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## (71) Applicant: TVS MOTOR COMPANY LIMITED

[IN/IN]; "Chaitanya", No.12 Khader Nawaz Khan Road, Nungambakkam, Chennai 600 006, Tamil Nadu, India, CHENNAI 600 006 (IN).

## (72) Inventors: HARIRAM, Gopinath Sokka; "Chaitanya",

No.12 Khader Nawaz Khan Road, Nungambakkam, Chennai 600 006, Tamil Nadu, India, CHENNAI 600 006 (IN).

RAO, Pramila Nileshwar; "Chaitanya", No.12 Khader Nawaz Khan Road, Nungambakkam, Chennai 600 006, Tamil Nadu, India, CHENNAI 600 006 (IN).

SAGARE, Datta Rajaram; "Chaitanya", No.12 Khader Nawaz Khan Road, Nungambakkam, Chennai 600 006, Tamil Nadu, India, CHENNAI 600 006 (IN).

## (74) Agent: KHAITAN &amp; CO; One Indiabulls Centre, 13th

Floor, 841, Senapati Bapat Marg, Elphinstone Road, Mumbai 400013, Maharashtra (IN).

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(54) Title: SOLID-STATE ELECTRODE FOR ION CONDUCTING BATTERY AND METHOD OF FABRICATING THEREOF

Figure 1

100



(57) Abstract: The present invention provides a solid-state electrode (100) for an ion conducting battery (200). The solid-state electrode (100) includes an electrode mixture of Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI). The electrode (100) enhances thermal stability and ionic conductivity in the battery (200). Additionally, the ceramic material in the SSE (100) provides limited number of pores available for ionic transfer in a cathode electrode (102). As such, the lithium dendrites are retained in the cathode electrode (102), thereby preventing possibility of short-circuiting in the battery (200).



WO 2022/264161 A1

**TITLE OF INVENTION**

**Solid-State Electrode for Ion Conducting Battery and Method of Fabricating thereof**

**FIELD OF THE INVENTION**

[001] The present invention relates to a solid-state electrode for an ion conducting battery and a method of fabricating the solid-state electrode.

**BACKGROUND OF THE INVENTION**

5 [002] In recent past, technological advancement and lifestyle changes have resulted in rapid rise in use of electronic devices such as computers, mobile phones and the like. These electronic devices are typically powered by batteries. As such, development of battery technology is gaining precedence for improving usability of the electronic devices. The battery acts as a power storage device for powering the electronic device  
10 on demand, while also being environmentally safe. Due to these inherent advantages, batteries are also being employed in automobile industry for powering a vehicle as an alternative for fossil fuels. Presently, lithium batteries are being employed in the vehicles.

[003] Lithium batteries typically include organic solvents which contain a flammable  
15 electrolyte such as but not limiting to propylene carbonate, ethylene carbonate, ethylene carbonate and the like. The electrolyte is also characterized with a low ignition temperature. As such, the conventional lithium batteries render safety issues, as the electrolyte will ignite when operating temperature exceeds its ignition temperature. This ignition of the electrolyte results in detonation of the lithium batteries, which is  
20 catastrophic. Additionally, formation of lithium dendrites is a common occurrence in the

conventional lithium batteries. The lithium dendrites when transferred between the electrodes of the battery, results in short-circuiting which is undesirable.

[004] To overcome the aforementioned limitations, recent advancements in the field of battery technology have developed solid-state electrodes for use in the battery. The solid-state electrode replaces the organic solvent electrolyte employed in the conventional lithium batteries, and thus make the battery completely solid. Such a construction of the battery improves safety and reduce manufacturing costs. However, the batteries employing the solid-state electrode batteries generally have relatively lower thermal stability, specific energy output, mechanical strength, ionic conductivity and ionic diffusion. Such characteristics of the conventional solid-state batteries pose a challenge for catering to the present energy requirements, particularly in the automobile industries where the batteries are employed for powering the electric vehicles. Additionally, the materials employed in the conventional solid-state batteries are expensive, resulting in a costly lithium battery, which is undesirable.

[005] In view of the above, there is a need for a solid-state electrode which addresses one or more limitations stated above.

## SUMMARY OF THE INVENTION

[006] In one aspect, a solid-state electrode for an ion conducting battery is disclosed.

The solid-state electrode includes an electrode mixture of Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI).

[007] In an embodiment, the electrode mixture includes 80% of the Bi-metallic ceramic nano composite material, 20% of the Polyethylene Oxide (PEO) and 50% of the Lithium bistrifluoromethanesulfonimide (LiTFSI) by weight. Further, the Bi-metallic ceramic

nano composite material includes 30% of  $\text{Al}_2\text{O}_3$ , 50% to 55% of titania ( $\text{TiO}_2$ ) and 15% to 20% of Silicon Carbide ( $\text{SiC}$ ) in weight.

[008] In another aspect, a method of fabricating a solid-state electrode for an ion conducting battery is disclosed. The method includes steps of preparing the electrode mixture of Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide ( $\text{LiTFSI}$ ). The electrode mixture is then mixed with the solvent to form the electrode paste. The electrode paste is thereafter coated on at least one of the cathode electrode and the anode electrode of the ion conducting battery to form the solid-state electrode.

[009] In an embodiment, the solvent employed for mixing the electrode mixture is acetonitrile. The electrode mixture is mixed with acetonitrile in vacuum conditions.

[010] In an embodiment, the electrode paste is coated on at least one of the cathode electrode and the anode electrode by one of a doctor blade coating, a spray coating and a printing technique.

