(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 March 2019 (28.03.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/057272 A1

(51) International Patent Classification:
C23C 14/08 (2006.01) *C23C 16/40* (2006.01)
C23C 14/06 (2006.01) *C23C 16/34* (2006.01)
C23C 14/00 (2006.01) *C23C 16/54* (2006.01)
C23C 14/26 (2006.01) *C23C 16/52* (2006.01)
C23C 14/56 (2006.01) *H01M 2/14* (2006.01)
C23C 14/54 (2006.01)

(21) International Application Number:
PCT/EP2017/073778

(22) International Filing Date:
20 September 2017 (20.09.2017)

(25) Filing Language: English

(26) Publication Language: English

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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, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, 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, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, 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, 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).

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

(54) Title: METHOD AND PROCESSING SYSTEM FOR CONTROLLING A THICKNESS OF A CERAMIC LAYER ON A SUBSTRATE

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FIG. 5

(57) Abstract: A method for controlling a thickness of a ceramic layer on a substrate, comprising providing a substrate having a front side and a back side, the substrate being coated with the ceramic layer on at least one of the front side and the back side, subjecting at least a first position L1 of the ceramic layer to ionizing radiation, detecting an emission released at the at least first position L1 of the ceramic layer in response to the ionizing radiation, and assessing the thickness of the ceramic layer at the at least first position L1 based on the detected emission. A processing system for controlling a thickness of a ceramic layer on a substrate, comprising at least one radiation unit configured to emit ionizing radiation towards at least a first position L1 of the ceramic layer; at least a first sensor being arranged at a first position S1 within the at least one radiation unit, the at least first sensor being configured to detect an emission released at the at least first position L1 of the ceramic layer in response to the ionizing radiation, and at least one controller configured to assess the thickness of the ceramic layer at least at a first position L1 based on the detected emission.

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METHOD AND PROCESSING SYSTEM FOR CONTROLLING A THICKNESS OF A CERAMIC LAYER ON A SUBSTRATE

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TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate to a method and processing system for controlling a thickness of a ceramic layer on a substrate. Embodiments of the present disclosure more particularly relate to an ionizing radiation method and ionizing radiation system for controlling the thickness of a ceramic layer deposited onto a substrate. 10 Embodiments of the present disclosure relate to a method and a processing system for manufacturing a component of electrochemical energy storage devices such as batteries, fuel cells and accumulators, more particularly at least one of the components selected from the group consisting of separator, electrolyte, cathode and anode.

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BACKGROUND

[0002] Techniques for ceramic layer deposition on a substrate include, for example, printing deposition, sputter deposition, thermal evaporation, and chemical vapor deposition. A sputter deposition process can be used to deposit a material layer on the substrate, such as a layer of a conducting material or an insulating material. Ceramic 20 coated materials may be used in several applications and in several technical fields. For instance, one application lies in the field of electrochemical energy storage, such as for battery, fuel cell devices and accumulators. In addition, substrates for separators are often ceramic coated by physical vapor deposition (PVD), e.g. a sputter deposition process, or chemical vapor deposition (CVD). Further applications include cathodes, anodes, 25 electrolytes and the like.

[0003] The thickness of a ceramic layer on a substrate can also be understood as the uniformity of a ceramic layer on a substrate. The thickness can often vary over the length of the substrate. This thickness variation can be readily influenced by different parameters such as the deposition rate, the speed at which the substrate is guided from one module to

another, the amount and/or orientation of a gas flow of the reactive gas, or the evaporation and/or plasma power applied or the like.

[0004] In order to control the uniformity of a ceramic layer deposited on a substrate, several common techniques can be applied, such as UV light techniques, inductive current
5 techniques, or optical techniques. These techniques are dependent on the nature and/or properties of the substrate and the ceramic layer and may not be generalized. For instance, these techniques may not be used with a non-transparent and/or non-reflective substrate coated with a highly transparent ceramic layer.

[0005] In view of the above, methods and systems that overcome at least some of the
10 problems in the art are beneficial. The present disclosure particularly aims at providing methods and systems for controlling a thickness of a ceramic layer on a substrate, particularly providing vacuum processing systems and vacuum processing methods for manufacturing at least one of the components of an electrochemical device that overcome at least some of the problems in the art.

