficiency of laser drilling. And an array of cylinder cavities with a size ratio of a depth of a cavity to a size of an opening of the cavity being 6 was formed. The size (e.g., the diameter) of the opening of the cavity was 9 μm. A distance between two adjacent cavities was 2 μm. Then the array of cylinder cavities was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85 °C in a bake oven for 30 minutes.

**[00226]** A difference between the Comparative Example 2.4 and the embodiment 2.3 is that the distance between two adjacent cavities in the Comparative Example 2.4 was 2 μm, but the distance between two adjacent cavities in the embodiment 2.3 was 4 μm.

#### **Comparative Example 2.5**

**[00227]** Preparing the aluminum substrate: the aluminum substrate was obtained by processing an Al 6063 substrate into the aluminum substrate to a required size.

**[00228]** Preparing the alumina layer: the aluminum substrate was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was H<sub>2</sub>SO<sub>4</sub> solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum substrate.

**[00229]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass, Cr<sub>2</sub>O<sub>3</sub> with a proportion of 50% in mass, MnO<sub>2</sub> with a proportion of 1% in mass, NiO with a proportion of 5% in mass, SiC with a proportion of 15% in mass, and TiO<sub>2</sub> with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum substrate to obtain the radiation layer.

**[00230]** Polishing: a sand blasting was performed on a surface of radiation layer of the plane source blackbody with 40 mesh emery. After being processed by the sand blasting, a surface roughness of the radiation layer was 8 μm.

**[00231]** A difference between the Comparative Example 2.5 and the embodiment 2.3 is that the surface of the

radiation layer in the Comparative Example 2.5 needed to be polished, and there was no cavity arranged on the surface of the radiation layer in the Comparative Example 2.5.

**[00232]** A device FLIR E60 was used to test an emissivity of the plane source blackbody prepared from Embodiments 2.1-2.5 and the Comparative Examples 2.1-2.5. A testing result is shown in Table 3.

Table 3-Testing result for testing an emissivity of the plane source blackbody prepared from Embodiments 2.1-2.5 and the Comparative Examples 2.1-2.5

|                         | Material of a substrate                             | Size ratio of a depth of a cavity to a size of an opening of a cavity | Depth of a cavity ( $\mu\text{m}$ ) | Size of an opening of the cavity ( $\mu\text{m}$ ) | Distance between two adjacent cavities ( $\mu\text{m}$ ) | Emissivity (%) |
|-------------------------|-----------------------------------------------------|-----------------------------------------------------------------------|-------------------------------------|----------------------------------------------------|----------------------------------------------------------|----------------|
| Embodiment 2.1          | AL6063 substrate                                    | 6                                                                     | 54                                  | 9                                                  | 4                                                        | 0.991          |
| Embodiment 2.2          | AL6063 substrate                                    | 6.5                                                                   | 65                                  | 10                                                 | 5                                                        | 0.99           |
| Embodiment 2.3          | Aluminum alloy substrate prepared in Embodiment 1.1 | 6                                                                     | 54                                  | 9                                                  | 4                                                        | 0.993          |
| Embodiment 2.4          | Aluminum alloy substrate prepared in Embodiment 1.1 | 10                                                                    | 70                                  | 7                                                  | 3                                                        | 0.994          |
| Embodiment 2.5          | Aluminum alloy substrate prepared in Embodiment 1.1 | 6.5                                                                   | 65                                  | 10                                                 | 5                                                        | 0.992          |
| Comparative Example 2.1 | AL6063 substrate                                    | /                                                                     | /                                   | /                                                  | /                                                        | 0.989          |
| Comparative Example 2.2 | AL6063                                              | /                                                                     | /                                   | /                                                  | /                                                        | 0.983          |
| Comparative Example 2.3 | Aluminum alloy substrate prepared in Embodiment 1.1 | 5                                                                     | 45                                  | 9                                                  | 4                                                        | 0.988          |
| Comparative Example 2.4 | Aluminum alloy substrate prepared in Embodiment 1.1 | 6                                                                     | 54                                  | 9                                                  | 2                                                        | 0.989          |
| Comparative Example 2.5 | AL6063 substrate                                    | /                                                                     | /                                   | /                                                  | /                                                        | 0.985          |

**[00233]** As shown in Table 3, emissivity of the plane source blackbodies with cavities prepared in Embodiment 2.1, Comparative Examples 2.1, 2.2, and 2.5 are higher than emissivity of the plane source blackbodies prepared in other Embodiments or Comparative Examples.

**[00234]** By comparing the Embodiment 2.3 and Comparative Example 2.3 in Table 3, an emissivity of a plane source blackbody with cavities arranged on the radiation layer with a size ratio of a depth of a cavity to a size of an opening of the cavity greater than or equal to 6 is higher, and the emissivity is up to 0.993.

**[00235]** By comparing the Embodiment 2.3 and Comparative Example 2.4 in Table 3, an emissivity of a plane source blackbody with cavities arranged on the radiation layer with a distance between two adjacent cavities greater than or equal to 3 is higher, and the emissivity is up to 0.993.

**[00236]** By comparing the Embodiment 2.3 and Comparative Example 2.5 in Table 3, an emissivity of the plane source blackbody with cavities arranged on the radiation layer is much higher than an emissivity of the plane source blackbody with a randomly polished radiation layer. Since a concave-convex structure formed by a random polishing on a surface of the radiation layer is random and irregular, and the size ratio of the depth of the cavity to the size of the opening of the cavity cannot be accurately adjusted, thus increasing the scattering of photons and increasing the photon loss, thus a relatively high emissivity cannot be reached.

**[00237]** By comparing the Embodiment 2.1 and Embodiments 2.3 in Table 3, an emissivity of a plane source blackbody made of aluminum alloy is higher than an emissivity of a plane source blackbody made of AL6063 substrate.

**[00238]** Accordingly, selecting an aluminum alloy substrate to prepare a plane source blackbody, and providing a plurality of cavities with a size ratio of a depth of a cavity to a size of an opening of the cavity greater than or equal to 6 on the surface of the radiation layer of the plane source blackbody may effectively improve the photon transmission distance, thus further improving the emissivity of the plane source blackbody in a wave range of 8  $\mu\text{m}$  - 14  $\mu\text{m}$ . Thus, the plane source blackbody provided in the present disclosure may further improve the emissivity of the plane source blackbody without changing the structure and material of the plane source blackbody, and the plane source blackbody may be directly compatible with the existing device of the plane source blackbody.

**[00239]** FIG. 3 is a schematic diagram illustrating an exemplary structure of a plane source blackbody according to some embodiments of the present disclosure.

**[00240]** In some embodiments, the plane source blackbody may include a rare-earth fluoride layer arranged on a surface of a radiation layer away from an alumina layer.

**[00241]** In some embodiments, the plane source blackbody may include an aluminum substrate, an alumina layer, a radiation layer, and a rare-earth fluoride layer.

**[00242]** As shown in FIG. 3, the plane source blackbody 300 may include an aluminum alloy substrate 301, an alumina layer 302, a radiation layer 303, and a rare-earth fluoride layer 304. The aluminum alloy substrate 301, the alumina layer 302 and the radiation layer 303 may be referred to as a body 30. That is, the plane source blackbody 300 may include the body 30 and the rare-earth fluoride layer 304. The aluminum alloy substrate may be replaced by a pure aluminum substrate, and/or the radiation layer may be provided with a plurality of cavities as illustrated in FIG. 2. In some embodiments, the alumina layer 302 may be arranged on the aluminum alloy substrate 301, and the radiation layer 303 may be arranged on a surface of the alumina layer 302 away from the aluminum alloy substrate 301. In some embodiments, the aluminum alloy substrate

301 may be the same as the aluminum alloy substrate 101 described in FIG. 1. In some embodiments, the aluminum alloy substrate 301 may also be an aluminum alloy substrate made of other materials, such as an Al 6063 substrate. In some embodiments, the radiation layer 303 may be the same as the radiation layer 203 including a plurality of cavities described in FIG. 2, or a radiation layer without cavities.

**[00243]** In some embodiments, the rare-earth fluoride layer 304 may include a lanthanum trifluoride layer, a cerium fluoride layer, a praseodymium fluoride layer, a neodymium (III) fluoride layer, a promethium (III) fluoride layer, a samarium (III) fluoride layer, a europium (III) fluoride layer, a gadolinium (III) fluoride layer, a terbium fluoride layer, a dysprosium (III) fluoride layer, a holmium (III) fluoride layer, an erbium (III) fluoride layer, a thulium fluoride layer, an ytterbium fluoride layer, a lutetium (III) fluoride layer, a scandium fluoride layer, or an yttrium fluoride layer.