[011] In an embodiment, the solid-state ion conducting battery is disclosed. The battery includes the cathode electrode having a cathode current collector and a cathode active material layer disposed thereon. The cathode active material layer includes a cathode mixture containing 95% of a Lithium Metal Oxide compound and 5% of a conductive super Phosphorous-Carbon powder. The battery also includes the anode electrode having an anode current collector and an anode active material layer disposed thereon. The anode active material layer is made of an alkali metal. the solid-state electrode is disposed between the cathode active material layer and the anode active material layer. The solid-state electrode is adapted to connect the cathode electrode with the anode electrode for ion conduction therebetween to enable operation of the battery. The solid-state electrode is further disposed on at least one of the cathode active material layer

and the anode active material layer. Additionally, the solid-state electrode includes the electrode mixture of a Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI).

[012] In an embodiment, the alkali metal for the anode active material layer is made by one of a Lithium metal, Sodium metal and Potassium metal.

[013] In an embodiment, the solid-state electrode disposed over the cathode active material layer is configured with a thickness of 80 $\mu$ m to 100 $\mu$ m.

[014] In an embodiment, the cathode active material layer disposed over the cathode current collector is configured with a thickness of 50 $\mu$ m to 70 $\mu$ m.

[015] In an embodiment, the cathode current collector is an aluminum current collector made of 99.3% pure aluminum foil having a thickness of 15 $\mu$ m and the anode current collector is a copper current collector made of 99.9% pure copper foil made having a thickness of 9 $\mu$ m to 12 $\mu$ m.

[016] In an embodiment, a method of fabricating the solid-state ion conducting battery is disclosed. The method includes providing the cathode active material layer over the cathode current collector to form the cathode electrode. The cathode active material layer is formed by coating a cathode active material paste prepared by mixing a cathode mixture with the solvent. The cathode mixture includes a cathode mixture containing 95% of a Lithium Metal Oxide compound and 5% of a conductive super Phosphorous-Carbon powder. The anode active material layer made of an alkali metal, is then provided over the anode current collector to form the anode electrode. Further, the solid-state electrode is provided between the cathode active material layer and the anode active material layer, which is adapted to connect the cathode electrode with the anode electrode for ion conduction therebetween to enable operation of the battery. The solid-state electrode is formed then on at least one of the cathode active material layer

and the anode active material layer by coating an electrode paste prepared by mixing the electrode mixture with the solvent. The electrode mixture includes a Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI).

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## BRIEF DESCRIPTION OF THE DRAWINGS

[017] Reference will be made to embodiments of the invention, examples of which may be illustrated in accompanying figures. These figures are intended to be illustrative, not limiting. Although the invention is generally described in context of these embodiments, 10 it should be understood that it is not intended to limit the scope of the invention to these particular embodiments.

Figure 1 is a schematic cross-sectional view of a solid-state electrode for an ion conducting battery, in accordance with an embodiment of the present invention.

Figure 2 is a flow diagram depicting method steps involved in fabricating the 15 solid-state electrode, in accordance with an embodiment of the invention.

Figure 3 is a schematic cross-sectional view of a cathode electrode of a solid-state ion conducting battery coated with the solid-state electrode, in accordance with an embodiment of the invention.

Figure 4 is a schematic cross-sectional view of an anode electrode of the solid- 20 state ion conducting battery coated with the solid-state electrode, in accordance with an embodiment of the invention.

Figure 5 is a schematic cross-sectional view of the solid-state ion conducting battery, in accordance with an embodiment of the invention.

Figure 6 is a schematic cross-sectional view of the solid-state ion conducting battery formed via pouch cell construction technique, in accordance with an embodiment of the invention.

Figure 7 is a flow diagram depicting method steps involved in preparing the solid-state ion conducting battery, in accordance with an embodiment of the invention.

## DETAILED DESCRIPTION OF THE INVENTION

[018] Various features and embodiments of the present invention here will be discernible from the following further description thereof, set out hereunder.

[019] In one aspect, the present invention discloses a solid-state electrode for an ion conducting battery. The solid-state electrode is made of an electrode mixture having Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI). The electrode mixture is coated on at least one of a cathode electrode or an anode electrode of the ion conducting battery to form the solid-state electrode. Alternatively, the electrode mixture can also be coated on a solid separator material to form the solid-state electrode. The solid-state electrode is adapted to enhance thermal stability, ionic conductivity and mechanical strength of the battery upon coating, thereby improving the performance and life of the battery.

[020] The present invention also provides a method of fabricating the solid-state electrode for the battery. The method includes firstly preparing the electrode mixture having the Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI). The mixture is thereafter mixed with acetonitrile solvent to form an electrode paste. The electrode paste is thereafter coated on at least one of the cathode electrode and the anode electrode to form the solid-state

electrode. In an embodiment, the electrode paste is coated on a separator to form the solid-state electrode.

[021] The present invention also provides the solid-state ion conducting battery. The battery includes the cathode electrode and the anode electrode. The cathode electrode includes a cathode current collector and a cathode active material layer deposited over the cathode current collector. The anode electrode includes an anode current collector and an anode active material layer deposited over the anode current collector. The solid-state electrode is provided between the cathode active material layer and the anode active material layer. The solid-state electrode connects the anode electrode with the cathode electrode for ion conducting therebetween to enable operation of the battery.

[022] Furthermore, the present invention provides a method for fabricating the solid-state ion conducting battery.

[023] The solid-state electrode formed upon coating on anode minimizes the availability of the pores on its surface area. As such, lithium-ion dendrites that are formed during operation of the battery are retained in the anode itself, thereby preventing short-circuit. Further, the solid-state electrode upon coating on the cathode material improves thermal stability enhancing cyclic performance of the battery, while providing interface support.

[024] Figure 1 in one embodiment of the present invention illustrates a schematic cross-sectional view of a solid-state electrode ("SSE") 100. The SSE 100 is disposed in an ion conducting battery, such as battery 200 shown in Figure 5 or battery 300 shown in Figure 6. The description pertaining to disposal or fabricating the SSE 100 in the battery is mentioned in description pertaining to Figure 2. The SSE 100 is adapted to



improve thermal stability, ionic conductivity and mechanical strength of the battery, thereby improving the performance and life of the battery.

[025] The SSE 100 is made of an electrode mixture having Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI). The LiTFSI is adapted to provide the Lithium ions for lithium-ionic movement in the battery. The Bi-metallic ceramic nano composite material further includes alumina (Al<sub>2</sub>O<sub>3</sub>), titania (TiO<sub>2</sub>) and Silicon Carbide (SiC).

[026] In an embodiment, the electrode mixture has 53% of the Bi-metallic ceramic nano composite material, 14% of the Polyethylene Oxide (PEO) and 33% of the Lithium bistrifluoromethanesulfonimide (LiTFSI) by weight. In other words, in 10 grams of the electrode mixture, 5.3 grams constitutes the Bi-metallic ceramic nano composite material, 1.4 grams constitute the PEO and 3.3 grams constitute the LiTFSI. In an embodiment, the weight of the LiTFSI in the electrode mixture is half the sum of weights of the Bi-metallic ceramic nano composite material and PEO.

[027] In an embodiment, the Bi-metallic ceramic nano composite material includes 30% of Al<sub>2</sub>O<sub>3</sub>, 50% to 55% of titania (TiO<sub>2</sub>) and 15% to 20% of Silicon Carbide (SiC) in weight.

[028] The constituents in the SSE 100, particularly alumina, enhances thermal stability upon disposal in the battery due to its higher thermal resistance. The alumina also enhances ionic conductivity in the battery. Further, the SiC included in the SSE 100 provides interface support to the battery, thereby reducing the rate of degradation of the battery. Thus, cycle performance of the battery is enhanced. Additionally, the SiC in the SSE 100 provides limited number of pores available for ionic transfer in the cathode electrode 102. As such, the lithium dendrites are retained in the cathode electrode 102, thereby preventing short-circuiting in the battery.

[029] Referring to Figure 2 in conjunction with Figure 1, a method 200 of fabricating the SSE 100 for the battery is disclosed. The method 200 is typically carried out in tool room or clean room conditions, for fabricating the SSE 100. Alternatively, the conditions for fabricating the SSE 100 are adjusted as per feasibility and requirement.

5 [030] At step 202 the electrode mixture of Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI) as described hereinabove is prepared. For preparing the electrode mixture, milled particles of Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI) of predetermined particle sizes are  
10 considered. The particle size is considered based on the porosity requirements of the SSE 100 upon coating. In an embodiment, particle size of each of the Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI) ranges from 1 $\mu$ m to 5 $\mu$ m.

[031] At step 204, the electrode mixture is mixed with a solvent in vacuum conditions to  
15 form an electrode paste. The mixing is carried out in vacuum conditions for ensuring homogeneity of the electrode paste. Alternatively, mixing of the electrode mixture may be carried out in other surrounding conditions such as high or low temperature conditions and the like, as per requirement in the consistency of the mixture. The solvent employed for mixing the electrode mixture is one of acetonitrile or poly  
20 carbonate and vinyl carbonate with ethyl carbonate or dimethyl carbonate.

[032] At step 206, the electrode paste is coated on at least one of a cathode electrode 102 [for e.g. as shown in Figure 3] and an anode electrode 108 [for e.g. as shown in Figure 4] of the battery, to form the SSE 100. Alternatively, the electrode mixture is coated on a separator 202 [for e.g. as shown in Figure 5] of the battery, instead of the  
25 cathode electrode 102 and/or the anode electrode 108. The coating of the electrode

paste is carried by conventionally known coating techniques such as a doctor blade coating, a spray coating or a printing technique and the like.

[033] The SSE 100 is thereafter subjected to compression for compacting or controlling the thickness of the SSE layer. The SSE layer is subjected to drying, optionally in a long oven, for solidification. The solidified SSE layer is then slit for removing burrs at the edges, if any, and to adjust its size as per requirement.

[034] Referring to Figure 3, a schematic cross-sectional view of the cathode electrode 102 of the battery 200 coated with the SSE 100 is depicted. The cathode electrode 102 includes a cathode current collector 104 adapted to be a positive terminal of the battery 200. The cathode current collector 104 is an aluminum current collector made of 99.3% pure aluminum foil having a thickness of 15 $\mu$ m. A cathode active material layer 106 is disposed over the cathode current collector 104. The cathode active material layer 106 is adapted to enable flow of lithium ions from an anode electrode 108 [for e.g. as shown in Figure 4] of the battery 200.

[035] The cathode active material layer 106 is made of a cathode mixture having lithium metal oxide compound and a conductive super phosphorous-carbon powder. The cathode mixture is disposed over the cathode current collector 104 to form the cathode active material layer 106. The cathode active material layer 106 is disposed such that, ends of the cathode current collector 104 project outwardly therefrom. Such a construction enables the cathode current collector 104 to act as a positive terminal of the battery 200. Further, the thickness of the cathode active material layer 106 is selected as per power or energy density required from the battery 200. In an embodiment, the thickness of the cathode active material layer 106 disposed over the cathode current collector is 50 $\mu$ m to 70 $\mu$ m.

[036] In an embodiment, the cathode mixture includes 95% of bare composition of lithium metal oxide compound and 5% of super phosphorous-carbon powder, wherein the carbon additive provides uniformity and enhancement in surface conductivity of the cathode active material layer 106. Further, each of the constituents in the cathode mixture are milled and the milled particles of the bare composition of lithium metal oxide compound and super phosphorous-carbon powder are added in required quantities for arriving at the cathode mixture. Also, the particle size of each of the constituent is considered suitably during milling, so that the cathode active material layer 106 upon coating attains the required porosity. In an embodiment, the particle size of each of the lithium metal oxide compound and the super phosphorous-carbon powder employed for forming the cathode active material layer 106 ranges from about 1 $\mu$ m to 2 $\mu$ m, resulting in a porosity of 60% of the cathode active material layer 106.