**[00244]** In some embodiments, the rare-earth fluoride layer 304 may include a lanthanum trifluoride layer or an yttrium fluoride layer.

**[00245]** A preparation method of the rare-earth fluoride layer 304 may be related to whether the plurality of cavities are arranged on the radiation layer 303. For example, when there is no cavity arranged on the radiation layer 303, the rare-earth fluoride layer 304 may be directly prepared on the radiation layer 303. When the plurality of cavities are arranged on the radiation layer 303, the rare-earth fluoride layer 304 may need to be prepared on the substrate first, and then be transferred to the radiation layer 303.

**[00246]** Specifically, when there is no cavity arranged on the radiation layer 303, the rare-earth fluoride layer 304 may be prepared on the radiation layer 303 using at least one of sputtering, chemical vapor deposition, or evaporation, or the like.

**[00247]** In some embodiments, when the plurality of cavities are arranged on the radiation layer 303, the rare-earth fluoride layer may be provided on the surface of the radiation layer away from the alumina layer in a variety of ways. For example, the rare-earth fluoride layer 304 may be prepared on a substrate (e.g., a substrate made of polydimethylsiloxane (PDMS)), and then the prepared rare-earth fluoride layer 304 may be transferred to surfaces of the plurality of cavities arranged on the radiation layer 303. A transferring method may include hot pressing, etc. In some embodiments, the substrate may be modified first, and then the rare-earth fluoride layer 304 may be prepared on the modified substrate, and then the rare-earth fluoride layer may be transferred from the substrate to the surfaces of the plurality of cavities. The purpose of the substrate modification is to weaken the bonding force between the substrate and the rare-earth fluoride layer. Because the rare earth fluoride is non-polar, by, e.g., hydrophilic modification on the surface of the substrate, such as the use of silane coupling agent, plasma treatment, etc., the bonding force between the substrate and the film layer is weakened, which makes the rare-earth fluoride layer easy to be transferred from the substrate. In some embodiments, the rare-earth fluoride layer 304 may be prepared on the substrate by evaporation. In this way, the rare-earth fluoride layer and the substrate may be combined by the Van der Waals with a weak binding force. The rare-earth fluoride layer may be bonded with the surfaces of the plurality of cavities arranged on the radiation layer 303 by a hot pressing. The rare-earth fluoride layer and the surfaces of the plurality of cavities arranged on the radiation layer 303 may be bonded by hydrogen bonds with a stronger binding force, which is easier to transfer the rare-earth fluoride layer from the substrate to the surfaces of the plurality of cavities arranged on the radiation layer 303.

**[00248]** The rare-earth fluoride layer with a certain refractive index and a certain thickness may be

determined based on the principle of coherent subtraction and a transfer matrix. The arrangement of the rare-earth fluoride layer 304 reduces the loss of the emissivity of the body 30, and further improves the emissivity of the plane source blackbody in a wave range of 8  $\mu\text{m}$  - 14  $\mu\text{m}$ .

**[00249]** If a thickness of the rare-earth fluoride layer is too large, an internal stress of the rare-earth fluoride layer is greater, the reliability of the rare-earth fluoride layer is poorer, thus the rare-earth fluoride layer may be easy to crack, thus affecting the quality and effectiveness of the plane source blackbody. If the thickness of the rare-earth fluoride layer is too small, the effect of emission loss may be weakened in the mid infrared band. In some embodiments, the thickness of the rare-earth fluoride layer 304 may be 1200 nm-1400 nm. The thickness of the rare-earth fluoride layer 304 may be obtained based on the transfer matrix. In some embodiments, the thickness of the rare-earth fluoride layer 304 may be 1200 nm, 1250 nm, 1280 nm, 1300 nm, 1320 nm, 1350 nm, 1370, 1400 nm, etc. In some embodiments, the thickness of rare-earth fluoride layer 304 may be 1200 nm-1280 nm, 1200 nm-1300 nm, 1200 nm-1320 nm, 1200 nm-1350 nm, 1200 nm-1370 nm, 1250 nm-1300 nm, 1230 nm-1320 nm, 1250 nm-1350 nm, 1250 nm-1370 nm, 1250 nm-1400 nm, 1280 nm-1320 nm, 1280 nm-1350 nm, 1280 nm-1370 nm, 1280 nm-1400 nm, 1300 nm-1350 nm, 1300 nm-1370 nm, 1300 nm-1400 nm, 1320 nm-1370 nm, 1320 nm-1400 nm, 1350 nm-1400 nm, 1370 nm-1400 nm, etc.

**[00250]** In some embodiments, the rare-earth fluoride layer 304 may include at least two sub-layers.

**[00251]** FIG. 4 is a schematic diagram illustrating an exemplary structure of a plane source blackbody according to some embodiments of the present disclosure. As shown in FIG. 4, a rare-earth fluoride layer 304 may include at least two sub-layers 304-1. For example, rare-earth fluoride layer 304 may include two sub-layers 304-1, three sub-layers 304-1, four sub-layers 304-1, or the like. A count of the at least two sub-layers may be determined based on actual requirements. The more sub-layers are, the greater the internal stress of the rare-earth fluoride layer is, which may be easy to cause problems such as cracking, thus affecting an emissivity of the plane source blackbody, and a dislocation between the at least two sub-layers may be more likely to occur, reducing the stability of the rare-earth fluoride layer. In addition, the more the sub-layers are, the more times the operation of sputtering are needed to be performed. Each sputtering is equivalent to a bombardment on the substrate, affecting the stability of the substrate. At the same time, the complexity of the whole processes for preparing the plane source blackbody may be increased and the stability of the whole processes may be reduced.

**[00252]** In some embodiments, when the rare-earth fluoride layer 304 may include the at least two sub-layers 304-1, a thickness of each of the at least sub-layers 304-1 in the rare-earth fluoride layer 304 may be 50 nm, 100 nm, 200 nm, 300 nm, 320 nm, 330 nm, 350 nm, 380 nm, 400 nm, 500 nm, 600 nm, 700 nm, 800 nm, etc. In some embodiments, the thickness of each of the at least two sub-layers 304-1 in the rare-earth fluoride layer 304 may be 300 nm-500 nm.

**[00253]** In some embodiments, the thickness of each of the at least two sub-layers 304-1 in the rare-earth fluoride layer 304 may be 320 nm-380 nm. In some embodiments, a range of the thickness of each of the at least two sub-layers in the rare-earth fluoride layer 304 may be determined based on the transfer matrix.

**[00254]** In some embodiments, the thickness of each of the at least two sub-layers 304-1 in the rare-earth fluoride layer 304 may be independently 320 nm-330 nm, 320 nm-350 nm, 330 nm-350 nm, 330 nm-380 nm, 350 nm-380 nm, etc.

**[00255]** For each of the at least two sub-layers, a transmittance of each of the at least two sub-layers in the

mid infrared band may be related to a refractive index and the thickness of the sub-layer, and the transmittance in the mid infrared band may be adjusted by adjusting the thickness of the sub-layer. According to a calculation result of a transfer matrix, in the mid infrared band, the transmittance of the sub-layer may be the best when the thickness of the sub-layer is in a range of 320 nm-380 nm.

**[00256]** In some embodiments, when the rare-earth fluoride layer 304 includes at least two stacked sub-layers 304-1, the thickness of the at least two sub-layers 304-1 in the rare-earth fluoride layer 304 may be the same or different. In some embodiments, the thickness of each sub-layer 304-1 in the rare-earth fluoride layer 304 may decrease or increase layer by layer from a radiation layer 303, or may be distributed irregularly. In some embodiments, the thickness of each sub-layer 304-1 in the rare-earth fluoride layer 304 may be the same.

**[00257]** In some embodiments, materials of the at least two sub-layers 304-1 in the rare-earth fluoride layer 304 may be the same or different. In some embodiments, the materials of the at least two sub-layers 304-1 in the rare-earth fluoride layer 304 may be the same.

**[00258]** In some embodiments, when the rare-earth fluoride layer 304 includes three sub-layers 304-1, the thickness of each of the three sub-layers 304-1 in the rare-earth fluoride layer 304 may be 400 nm, and each sub-layer 304-1 may be a lanthanum trifluoride layer. In some embodiments, when the rare-earth fluoride layer 304 includes three sub-layers 304-1, the thickness of each sub-layer 304-1 in the rare-earth fluoride layer 304 may be 400 nm, and each sub-layer 304-1 may be an yttrium fluoride layer. In some embodiments, when the rare-earth fluoride layer 304 includes three sub-layers 304-1, the thickness of each sub-layer 304-1 in the rare-earth fluoride layer 304 may be 450 nm, and each sub-layer 304-1 may be a lanthanum trifluoride layer. In some embodiments, when the rare-earth fluoride layer 304 includes three sub-layers 304-1, the thickness of each sub-layer 304-1 in the rare-earth fluoride layer 304 may be 420 nm, and each sub-layer 304-1 may be an yttrium fluoride layer, etc.