[037] Over the cathode active material layer 106, the SSE 100 is disposed. The SSE 100 envelops over the entire surface area of the cathode active material layer 106. The thickness of the SSE 100 disposed over the cathode active material layer 106 is selected as per power requirements in the battery 200. In an embodiment, the thickness of the SSE 100 disposed over the cathode active material layer 106 is 80 $\mu$ m to 100 $\mu$ m.

[038] Referring to Figure 4, a schematic cross-sectional view of the anode electrode 108 of the battery 200 coated with the SSE 100 is depicted. The anode electrode 108 includes an anode current collector 110 adapted to be a negative terminal of the battery 200. The anode current collector 110 is a copper current collector made of 99.9% pure copper foil made having a thickness of 9 $\mu$ m to 12 $\mu$ m. An anode active material layer 112 is disposed over the anode current collector 110 and is made of an alkali metal. The alkali metal is selected as per the configuration of the battery 200. In an embodiment, the anode active material layer 112 is made from alkali metals such as a

Lithium metal, a Sodium metal or a Potassium metal. Similar to the cathode active material layer 106, the anode active material layer 106 is disposed such that, ends of the anode current collector 110 project outwardly therefrom. Such a construction enables the anode current collector 110 to act as a negative terminal of the battery 200.

5 Further, the thickness of the anode active material layer 112 is selected as per power or energy density required from the battery 200. In an embodiment, the thickness of the anode active material layer 112 disposed over the anode current collector 110 is 30 $\mu$ m to 50 $\mu$ m.

[039] In an embodiment, the anode active material layer 112 and the SSE 100 may be  
10 provided below the anode current collector 110. Such a construction facilitates stacking of anode electrode 108 with the cathode electrode 102, thereby enabling stacking of the battery 200.

[040] Over the anode active material layer 112, the SSE 100 is disposed. The SSE 100 envelops over the entire surface area of the cathode active material layer 112. The  
15 thickness of the SSE 100 disposed over the anode active material layer 112 is selected as per power requirements of the battery 200. In an embodiment, the thickness of the SSE 100 disposed over the anode active material layer 112 is 80 $\mu$ m to 100 $\mu$ m. The SSE 100 is configured to electrically connect the cathode and the anode electrodes 102, 108 for facilitating operation of the battery 200.

20 [041] The cathode and the anode electrodes 102, 108 are stacked adjacent to one another with the SSE 100 being sandwiched therebetween. In an embodiment, the SSE 100 is provided on the separator 202 which is thereafter sandwiched between the cathode and the anode electrodes 102, 108. Upon stacking, the SSE 100 electrically connects the cathode and the anode electrodes 102, 108 for operation of the battery.

[042] In an embodiment, the cathode and the anode electrodes 102, 108 are stacked by employing conventionally known techniques such as cylindrical cell construction technique, a pouch cell construction technique and the like to form the battery, such as the battery 200 or 300. In an embodiment, the cathode and the anode electrode 102, 108 are stacked in layers or laminations and are enclosed in a foil envelope to fabricate the battery 300 [as shown in Figure 6] in the form of a pouch cell. Suitable allowances are provided between each layer or lamination considering possible swelling of the layers during operation of the battery 300.

[043] In an embodiment, layers of the cathode electrode 102, the anode electrode 108 and the SSE 100 are rolled continuously depending upon power density requirement of the battery 300, resulting in a cylindrical construction of the battery 300.

[044] Figure 7 in one embodiment of the present invention provides a method 700 for fabricating the solid-state ion conducting battery 200. The method 700 is typically carried out in tool room or clean room conditions for fabricating the battery 200.

Alternatively, the conditions for fabricating the battery 200 are adjusted as per feasibility and requirement.

[045] At step 702, the cathode active material layer 106 is disposed over the cathode current collector 104 to form the cathode electrode 102. The cathode active material layer 106 is disposed by coating a slurry or a paste of the cathode mixture and the solvent. The paste is prepared by mixing the cathode mixture with the solvent in vacuum conditions. The characteristics of the cathode mixture required for the cathode active material layer 106 has already been described in description pertaining to Figure 3. The paste is coated by conventionally known coating techniques such as the doctor blade technique, the spray technique and the printing technique to form the cathode active material 106 over the cathode current collector 104. The cathode active material

layer 106 is subjected to compressing for compacting or controlling the thickness of the layer on the cathode current collector 104. The cathode active material layer 106 is then subjected to drying, optionally in a long oven, for solidifying the layer. The cathode active material layer 106 is subsequently subjected to slitting for removing burrs at the edges, if any, and to adjust the size as per requirement.

[046] At step 704, the anode active material layer 112 is disposed or coated over the anode current collector 110 to form the anode electrode. The anode active material layer 112 is coated over the anode current collector 110 by conventionally known coating techniques such as the doctor blade technique, the spray technique and the printing technique. The anode active material layer 112 is subjected to compressing for compacting or controlling the thickness of the layer on the anode current collector 110. The anode active material layer 112 is then subjected to drying, optionally in a long oven, for solidifying the layer. The anode active material layer 112 is subsequently subjected to slitting for removing burrs at the edges, if any, and to adjust the size as per requirement.

[047] At step 706, the SSE 100 is disposed between the cathode active material 106 and the anode active material layer 112. The method in which the SSE 100 is coated on at least one of the cathode electrode 102 and the anode electrode 108 is already described in description pertaining to Figure 2. The SSE 100 is adapted to connect the cathode electrode 102 and the anode electrode 108 for ion conduction therebetween to enable operation of the battery 200.

[048] The constituents in the SSE 100, particularly alumina, enhances thermal stability upon disposal in the battery 200 due to its higher thermal resistance. The alumina also enhances ionic conductivity in the battery 200. Further, the ceramic material [SiC] included in the SSE 100 provides interface support to the battery 200, thereby reducing

the rate of degradation of the battery 200. Hence, cycle performance of the battery 200 is enhanced. Additionally, the ceramic material in the SSE 100 provides limited number of pores available for ionic transfer in the cathode electrode 102. As such, the lithium dendrites are retained in the cathode electrode 102, thereby preventing possibility of short-circuiting in the battery 200.

[049] While the present invention has been described with respect to certain embodiments, it will be apparent to those skilled in the art that various changes and modification may be made without departing from the scope of the invention as defined in the following claims.



**CLAIMS:**

1. A solid-state electrode (100) for an ion conducting battery, the solid-state electrode (100) comprising: an electrode mixture of Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI).  
5
2. The solid-state ion electrode (100) as claimed in claim 1, wherein the electrode mixture comprises 53% of the Bi-metallic ceramic nano composite material, 14% of the Polyethylene Oxide (PEO) and 33% of the Lithium bistrifluoromethanesulfonimide (LiTFSI) by weight.  
10
3. The solid-state electrode (100) as claimed in claim 1, wherein the Bi-metallic ceramic nano composite material comprises 30% of Al<sub>2</sub>O<sub>3</sub>, 50% to 55% of titania (TiO<sub>2</sub>) and 15% to 20% of Silicon Carbide (SiC) in weight.  
15
4. A method for fabricating a solid-state electrode (100) for an ion conducting battery, the method comprising:  
preparing, an electrode mixture of Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI);  
20 mixing, the electrode mixture with a solvent to form an electrode paste; and  
coating the electrode paste on at least one of a cathode electrode (102) and an anode electrode (108) of the ion conducting battery (200) to form the solid-state electrode (100).

5. The method as claimed in claim 4, wherein the solvent is acetonitrile, the acetonitrile being mixed with the electrode mixture in vacuum conditions.

6. The method as claimed in claim 4, wherein the electrode paste is coated on at least one of the cathode electrode (102) and an anode electrode (108) by one of a doctor blade coating, a spray coating and a printing technique.

7. A solid-state ion conducting battery (200), comprising:

a cathode electrode (102) comprising a cathode current collector (104); and a cathode active material layer (106) disposed over the cathode current collector (104), wherein the cathode active material layer (106) comprises a cathode mixture containing 95% of a Lithium Metal Oxide compound and 5% of a conductive super Phosphorous-Carbon powder;

an anode electrode (108) comprising an anode current collector (110) and an anode active material layer (112) disposed over the anode current collector (110), wherein the anode active material layer (112) is comprised of an alkali metal; and a solid-state electrode (100) provided between the cathode active material layer (106) and the anode active material layer (112), the solid-state electrode (100) adapted to connect the cathode electrode (102) with the anode electrode (108) for ion conduction therebetween to enable operation of the battery (200);

wherein the solid-state electrode (100) is disposed on at least one of the cathode active material layer (106) and the anode active material layer (112), the solid-state electrode (100) comprising an electrode mixture of a Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI).

8. The solid-state ion conducting battery (200) as claimed in claim 7, wherein the alkali metal for the anode active material layer (112) is made by one of a Lithium metal, Sodium metal and Potassium metal.

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9. The solid-state ion conducting battery (200) as claimed in claim 7, wherein the Bi-metallic ceramic nano composite material comprises 30% of  $\text{Al}_2\text{O}_3$ , 50% to 55% of titania ( $\text{TiO}_2$ ) and 15% to 20% of Silicon Carbide ( $\text{SiC}$ ) in weight.

10. The solid-state ion conducting battery (200) as claimed in claim 7, wherein the electrode mixture comprises 53% of the Bi-metallic ceramic nano composite material, 14% of the Polyethylene Oxide (PEO) and 33% of the Lithium bistrifluoromethanesulfonimide ( $\text{LiTFSI}$ ) by weight.

11. The solid-state ion conducting battery (200) as claimed in claim 7, wherein the solid-state electrode (100) disposed over the cathode active material layer (106) is configured with a thickness of  $80\mu\text{m}$  to  $100\mu\text{m}$ .

12. The solid-state ion conducting battery (200) as claimed in claim 7, wherein the cathode active material layer (106) disposed over the cathode current collector (104) is configured with a thickness of  $50\mu\text{m}$  to  $70\mu\text{m}$ .

13. The solid-state ion conducting battery (200) as claimed in claim 7, wherein the solvent is acetonitrile, the acetonitrile being mixed with at least one of the cathode mixture and the electrode mixture in vacuum conditions.

14. The solid-state ion conducting battery (200) as claimed in claim 7, wherein the cathode current collector (104) is an aluminum current collector made of 99.3% pure aluminum foil having a thickness of 15 $\mu$ m and the anode current collector (110) is a copper current collector made of 99.9% pure copper foil made having a thickness of 9 $\mu$ m to 12 $\mu$ m.