**[00259]** In some embodiments, when the rare-earth fluoride layer 304 includes four sub-layers 304-1, the thickness of each sub-layer 304-1 in the rare-earth fluoride layer 304 may be 350 nm, and each sub-layer 304-1 may be a lanthanum trifluoride layer. In some embodiments, when the rare-earth fluoride layer 304 includes four layered sub-layers 304-1, the thickness of each sub-layer 304-1 in the rare-earth fluoride layer 304 may be 350 nm, and each sub-layer 304-1 may be an yttrium fluoride layer. In some embodiments, when the rare-earth fluoride layer 304 includes four sub-layers 304-1, the thickness of each sub-layer 304-1 in the rare-earth fluoride layer 304 may be 320 nm, and each sub-layer 20a may be a lanthanum trifluoride layer. In some embodiments, when the rare-earth fluoride layer 304 includes four sub-layers 304-1, the thickness of each sub-layer 304-1 in the rare-earth fluoride layer 304 may be 330 nm, and each sub-layer 304-1 may be an yttrium fluoride layer, etc.

**[00260]** In some embodiments, a surface of an alumina layer 302 away from an aluminum alloy substrate 301 may be a rough surface, which may better improve an adhesion between the radiation layer 303 and the alumina layer 302.

**[00261]** In some embodiments, a surface of the radiation layer 303 away from the alumina layer 302 may also be a rough surface, which may better improve an adhesion between the radiation layer 303 and the rare-earth fluoride layer 304. However, in order to ensure the emissivity of the plane source blackbody, the radiation layer 303 may be a continuous film, and there may be no cracks or through holes and other defects penetrating the radiation layer 303 in a depth direction of the plane source blackbody. At the same time, a

roughness of the radiation layer may be reduced.

**[00262]** In some embodiments, a roughness of the surface of the alumina layer away from the aluminum alloy substrate is  $Ra_1$ , and a roughness of a surface of the rare-earth fluoride layer away from the radiation layer is  $Ra_2$ , and  $Ra_1 > Ra_2$ . The rare-earth fluoride layer 304 may have no defects such as cracks or deep holes, and the density of the rare-earth fluoride layer 304 may be high.

**[00263]** The radiation layer of the plane source blackbody provided by some embodiments of the present disclosure may be provided with a rare-earth fluoride layer, which may reduce the loss of the emissivity of a body of the plane source blackbody, thus improving the emissivity of the plane source blackbody in a wave range of  $8\ \mu\text{m}$  -  $14\ \mu\text{m}$ .

### Embodiment 3.1

**[00264]** Preparing the aluminum substrate: the aluminum substrate was obtained by processing an Al 6063 substrate into the aluminum substrate to a required size.

**[00265]** Preparing the alumina layer: the aluminum substrate was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was  $\text{H}_2\text{SO}_4$  solution with a concentration of 18% -20%. A solution temperature was  $18^\circ\text{C}$  -  $25^\circ\text{C}$ , an anode current density was  $1\ \text{A}/\text{dm}^2$ - $2\ \text{A}/\text{dm}^2$ , a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum substrate.

**[00266]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials:  $\text{MgO}$  with a proportion of 14% in mass,  $\text{Cr}_2\text{O}_3$  with a proportion of 50% in mass,  $\text{MnO}_2$  with a proportion of 1% in mass,  $\text{NiO}$  with a proportion of 5% in mass,  $\text{SiC}$  with a proportion of 15% in mass, and  $\text{TiO}_2$  with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum substrate to obtain the radiation layer.

**[00267]** Preparing the rare-earth fluoride layer: a sputtering operation was performed was performed on a surface of the radiation layer for 4 times to obtain a lanthanum trifluoride layer including four sub-layers. A thickness of each of the four sub-layers was 350 nm. Then, the lanthanum trifluoride layer including four sub-layers was cleaned with ultrasound for 2 minutes, and baked with a temperature of  $85^\circ\text{C}$  in a bake oven for 30 minutes.

### Embodiment 3.2

**[00268]** Preparing the alumina layer: the aluminum alloy substrate obtained in Embodiment 1.1 was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was  $\text{H}_2\text{SO}_4$  solution with a concentration of 18% -20%. A solution temperature was  $18^\circ\text{C}$  -  $25^\circ\text{C}$ , an anode current density was  $1\ \text{A}/\text{dm}^2$ - $2\ \text{A}/\text{dm}^2$ , a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum alloy substrate.

**[00269]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and

anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass, Cr<sub>2</sub>O<sub>3</sub> with a proportion of 50% in mass, MnO<sub>2</sub> with a proportion of 1% in mass, NiO with a proportion of 5% in mass, SiC with a proportion of 15% in mass, and TiO<sub>2</sub> with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum alloy substrate to obtain the radiation layer.

**[00270]** Preparing the rare-earth fluoride layer: a sputtering operation was performed was performed on a surface of the radiation layer for 4 times to obtain a lanthanum trifluoride layer including four sub-layers. A thickness of each of the four sub-layers was 350 nm. Then, the lanthanum trifluoride layer including four sub-layers was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85 °C in a bake oven for 30 minutes.

### **Embodiment 3.3**

**[00271]** Preparing the alumina layer: the aluminum alloy substrate obtained in Embodiment 1.1 was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was H<sub>2</sub>SO<sub>4</sub> solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum alloy substrate.

**[00272]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass, Cr<sub>2</sub>O<sub>3</sub> with a proportion of 50% in mass, MnO<sub>2</sub> with a proportion of 1% in mass, NiO with a proportion of 5% in mass, SiC with a proportion of 15% in mass, and TiO<sub>2</sub> with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum alloy substrate to obtain the radiation layer.

**[00273]** Preparing the rare-earth fluoride layer: a sputtering operation was performed was performed on a surface of the radiation layer for 4 times to obtain an yttrium fluoride layer including four sub-layers. A thickness of each of the four sub-layers was 330 nm. Then, the lanthanum trifluoride layer including four sub-layers was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85 °C in a bake oven for 30 minutes.

### **Embodiment 3.4**

**[00274]** Preparing the alumina layer: the aluminum alloy substrate obtained in Embodiment 1.1 was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was H<sub>2</sub>SO<sub>4</sub> solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum alloy substrate.

**[00275]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and

anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass, Cr<sub>2</sub>O<sub>3</sub> with a proportion of 50% in mass, MnO<sub>2</sub> with a proportion of 1% in mass, NiO with a proportion of 5% in mass, SiC with a proportion of 15% in mass, and TiO<sub>2</sub> with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum alloy substrate to obtain the radiation layer.

**[00276]** Preparing the rare-earth fluoride layer: a sputtering operation was performed on a surface of the radiation layer for 4 times to obtain an yttrium fluoride layer including four sub-layers. Thickness of the four sub-layers was 380 nm, 330 nm, 330 nm, and 330 nm, respectively. Then, the yttrium fluoride layer including four sub-layers was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85 °C in a bake oven for 30 minutes.

### **Embodiment 3.5**

**[00277]** Preparing the alumina layer: the aluminum alloy substrate obtained in Embodiment 1.1 was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was H<sub>2</sub>SO<sub>4</sub> solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum alloy substrate.

**[00278]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass, Cr<sub>2</sub>O<sub>3</sub> with a proportion of 50% in mass, MnO<sub>2</sub> with a proportion of 1% in mass, NiO with a proportion of 5% in mass, SiC with a proportion of 15% in mass, and TiO<sub>2</sub> with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum alloy substrate to obtain the radiation layer.

**[00279]** A laser processing: a laser processing was performed on a surface of the radiation layer of the plane source blackbody; and the plane source blackbody was fixed on a femtosecond laser workbench. A femtosecond laser was modulated and beamed by a diffractive optical element (DOE) to form a 20 \* 20 laser point cloud array with uniform energy. A laser point was circular, and an energy diameter of the laser point was 9 μm. An interval between two adjacent laser points in the laser point cloud array was 13 μm. The femtosecond laser was used to perform a laser direct writing, and a material vapor was reduced by a lateral blowing airflow during etching, thus reducing a generation of plasma, avoiding heat accumulation, reducing an area of a heat affected zone, and improving the processing quality and efficiency of laser drilling. And an array of cylinder cavities with a size ratio of a depth of a cavity to a size of an opening of the cavity being 6 was formed. The opening of the cavity was 9 μm. A distance between two adjacent cavities was 13 μm.