15. A method of fabricating a solid-state ion conducting battery (200), the method comprising:

providing a cathode active material layer (106) over a cathode current collector (104) to form a cathode electrode (102), the cathode active material layer (106) being formed by coating a cathode active material paste prepared by mixing a cathode mixture with a solvent, the cathode mixture comprising a cathode mixture containing 95% of a Lithium Metal Oxide compound and 5% of a conductive super Phosphorous-Carbon powder;

providing an anode active material layer (112) over an anode current collector (110) to form an anode electrode (108), wherein the anode active material layer (112) comprises an alkali metal; and

providing a solid-state electrode (100) between the cathode active material layer (106) and the anode active material layer (112), the solid-state electrode (100) adapted to connect the cathode electrode (102) with the anode electrode (108) for ion conduction therebetween to enable operation of the battery (200),

wherein the solid-state electrode (100) is formed on at least one of the cathode active material layer (106) and the anode active material layer (112) by coating an electrode paste prepared by mixing an electrode mixture with the solvent, the

electrode mixture comprising a Bi-metallic ceramic nano composite material, Polyethylene Oxide (PEO) and Lithium bistrifluoromethanesulfonimide (LiTFSI).

16. The method as claimed in claim 15, wherein the cathode active material paste is  
5 coated over the cathode current collector by one of a doctor blade coating, a spray coating and a printing technique.

17. The method as claimed in claim 15, wherein the electrode paste is coated over  
each of the cathode active material layer and the anode active material layer by one  
10 of a doctor blade coating, a spray coating and a printing technique.