**[00280]** Preparing the rare-earth fluoride layer: a lanthanum trifluoride layer including four sub-layers was evaporated on a PDMS substrate, a thickness of each of the four sub-layers being 320 nm, and then the prepared lanthanum trifluoride layer was transferred to surfaces of a plurality of cavities arranged on the radiation layer by an operation of hot pressing. Then, the lanthanum trifluoride layer including four sub-layers

was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85 °C in a bake oven for 30 minutes.

### **Comparative Example 3.1**

**[00281]** Preparing the aluminum substrate: the aluminum substrate was obtained by processing an Al 6063 substrate into the aluminum substrate to a required size.

**[00282]** Preparing the alumina layer: the aluminum substrate was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was H<sub>2</sub>SO<sub>4</sub> solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum substrate.

**[00283]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass, Cr<sub>2</sub>O<sub>3</sub> with a proportion of 50% in mass, MnO<sub>2</sub> with a proportion of 1% in mass, NiO with a proportion of 5% in mass, SiC with a proportion of 15% in mass, and TiO<sub>2</sub> with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum substrate to obtain the radiation layer.

**[00284]** Preparing the rare-earth fluoride layer: a sputtering operation was performed on a surface of the radiation layer for 3 times to obtain a lanthanum trifluoride layer including three sub-layers. A thickness of each of the four sub-layers was 450 nm. Then, the lanthanum trifluoride layer including three sub-layers was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85 °C in a bake oven for 30 minutes.

**[00285]** A difference between the Comparative Example 3.1 and the Embodiment 3.1 is that the rare-earth fluoride layer prepared in the Comparative Example 3.1 included three sub-layers, and the thickness of each of the three sub-layers in the Comparative Example 3.1 was 450 nm.

### **Comparative Example 3.2**

**[00286]** Preparing the aluminum substrate: the aluminum substrate was obtained by processing an Al 6063 substrate into the aluminum substrate to a required size.

**[00287]** Preparing the alumina layer: the aluminum substrate was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was H<sub>2</sub>SO<sub>4</sub> solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum substrate.

**[00288]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass, Cr<sub>2</sub>O<sub>3</sub> with a proportion of 50% in mass, MnO<sub>2</sub> with a proportion of 1% in mass, NiO with a proportion of 5% in

mass, SiC with a proportion of 15% in mass, and TiO<sub>2</sub> with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum alloy substrate to obtain the radiation layer. And the aluminum substrate with the alumina layer was dried under a temperature of 180°C to obtain the plane source blackbody.

**[00289]** A difference between the Comparative Example 3.2 and the Embodiment 3.1 is that the plane source blackbody prepared in the Comparative Example 3.2 does not include a rare-earth fluoride layer.

### **Comparative Example 3.3**

**[00290]** Preparing the alumina layer: the aluminum alloy substrate obtained in Embodiment 1.1 was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was H<sub>2</sub>SO<sub>4</sub> solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum alloy substrate.

**[00291]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass, Cr<sub>2</sub>O<sub>3</sub> with a proportion of 50% in mass, MnO<sub>2</sub> with a proportion of 1% in mass, NiO with a proportion of 5% in mass, SiC with a proportion of 15% in mass, and TiO<sub>2</sub> with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum alloy substrate to obtain the radiation layer.

**[00292]** Preparing the rare-earth fluoride layer: a sputtering operation was performed was performed on a surface of the radiation layer for 4 times to obtain a lanthanum trifluoride layer including four sub-layers. A thickness of each of the four sub-layers was 300 nm. Then, the lanthanum trifluoride layer including four sub-layers was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85 °C in a bake oven for 30 minutes.

**[00293]** A difference between the Comparative Example 3.3 and the Embodiment 3.2 is that the thickness of each of the four sub-layers prepared in the Comparative Example 3.3 was 300 nm.

### **Comparative Example 3.4**

**[00294]** Preparing the alumina layer: the aluminum alloy substrate obtained in Embodiment 1.1 was processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing was H<sub>2</sub>SO<sub>4</sub> solution with a concentration of 18% -20%. A solution temperature was 18°C - 25°C, an anode current density was 1 A/dm<sup>2</sup>-2 A/dm<sup>2</sup>, a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate was 25 minutes - 35 minutes. A colorant was used to color the anodized aluminum alloy substrate.

**[00295]** Preparing the radiation layer: a ball-milling operation was performed on inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 for 12h to obtain a mixed slurry; then the mixed slurry and anhydrous ethanol were added into a container for dispersion to obtain a uniform dispersion solution. The inorganic powder was composed of following raw materials: MgO with a proportion of 14% in mass, Cr<sub>2</sub>O<sub>3</sub> with a proportion of 50% in mass, MnO<sub>2</sub> with a proportion of 1% in mass, NiO with a proportion of 5% in

mass, SiC with a proportion of 15% in mass, and TiO<sub>2</sub> with a proportion of 15% in mass. The obtained uniform dispersion solution was sprayed and deposited on the anodized aluminum alloy substrate to obtain the radiation layer.

**[00296]** Preparing the rare-earth fluoride layer: a sputtering operation was performed on a surface of the plane source blackbody for 1 time to obtain a lanthanum trifluoride layer with a thickness of 1200 nm. Then, the lanthanum trifluoride layer was cleaned with ultrasound for 2 minutes, and baked with a temperature of 85 °C in a bake oven for 30 minutes.

**[00297]** A device FLIR E60 was used to test an emissivity of the plane source blackbody prepared from Embodiments 3.1-3.5 and the Comparative Examples 3.1-3.4. A testing result is shown in Table 4.

Table 4-Testing result for testing an emissivity of the plane source blackbody prepared from Embodiments 3.1-3.5 and the Comparative Examples 3.1-3.4

|                         | Material of a substrate                             | Whether cavities are arranged on the radiation layer                                  | Rare-earth fluoride layer and preparation method thereof | Thickness of the rare-earth fluoride layer (nm) | Count of sub-layers | Thickness of a sub-layer (nm) | Emissivity (%) |
|-------------------------|-----------------------------------------------------|---------------------------------------------------------------------------------------|----------------------------------------------------------|-------------------------------------------------|---------------------|-------------------------------|----------------|
| Embodiment 3.1          | AL6063 substrate                                    | No                                                                                    | Lanthanum trifluoride layer, sputtering                  | 1400                                            | 4                   | 350                           | 0.99           |
| Embodiment 3.2          | Aluminum alloy substrate prepared in Embodiment 1.1 | No                                                                                    | Lanthanum trifluoride layer, sputtering                  | 1400                                            | 4                   | 350                           | 0.991          |
| Embodiment 3.3          | Aluminum alloy substrate prepared in Embodiment 1.1 | No                                                                                    | Yttrium fluoride layer, sputtering                       | 1320                                            | 4                   | 330                           | 0.99           |
| Embodiment 3.4          | Aluminum alloy substrate prepared in Embodiment 1.1 | No                                                                                    | Yttrium fluoride layer, sputtering                       | 1370                                            | 4                   | 380,330,330                   | 0.989          |
| Embodiment 3.5          | Aluminum alloy substrate prepared in Embodiment 1.1 | Yes (a size ratio of a depth of a cavity to a size of an opening of a cavity being 6) | Lanthanum trifluoride layer, sputtering                  | 1280                                            | 4                   | 320                           | 0.992          |
| Comparative Example 3.1 | AL6063 substrate                                    | No                                                                                    | Lanthanum trifluoride                                    | 1350                                            | 3                   | 450                           | 0.988          |

|                         |                                                     |    |                             |      |   |     |       |
|-------------------------|-----------------------------------------------------|----|-----------------------------|------|---|-----|-------|
|                         |                                                     |    | layer                       |      |   |     |       |
| Comparative Example 3.2 | AL6063 substrate                                    | No | /                           | /    | / | /   | 0.983 |
| Comparative Example 3.3 | Aluminum alloy substrate prepared in Embodiment 1.1 | No | Lanthanum trifluoride layer | 1200 | 4 | 300 | 0.988 |
| Comparative Example 3.4 | Aluminum alloy substrate prepared in Embodiment 1.1 | No | Lanthanum trifluoride layer | 1200 | 1 | /   | 0.986 |

**[00298]** By comparing the Embodiments 3.1 and 3.2 shown in the Table 4, when other conditions are the same, an emissivity of the plane source blackbody prepared from the aluminum alloy substrate prepared in Embodiment 1.1 are higher.

**[00299]** By comparing the Embodiment 3.1 and the Comparative Example 3.1 shown in the Table 4, when the thickness of a sub-layer of the rare-earth fluoride layer is too thick, the emissivity of the plane source blackbody is relatively low.