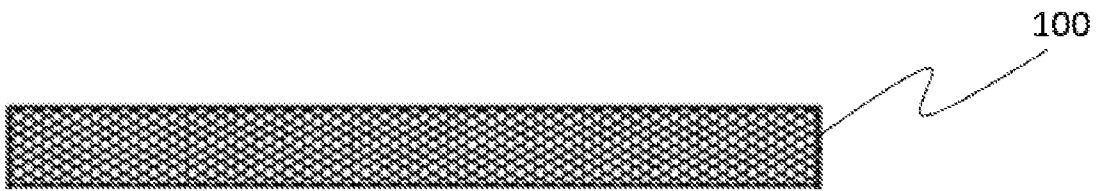


Figure 1

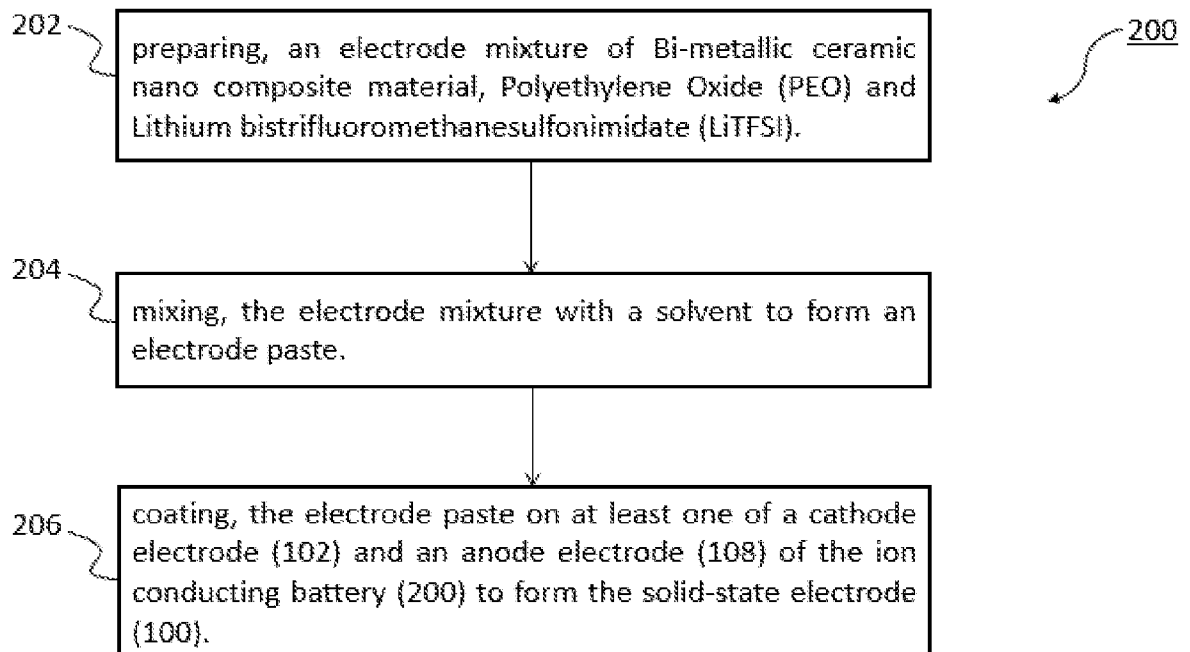


Figure 2

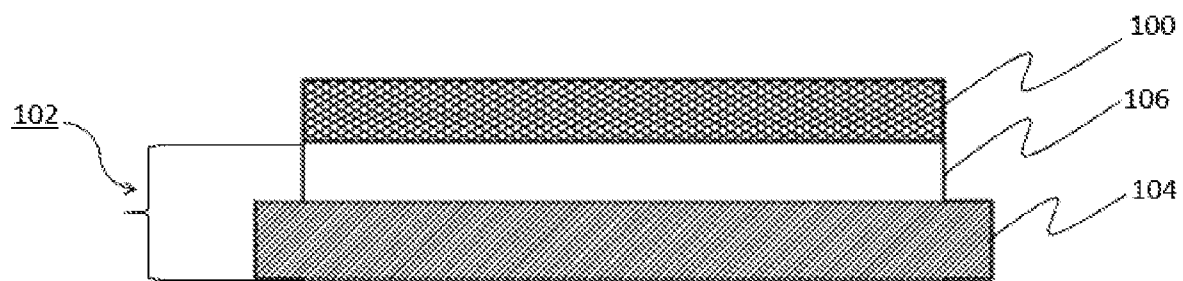


Figure 3



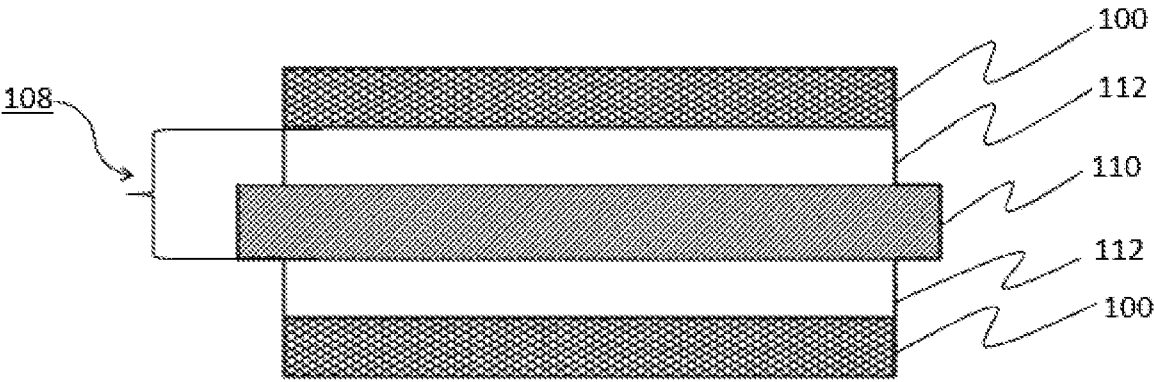


Figure 4

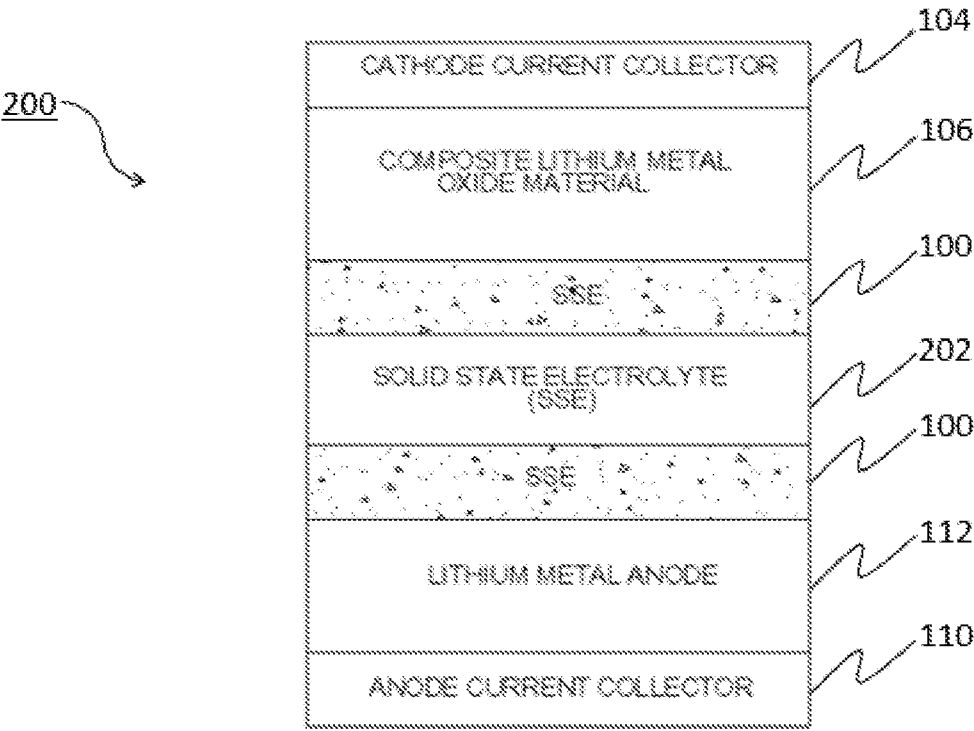


Figure 5

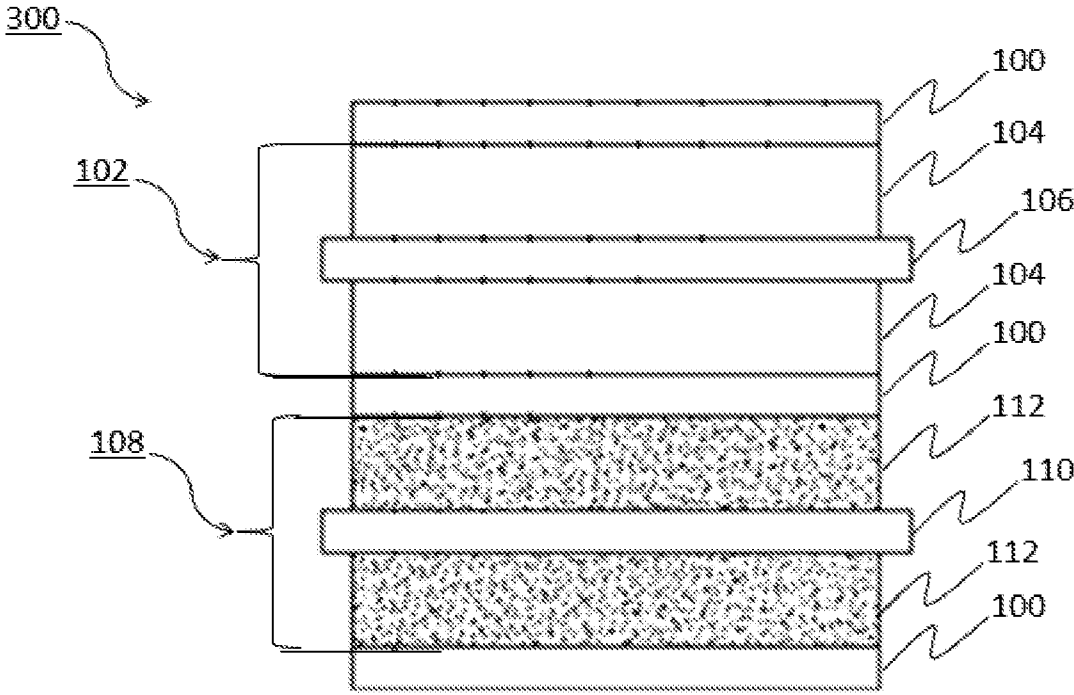
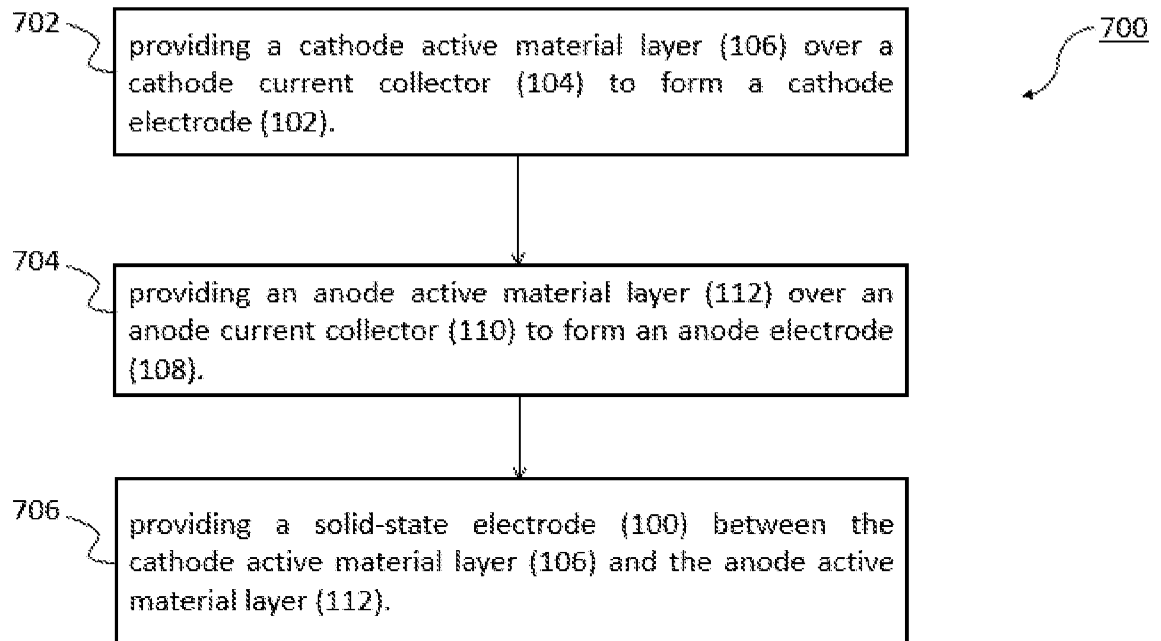


Figure 6

**Figure 7**

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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                      |                                                                                                                    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br><b>INV.</b> <b>H01M4/131</b> <b>H01M4/1391</b> <b>H01M4/36</b> <b>H01M4/485</b> <b>H01M4/62</b><br><b>H01M4/66</b> <b>H01M10/052</b><br><b>ADD.</b><br>According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                      |                                                                                                                    |
| <b>B. FIELDS SEARCHED</b><br>Minimum documentation searched (classification system followed by classification symbols)<br><b>H01M</b><br><br>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched<br><br>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br><b>EPO-Internal, WPI Data</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                      |                                                                                                                    |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                      |                                                                                                                    |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                   | Relevant to claim No.                                                                                              |
| <b>X</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>EP 1 760 819 A2 (OHARA KK [JP])</b><br><b>7 March 2007 (2007-03-07)</b><br><b>paragraph [0110]</b><br>-----                                                                                       | <b>1-17</b>                                                                                                        |
| <b>X</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>CN 111 092 260 B (UNIV ZHEJIANG TECHNOLOGY) 5 March 2021 (2021-03-05)</b><br><b>example 2</b><br>-----                                                                                            | <b>1-17</b>                                                                                                        |