**[00300]** By comparing the Embodiment 3.1 and the Comparative Example 3.2 shown in the Table 4, when the radiation layer includes the rare-earth fluoride layer, the emissivity of the plane source blackbody including the rare-earth fluoride layer is higher than the emissivity of the plane source blackbody not including the rare-earth fluoride layer.

**[00301]** By comparing the Embodiments 3.2-3.5 and the Comparative Example 3.3 shown in the Table 4, when the thickness of a sub-layer of the rare-earth fluoride layer is too thin, the emissivity of the plane source blackbody is also relatively low.

**[00302]** By comparing the Embodiments 3.2-3.5 and the Comparative Example 3.4 shown in the Table 4, the emissivity of a rare-earth fluoride layer with only one layer is lower than the emissivity of a rare-earth fluoride layer with at least two sub-layers.

**[00303]** FIG. 5 is a flowchart illustrating an exemplary process for preparing a plane source blackbody according to some embodiments of the present disclosure.

**[00304]** As shown in FIG. 5, process 500 includes the following operations.

**[00305]** In 510, an aluminum alloy substrate may be prepared.

**[00306]** The description of a composition of the aluminum alloy substrate may be found in FIG. 1.

**[00307]** In some embodiments, operations for preparing the aluminum alloy substrate may include: melting raw materials into an alloy liquid; refining the alloy liquid for degassing; pouring the refined alloy liquid into an ingot; obtaining a prefabricated component by performing a die-casting operation on the ingot; and obtaining the aluminum alloy substrate by performing an aging treatment on the prefabricated component.

**[00308]** A material composed of aluminum (Al), a material composed of iron (Fe), a material composed of magnesium (Mg), a material composed of silicon (Si), a material composed of manganese (Mn), a material composed of chromium (Cr), a material composed of erbium (Er), and a material composed of praseodymium (Pr) may be melted under a temperature of 720°C - 740°C to form the alloy liquid.

**[00309]** In some embodiments, a melting sequence of the above-mentioned material may not be limited. For example, under the temperature of 720°C - 740°C, the material composed of aluminum may be melted into a liquid first, and then the material composed of iron, the material composed of magnesium, the material composed of silicon, a material composed of manganese, the material composed of chromium, the material composed of erbium may be added into the liquid for melting (an order of adding the above materials is not limited, and the above materials may be added in sequence or together), and then the material composed of praseodymium may be added into the alloy liquid for melting (e.g., Pr may be uniformly dispersed in the alloy liquid for modification treatment), and a final alloy liquid may be obtained.

**[00310]** The modification treatment is adding some small nucleation agents (also referred to as inoculants or modifiers, such as Pr, etc.) to a metal liquid, thus a large count of dispersed artificially manufactured and non-spontaneous nuclei may be formed in the metal liquid, thereby obtaining small casting grains and achieving the goal of improving material performance.

**[00311]** A material composed of X (X=Al, Fe, Mg, Si, Mn, Cr, Er, Pr) refers to a simple substance X (metal Al, metal Fe, metal Mg, elemental Si, metal Mg, metal Cr, metal Er, metal Pr) or an alloy containing X. The most basic and independent substance that make up alloys may be called a component. The elements contained in the alloy composed of X may be one or more of Al, Fe, Mg, Si, Mn, Cr, Er, Pr except for X. For example, an iron alloy is an aluminum-iron alloy, and a silicon alloy is an aluminum-silicon alloy.

**[00312]** In some embodiments, an aluminum ingot, an aluminum-iron alloy, an aluminum-magnesium alloy, an aluminum-silicon alloy, an aluminum-manganese alloy, an aluminum-chromium alloy, an erbium ingot, and a praseodymium ingot may be melted under the temperature of 720°C - 740°C to form the alloy liquid.

**[00313]** The operation of refining and degassing refers to a refining process for removing gas from a molten metal, reducing the dissolved gas (e.g., hydrogen) in the metal to the lowest possible level.

**[00314]** In some embodiments, a temperature of refining the alloy liquid for degassing may be 700°C - 710°C, and a duration time of refining the alloy liquid for degassing is 10 minutes - 20 minutes.

**[00315]** In some embodiments, in an operation of refining the alloy liquid for degassing, a nitrogen gas (e.g., argon, nitrogen, etc.) may be introduced, and an amount of refining agent is 0.05% -0.15% with respect to a mass of the alloy liquid. The nitrogen gas introduced may be nitrogen.

**[00316]** A refining agents may be commonly used refining agents that is commercially available. The refining agent may be used for degassing and slag removal of molten metal during a casting process of the aluminum alloy. The refining agent is generally white (slightly gray) powder, mainly composed of chloride salt and fluoride salt, and may contain other compounds.

**[00317]** The alloy liquid may be poured into a fixed shape (e.g., into an ingot), and then may be performed a die-casting operation to obtain a prefabricated component (a casting).

**[00318]** An aging treatment refers to a heat treatment process in which an alloy workpiece undergoing a solid solution treatment, a cold plastic deformation or casting, and after being forged, being placed at a relatively high temperature or a room temperature with properties, a shape, and size changing over time.

**[00319]** The aluminum alloy substrate may be obtained by performing the aging treatment on the prefabricated component.

**[00320]** In some embodiments, a temperature of the aging treatment may be 120°C - 160°C, and a duration time of the aging treatment may be 2h - 12h.

**[00321]** In 520, an alumina layer may be prepared on the aluminum alloy substrate.

**[00322]** The method for preparing the alumina layer on the aluminum alloy substrate may be any oxidation method. In some embodiments, the alumina layer may be prepared by in-situ oxidation on any surface of the aluminum alloy substrate by an oxidation method including anodizing, hard oxidation, or arc oxidation, or any combination thereof.

**[00323]** For example, the aluminum alloy substrate may be processed by operations of degreasing, alkali washing, acid washing, chemical polishing, anodizing, coloring, sealing, and drying treatment in sequence. A solution used for anodizing is  $\text{H}_2\text{SO}_4$  solution with a concentration of 18% -20%. A solution temperature is  $18^\circ\text{C}$  -  $25^\circ\text{C}$ , an anode current density was  $1\text{ A/dm}^2$ - $2\text{ A/dm}^2$ , a voltage in an operation tank was 18 V-23 V, and a duration time of processing the aluminum substrate is 25 minutes - 35 minutes. A colorant is used to color the anodized aluminum alloy substrate.

**[00324]** In 530, a radiation layer is prepared on the alumina layer to obtain the plane source blackbody.

**[00325]** The preparation method of the radiation layer may be related to the radiation layer. For example, when the radiation layer is a carbon nanotube, the radiation layer may be deposited by a vacuum sputtering or other methods. When the radiation layer is an inorganic powder coating, the radiation layer may be obtained by spraying, coating and other methods.

**[00326]** For example, inorganic powder, an organic silicon resin, a BYK-163, a BYK-306 may be performed a ball milling operation for 12h to obtain a mixed slurry, then the mixed slurry and anhydrous ethanol may be added into a container for dispersion to obtain a uniform dispersion solution. The uniform dispersion solution is sprayed and deposited on the anodized aluminum substrate to obtain the radiation layer.

**[00327]** In some embodiments, the preparation method of the plane source blackbody may also include forming a plurality of cavities on the surface of the radiation layer.

**[00328]** In some embodiments, the plurality of cavities may be obtained by performing a laser etching or a chemical etching on a surface of the radiation layer away from the alumina layer. For each of the plurality of cavities, a size ratio of a depth of the cavity to a size of an opening of the cavity may be greater than or equal to 6. In some embodiments, a laser processing may be performed on a surface of the radiation layer of the plane source blackbody; and the plane source blackbody may be fixed on a femtosecond laser workbench. A femtosecond laser may be modulated and beamed by a diffractive optical element (DOE) to form a laser point cloud array with uniform energy. A shape of a laser point, an energy diameter of the laser point, and an interval between two adjacent laser points in the laser point cloud array may be adjustable. The femtosecond laser may be used to perform a laser direct writing, and a material vapor may be reduced by a lateral blowing airflow during etching, thus reducing a generation of plasma, avoiding heat accumulation, reducing an area of a heat affected zone, and improving the processing quality and efficiency of laser drilling. And an array of cavities with a ratio of a depth of a cavity to a size of an opening of the cavity being 6 may be formed. Then the array of cavities may be cleaned with ultrasound for 2 minutes, and baked with a temperature of  $85^\circ\text{C}$  in a bake oven for 30 minutes.

**[00329]** In some embodiments, a process of performing the chemical etching on the surface of the radiation layer may include: coating a layer of paraffin on the surface of the radiation layer of the plane source blackbody; etching, on the surface of the paraffin, holes with a size ratio greater than or equal to 6; pouring hydrofluoric acid into the etched holes; and pouring out mixed solution in the holes after a preset time period,

and a plurality of cavities with a size ratio greater than or equal to 6 may be formed on the surface of the radiation layer.

**[00330]** In some embodiments, the preparation method of the plane source blackbody may also include preparing a rare-earth fluoride layer on a surface of the radiation layer away from the alumina layer.

**[00331]** In some embodiments, the rare-earth fluoride layer may be prepared on the surface of the radiation layer using at least one of sputtering, chemical vapor deposition, or evaporation. Taking the lanthanum trifluoride as an example, a process of evaporation may include placing lanthanum trifluoride powder in a crucible; and preparing the lanthanum trifluoride layer with a high-temperature evaporation on the surface of the radiation layer.

**[00332]** In some embodiments, the rare-earth fluoride layer may be arranged on at least one of the plurality of cavities arranged on the surface of the radiation layer. Taking the lanthanum trifluoride as an example, a process of the chemical vapor deposition may include introducing a gas including fluorine and an organic matter including lanthanum to the surface of the radiation layer or the plurality of cavities on the surface of the radiation layer, and preparing the lanthanum trifluoride layer on the surface of the radiation layer or the surfaces of the plurality of cavities of the radiation layer after gasification and decomposition of the gas including fluorine and the organic matter including lanthanum by means of a high temperature/plasma.

**[00333]** In some embodiments of the present disclosure, a device with a plane surface blackbody is provided. The device may include the plane surface blackbody described in the above embodiments. In some embodiments, the device may be used as an infrared remote sensor, a thermographic camera, or the like.

**[00334]** Having thus described the basic concepts, it may be rather apparent to those skilled in the art after reading this detailed disclosure that the foregoing detailed disclosure is intended to be presented by way of example only and is not limiting. Various alterations, improvements, and modifications may occur and are intended to those skilled in the art, though not expressly stated herein. These alterations, improvements, and modifications are intended to be suggested by this disclosure and are within the spirit and scope of the exemplary embodiments of this disclosure.

**[00335]** Moreover, certain terminology has been used to describe embodiments of the present disclosure. For example, the terms “one embodiment,” “an embodiment,” and/or “some embodiments” mean that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. Therefore, it is emphasized and should be appreciated that two or more references to “an embodiment” or “one embodiment” or “an alternative embodiment” in various portions of the present disclosure are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures or characteristics may be combined as suitable in one or more embodiments of the present disclosure.

**[00336]** Furthermore, the recited order of processing elements or sequences, or the use of numbers, letters, or other designations therefore, is not intended to limit the claimed processes and methods to any order except as may be specified in the claims. Although the above disclosure discusses through various examples what is currently considered to be a variety of useful embodiments of the disclosure, it is to be understood that such detail is solely for that purpose and that the appended claims are not limited to the disclosed embodiments, but, on the contrary, are intended to cover modifications and equivalent arrangements that are within the spirit and scope of the disclosed embodiments. For example, although the implementation of various components

described above may be embodied in a hardware device, it may also be implemented as a software-only solution, e.g., an installation on an existing server or mobile device.

**[00337]** Similarly, it should be appreciated that in the foregoing description of embodiments of the present disclosure, various features are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure aiding in the understanding of one or more of the various inventive embodiments. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed subject matter requires more features than are expressly recited in each claim. Rather, inventive embodiments lie in less than all features of a single foregoing disclosed embodiment.

**[00338]** In some embodiments, the numbers expressing quantities, properties, and so forth, used to describe and claim certain embodiments of the application are to be understood as being modified in some instances by the term “about,” “approximate,” or “substantially.” For example, “about,” “approximate,” or “substantially” may indicate  $\pm 20\%$  variation of the value it describes, unless otherwise stated. Accordingly, in some embodiments, the numerical parameters set forth in the written description and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by a particular embodiment. In some embodiments, the numerical parameters should be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of some embodiments of the application are approximations, the numerical values set forth in the specific examples are reported as precisely as practicable.

**[00339]** Each of the patents, patent applications, publications of patent applications, and other material, such as articles, books, specifications, publications, documents, things, and/or the like, referenced herein is hereby incorporated herein by this reference in its entirety for all purposes, excepting any prosecution file history associated with same, any of same that is inconsistent with or in conflict with the present document, or any of same that may have a limiting effect as to the broadest scope of the claims now or later associated with the present document. By way of example, should there be any inconsistency or conflict between the description, definition, and/or the use of a term associated with any of the incorporated material and that associated with the present document, the description, definition, and/or the use of the term in the present document shall prevail.

**[00340]** In closing, it is to be understood that the embodiments of the application disclosed herein are illustrative of the principles of the embodiments of the application. Other modifications that may be employed may be within the scope of the application. Thus, by way of example, but not of limitation, alternative configurations of the embodiments of the application may be utilized in accordance with the teachings herein. Accordingly, embodiments of the present application are not limited to that precisely as shown and described.

**WHAT IS CLAIMED IS:**

1. A plane source blackbody, comprising an aluminum alloy substrate,  
wherein the aluminum alloy substrate includes Mn with a mass fraction of 0.04% -0.07%, Cr with a mass fraction of 0.07% -0.12%, Er with a mass fraction of 0.09% -0.11%, and Pr with a mass fraction of 0.04% - 0.06%.
2. The plane source blackbody of claim 1, wherein the aluminum alloy substrate further includes Si with a mass fraction of 6% -8%.
3. The plane source blackbody of claim 1 or claim 2, wherein the aluminum alloy substrate further includes Fe with a mass fraction of 0.4% -0.6%.
4. The plane source blackbody of any one of claims 1-3, wherein the aluminum alloy substrate further includes Mg with a mass fraction of 0.2% -0.3%.
5. The plane source blackbody of any one of claims 1-4, wherein a mass ratio of Fe to Mg in the aluminum alloy substrate is 1.7:1 ~ 2.3:1.
6. The plane source blackbody of any one of claims 1-5, wherein a mass ratio of Fe to Cr in the aluminum alloy substrate is 4.8:1 ~ 5.8:1.
7. The plane source blackbody of any one of claims 1-6, wherein a mass ratio of Fe to Mn in the aluminum alloy substrate is 8.8:1 ~ 10.2:1.
8. The plane source blackbody of any one of claims 1-7, further comprising:  
an alumina layer arranged on the aluminum alloy substrate; and  
a radiation layer arranged on the alumina layer.
9. The plane source blackbody of claim 8, wherein the aluminum alloy substrate and the alumina layer are integrated as a whole.
10. The plane source blackbody of claim 8 or claim 9, wherein  
a plurality of cavities are arranged on a surface of the radiation layer away from the alumina layer;  
for each of the plurality of cavities, a size ratio of a depth of the cavity to a size of an opening of the cavity is greater than or equal to 6; and  
the depths of the plurality of cavities are less than a thickness of the radiation layer.
11. The plane source blackbody of claim 10, wherein the size ratio of the depth of the cavity to the size of the opening of the cavity is 6-10.

12. The plane source blackbody of claim 10 or claim 11, wherein the depths of the plurality of cavities are  $54\text{ }\mu\text{m}$  -  $70\text{ }\mu\text{m}$ .

13. The plane source blackbody of any one of claims 10-12, wherein a distance between adjacent two cavities of the plurality of cavities is greater than or equal to  $3\text{ }\mu\text{m}$ .

14. The plane source blackbody of claim 13, wherein the distance between the adjacent two cavities is  $3\text{ }\mu\text{m}$  -  $5\text{ }\mu\text{m}$ .

15. The plane source blackbody of any one of claims 10-14, wherein the plurality of cavities are arranged in an array.

16. The plane source blackbody of any one of claims 10-15, wherein the plurality of cavities are cylinder cavities or cuboid cavities.

17. The plane source blackbody of any one of claims 8-16, further comprising a rare-earth fluoride layer arranged on a surface of the radiation layer away from the alumina layer.

18. The areal source blackbody of claim 17, wherein the rare-earth fluoride layer includes a lanthanum trifluoride layer or an yttrium fluoride layer.

19. The plane source blackbody of claim 17 or claim 18, wherein a thickness of the rare-earth fluoride layer is  $1200\text{ nm}$  -  $1400\text{ nm}$ .

20. The plane source blackbody of claim 19, wherein the rare-earth fluoride layer includes at least two sub-layers.

21. The plane source blackbody of claim 20, wherein a thickness of each of the at least two sub-layers is  $320\text{ nm}$ - $380\text{ nm}$ .

22. The plane source blackbody of claim 20 or claim 21, wherein thicknesses of the at least two sub-layers are the same.

23. The plane source blackbody of any one of claims 20-22, wherein materials of the at least two sub-layers are the same.