| <b>X</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>US 2021/021009 A1 (LI ZHE [CN] ET AL)</b><br><b>21 January 2021 (2021-01-21)</b><br><b>claims 1-8</b><br>-----                                                                                    | <b>1-17</b>                                                                                                        |
| <b>A</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>CN 110 957 471 A (HENGDIAN GROUP DMEGC MAGNETICS CO LTD)</b><br><b>3 April 2020 (2020-04-03)</b><br><b>step 2;</b><br><b>examples 1,5-7</b><br>-----<br><div style="text-align: right;">-/-</div> | <b>1-17</b>                                                                                                        |
| <div style="display: flex; justify-content: space-between;"> <div> <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. </div> <div> <input checked="" type="checkbox"/> See patent family annex. </div> </div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                      |                                                                                                                    |
| <div style="display: flex;"> <div style="flex: 1;"> <p>* Special categories of cited documents :</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"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)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="flex: 1;"> <p>"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</p> <p>"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</p> <p>"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</p> <p>"&amp;" document member of the same patent family</p> </div> </div> |                                                                                                                                                                                                      |                                                                                                                    |
| Date of the actual completion of the international search<br><br><div style="text-align: center;"><b>24 August 2022</b></div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                      | Date of mailing of the international search report<br><br><div style="text-align: center;"><b>21/09/2022</b></div> |
| Name and mailing address of the ISA/<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                      | Authorized officer<br><br><div style="text-align: center;"><b>Haering, Christian</b></div>                         |

## INTERNATIONAL SEARCH REPORT

International application No

PCT/IN2022/050488

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                             |                       |
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