24. The plane source blackbody of any one of claims 17-23, wherein a roughness of a surface of the alumina layer away from the aluminum alloy substrate is  $Ra_1$ , a roughness of a surface of the rare-earth fluoride layer away from the radiation layer is  $Ra_2$ , and  $Ra_1 > Ra_2$ .

25. A method for preparing a plane source blackbody, comprising:

preparing an aluminum alloy substrate, wherein the aluminum alloy substrate includes Mn with a mass fraction of 0.04% -0.07%, Cr with a mass fraction of 0.07% -0.12%, Er with a mass fraction of 0.09% -0.11%, and Pr with a mass fraction of 0.04% -0.06%;

preparing an alumina layer on the aluminum alloy substrate; and

preparing a radiation layer on the alumina layer to obtain the plane source blackbody.

26. The method of claim 25, wherein preparing the aluminum alloy substrate includes:

melting raw materials into an alloy liquid;

refining the alloy liquid for degassing;

pouring the refined alloy liquid into an ingot;

obtaining a prefabricated member by performing a die-casting operation on the ingot; and

obtaining the aluminum alloy substrate by performing an aging treatment on the prefabricated member.

27. The method of claim 26, wherein a temperature of refining the alloy liquid for degassing is 700°C - 710°C, and a duration time of refining the alloy liquid for degassing is 10 minutes - 20 minutes.

28. The method of claim 26 or claim 27, wherein in an operation of refining the alloy liquid for degassing, a nitrogen gas is introduced, and an amount of refining agent is 0.05% -0.15% with respect to a mass of the alloy liquid.

29. The method of any one of claims 26-28, wherein a temperature of the aging treatment is 120°C - 160°C, and a duration time of the aging treatment is 2h - 12h.

30. The method of any one of claims 25-29, further comprising:

obtaining a plurality of cavities by performing a laser etching or a chemical etching on a surface of the radiation layer away from the alumina layer, wherein for each of the plurality of cavities, a size ratio of a depth of the cavity to a size of an opening of the cavity is greater than or equal to 6.

31. The method of any one of claims 25-30, further comprising:

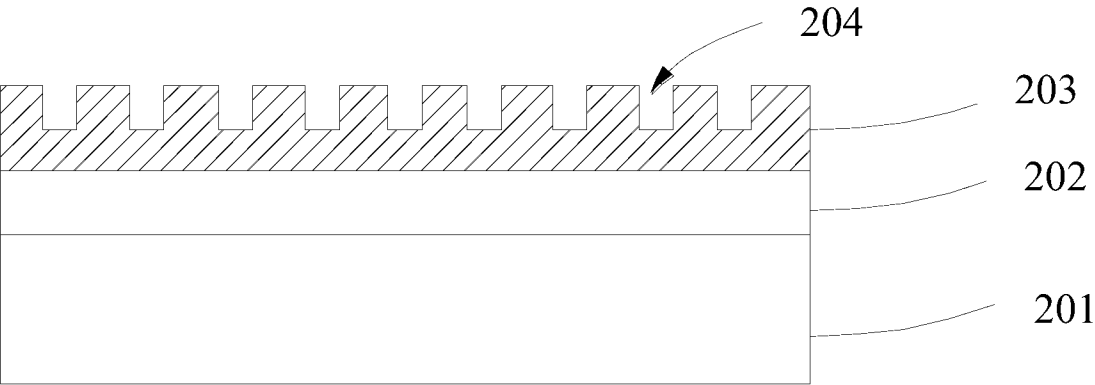
preparing a rare-earth fluoride layer on a surface of the radiation layer away from the alumina layer using at least one of sputtering, chemical vapor deposition, or evaporation.

32. A device, comprising the plane source blackbody of any one of claims 1-24.



**FIG. 1**

**200**



**FIG. 2**



**FIG. 3**

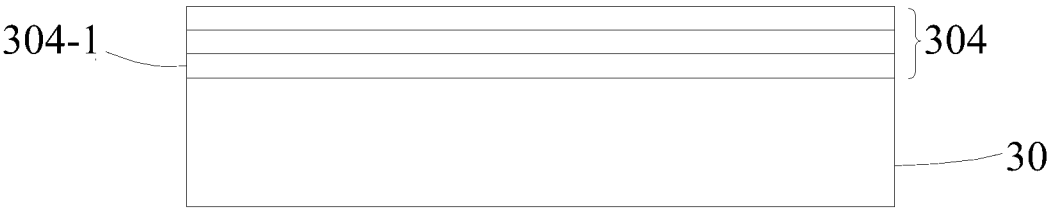
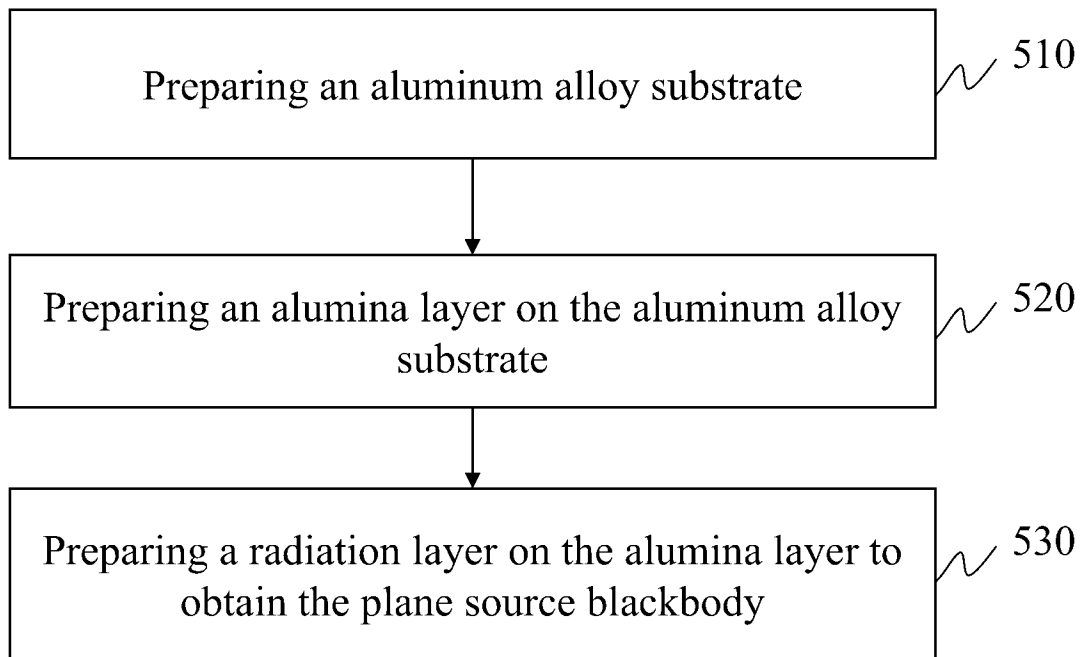


FIG. 4

**500****FIG. 5**

## INTERNATIONAL SEARCH REPORT

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| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br>C22C21/02(2006.01)i; C25D11/02(2006.01)i; C25D11/04(2006.01)i; C22C1/02(2006.01)i; C22C1/06(2006.01)i;<br>G01J5/53(2022.01)i<br>According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                      |                                                                              |           |                                                                                    |                       |    |                                                                                                                                |              |    |                                                                                                                                |             |    |                                                                                                                                   |             |    |                                                                                                                                   |             |   |                                                                                                                                      |              |
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| <b>B. FIELDS SEARCHED</b><br>Minimum documentation searched (classification system followed by classification symbols)<br>IPC:C22C,C25D11,C01J5<br>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched<br>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br>CNKI,CNTXT,CNABS,VEN,ENTXT,ENTXTC:blackbody, alloy,aluminium,Al,chromium,Cr,Er,erbium,Fe,iron,magnesium,<br>Mg,manganese,Mn,Pr,praseodymium,rare earth ,Si, silicon, corrosion, intensity, lanthanum fluoride , yttrium fluoride                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                      |                                                                              |           |                                                                                    |                       |    |                                                                                                                                |              |    |                                                                                                                                |             |    |                                                                                                                                   |             |    |                                                                                                                                   |             |   |                                                                                                                                      |              |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b> <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>PX</td> <td>CN 114959375 A (ZHEJIANG DAHUA TECHNOLOGY CO LTD) 30 August 2022<br/>(2022-08-30)<br/>claims 1-10, description, paragraphs 19-76</td> <td>1-9,25-29,32</td> </tr> <tr> <td>PY</td> <td>CN 114959375 A (ZHEJIANG DAHUA TECHNOLOGY CO LTD) 30 August 2022<br/>(2022-08-30)<br/>claims 1-10, description, paragraphs 19-76</td> <td>10-24,30-31</td> </tr> <tr> <td>PY</td> <td>CN 217358766 U (ZHEJIANG DAHUA TECHNOLOGY CO LTD) 02 September 2022<br/>(2022-09-02)<br/>claims 1-11, description, paragraphs 25-34</td> <td>10-24,30-32</td> </tr> <tr> <td>PY</td> <td>CN 217358767 U (ZHEJIANG DAHUA TECHNOLOGY CO LTD) 02 September 2022<br/>(2022-09-02)<br/>claims 1-11, description, paragraphs 28-50</td> <td>17-24,31-32</td> </tr> <tr> <td>X</td> <td>CN 109439971 A (XUZHOU YINING ALUMINUM IND TECHNOLOGY CO) 08 March<br/>2019 (2019-03-08)<br/>claims 1-7, description, paragraphs 23-53</td> <td>1-9,25-29,32</td> </tr> </tbody> </table>                                                                                                                                                            |                                                                                                                                      |                                                                              | Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. | PX | CN 114959375 A (ZHEJIANG DAHUA TECHNOLOGY CO LTD) 30 August 2022<br>(2022-08-30)<br>claims 1-10, description, paragraphs 19-76 | 1-9,25-29,32 | PY | CN 114959375 A (ZHEJIANG DAHUA TECHNOLOGY CO LTD) 30 August 2022<br>(2022-08-30)<br>claims 1-10, description, paragraphs 19-76 | 10-24,30-31 | PY | CN 217358766 U (ZHEJIANG DAHUA TECHNOLOGY CO LTD) 02 September 2022<br>(2022-09-02)<br>claims 1-11, description, paragraphs 25-34 | 10-24,30-32 | PY | CN 217358767 U (ZHEJIANG DAHUA TECHNOLOGY CO LTD) 02 September 2022<br>(2022-09-02)<br>claims 1-11, description, paragraphs 28-50 | 17-24,31-32 | X | CN 109439971 A (XUZHOU YINING ALUMINUM IND TECHNOLOGY CO) 08 March<br>2019 (2019-03-08)<br>claims 1-7, description, paragraphs 23-53 | 1-9,25-29,32 |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Citation of document, with indication, where appropriate, of the relevant passages                                                   | Relevant to claim No.                                                        |           |                                                                                    |                       |    |                                                                                                                                |              |    |                                                                                                                                |             |    |                                                                                                                                   |             |    |                                                                                                                                   |             |   |                                                                                                                                      |              |
| PX                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | CN 114959375 A (ZHEJIANG DAHUA TECHNOLOGY CO LTD) 30 August 2022<br>(2022-08-30)<br>claims 1-10, description, paragraphs 19-76       | 1-9,25-29,32                                                                 |           |                                                                                    |                       |    |                                                                                                                                |              |    |                                                                                                                                |             |    |                                                                                                                                   |             |    |                                                                                                                                   |             |   |                                                                                                                                      |              |
| PY                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | CN 114959375 A (ZHEJIANG DAHUA TECHNOLOGY CO LTD) 30 August 2022<br>(2022-08-30)<br>claims 1-10, description, paragraphs 19-76       | 10-24,30-31                                                                  |           |                                                                                    |                       |    |                                                                                                                                |              |    |                                                                                                                                |             |    |                                                                                                                                   |             |    |                                                                                                                                   |             |   |                                                                                                                                      |              |
| PY                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | CN 217358766 U (ZHEJIANG DAHUA TECHNOLOGY CO LTD) 02 September 2022<br>(2022-09-02)<br>claims 1-11, description, paragraphs 25-34    | 10-24,30-32                                                                  |           |                                                                                    |                       |    |                                                                                                                                |              |    |                                                                                                                                |             |    |                                                                                                                                   |             |    |                                                                                                                                   |             |   |                                                                                                                                      |              |
| PY                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | CN 217358767 U (ZHEJIANG DAHUA TECHNOLOGY CO LTD) 02 September 2022<br>(2022-09-02)<br>claims 1-11, description, paragraphs 28-50    | 17-24,31-32                                                                  |           |                                                                                    |                       |    |                                                                                                                                |              |    |                                                                                                                                |             |    |                                                                                                                                   |             |    |                                                                                                                                   |             |   |                                                                                                                                      |              |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | CN 109439971 A (XUZHOU YINING ALUMINUM IND TECHNOLOGY CO) 08 March<br>2019 (2019-03-08)<br>claims 1-7, description, paragraphs 23-53 | 1-9,25-29,32                                                                 |           |                                                                                    |                       |    |                                                                                                                                |              |    |                                                                                                                                |             |    |                                                                                                                                   |             |    |                                                                                                                                   |             |   |                                                                                                                                      |              |
| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                      |                                                                              |           |                                                                                    |                       |    |                                                                                                                                |              |    |                                                                                                                                |             |    |                                                                                                                                   |             |    |                                                                                                                                   |             |   |                                                                                                                                      |              |
| * Special categories of cited documents:<br>“A” document defining the general state of the art which is not considered to be of particular relevance<br>“D” document cited by the applicant in the international application<br>“E” earlier application or patent but published on or after the international filing date<br>“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>“O” document referring to an oral disclosure, use, exhibition or other means<br>“P” document published prior to the international filing date but later than the priority date claimed<br>“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention<br>“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone<br>“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art<br>“&” document member of the same patent family |                                                                                                                                      |                                                                              |           |                                                                                    |                       |    |                                                                                                                                |              |    |                                                                                                                                |             |    |                                                                                                                                   |             |    |                                                                                                                                   |             |   |                                                                                                                                      |              |
| Date of the actual completion of the international search<br><b>28 September 2023</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                      | Date of mailing of the international search report<br><b>23 October 2023</b> |           |                                                                                    |                       |    |                                                                                                                                |              |    |                                                                                                                                |             |    |                                                                                                                                   |             |    |                                                                                                                                   |             |   |                                                                                                                                      |              |
| Name and mailing address of the ISA/CN<br><b>CHINA NATIONAL INTELLECTUAL PROPERTY ADMINISTRATION</b><br><b>6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                      | Authorized officer<br><b>DAN,YingMin</b><br>Telephone No. (+86) 62085543     |           |                                                                                    |                       |    |                                                                                                                                |              |    |                                                                                                                                |             |    |                                                                                                                                   |             |    |                                                                                                                                   |             |   |                                                                                                                                      |              |

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                 | Relevant to claim No. |
|-----------|------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Y         | CN 109439971 A (XUZHOU YINING ALUMINUM IND TECHNOLOGY CO) 08 March 2019 (2019-03-08)<br>claims 1-7, description, paragraphs 23-53  | 10-24,30-31           |
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| Y         | US 4735488 A (OPTICAL COATING LABORATORY INC) 05 April 1988 (1988-04-05)<br>claims 1-5, description, columns 1-8                   | 17-24,31-32           |
| A         | CN 113483900 A (UNIV YANSHAN) 08 October 2021 (2021-10-08)<br>the whole documents                                                  | 1-32                  |
| A         | CN 104630581 A (SUZHOU KESHENG WAREHOUSING LOGISTICS EQUIP CO LTD) 20 May 2015 (2015-05-20)<br>the whole documents                 | 1-32                  |
| A         | US 2021292874 A1 (SAMSUNG ELECTRONICS CO LTD) 23 September 2021 (2021-09-23)<br>the whole documents                                | 1-32                  |

**INTERNATIONAL SEARCH REPORT**  
**Information on patent family members**

International application No.

**PCT/CN2023/107381**

| Patent document<br>cited in search report |            |    | Publication date<br>(day/month/year) | Patent family member(s) |             |    | Publication date<br>(day/month/year) |
|-------------------------------------------|------------|----|--------------------------------------|-------------------------|-------------|----|--------------------------------------|
| CN                                        | 114959375  | A  | 30 August 2022                       | None                    |             |    |                                      |
| CN                                        | 217358766  | U  | 02 September 2022                    | None                    |             |    |                                      |
| CN                                        | 217358767  | U  | 02 September 2022                    | None                    |             |    |                                      |
| CN                                        | 109439971  | A  | 08 March 2019                        | None                    |             |    |                                      |
| CN                                        | 109556725  | A  | 02 April 2019                        | None                    |             |    |                                      |
| US                                        | 4735488    | A  | 05 April 1988                        | None                    |             |    |                                      |
| CN                                        | 113483900  | A  | 08 October 2021                      | None                    |             |    |                                      |
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|                                           |            |    |                                      | WO                      | 2020040602  | A1 | 27 February 2020                     |
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|                                           |            |    |                                      | EP                      | 3819393     | A4 | 11 August 2021                       |
|                                           |            |    |                                      | EP                      | 3819393     | B1 | 28 September 2022                    |