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SUMMARY

[0006] In light of the above, a method and processing system for controlling a thickness of a ceramic layer on a substrate are provided. Further, a vacuum processing system and a vacuum processing method for manufacturing a component of electrochemical devices are
20 provided. Further aspects, benefits, and features of the present disclosure are apparent from the claims, the description, and the accompanying drawings.

[0007] According to an aspect of the present disclosure, a method for controlling a thickness of a ceramic layer on a substrate is provided. The method includes providing a substrate having a front side and a second side. In addition, the substrate is coated with the
25 ceramic layer on at least one of the front side and the back side. The method further includes subjecting at least a first position L1 of the ceramic layer to ionizing radiation. In addition, the method includes detecting an emission released at the at least first position L1 of the ceramic layer in response to the ionizing radiation. The method further includes

assessing the thickness of the ceramic layer at the at least first position L1 based on the detected emission.

[0008] According a further aspect of the present disclosure, the method includes subjecting at least a second position L2 of the ceramic layer to ionizing radiation. Additionally, the at least second position L2 is different from the at least first position L1. Further, the method includes detecting an emission released at the at least second position L2 of the ceramic layer in response to the ionizing radiation. The method further includes assessing the thickness of the ceramic layer at the at least second position L2 based on the detected emission.

[0009] According to a further aspect of the disclosure, the method includes comparing the thickness at the first position L1 with the thickness at the second position. The method further includes comparing the thickness of the ceramic layer at the first location L1 with the thickness of the ceramic layer at a second position L2. Additionally, the method includes adjusting the thickness of the ceramic layer at the at least first position L1 to the thickness of the ceramic layer at the at least second position L2.

[0010] According to another aspect of the present disclosure, a processing system for controlling a thickness of a ceramic layer on a substrate is provided. The processing system includes at least one radiation unit configured to emit ionizing radiation towards at least a first position L1 of the ceramic layer. The processing system further includes at least a first sensor arranged at a first position S1 within the at least one radiation unit. Additionally, the at least first sensor is configured to detect an emission released at the first position L1 of the ceramic layer in response to the ionizing radiation. The processing system further includes at least one controller configured to assess the thickness of the ceramic layer at the at least first position L1 based on the detected emission.

[0011] According to a further aspect of the present disclosure, the processing system includes at least one radiation unit further configured to emit ionizing radiation towards at least a second position L2 of the ceramic layer. The processing system further includes at least a second sensor arranged at a second position S2 within the at least one radiation unit. Additionally, the at least second sensor is configured to detect an emission released at the second position L2 of the ceramic layer in response to the ionizing radiation. The

processing system includes at least one controller further configured to assess the thickness of the ceramic layer at the at least second position L2 based on the detected emission.

[0012] According to a further aspect of the present disclosure, the processing system includes at least one controller configured to compare the thickness of the ceramic layer at the at least first position L1 with the thickness of the ceramic layer at the at least second position L2. Additionally, the at least one controller is configured to adjust the thickness of the ceramic layer at the at least first position L1 to the thickness of the ceramic layer at the at least second position L2.

[0013] According to another aspect of the present disclosure, a processing system for controlling a thickness of a ceramic layer on a substrate is provided. The processing system includes at least one radiation unit, at least a first sensor, at least a second sensor and at least one controller.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] So that the manner in which the above-recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments. The accompanying drawings relate to embodiments of the disclosure and are described in the following:

FIG. 1 shows a schematic flow chart of a method for controlling a thickness of a ceramic layer on a substrate including at the at least first position L1 according to embodiments described herein;

FIG. 2 shows a flow chart of a method for controlling a thickness of a ceramic layer on a substrate including at least first position L1 different from at least a second position L2 according to embodiments described herein;

FIG. 3 shows a schematic cross sectional view of a roll-to-roll system, including a system for controlling a thickness of a

ceramic layer on a substrate as described in the embodiments herein;

FIG. 4 shows a schematic cross sectional view of a controlling system according to FIG. 3, as described in the embodiments herein;

FIG. 5 shows a schematic cross sectional view of a controlling system according to FIG.3, as described in further embodiments herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0015] Reference will now be made in detail to the various embodiments of the disclosure, one or more examples of which are illustrated in the drawings. Within the following description of the drawings, the same reference numbers refer to same components. Specifically the differences with respect to individual embodiments are described. Each example is provided by way of explanation of the disclosure and is not meant as a limitation of the disclosure. Further, features illustrated or described as part of one embodiment can be used on or in conjunction with further embodiments to further embodiments. Intended is that the description includes such modifications and variations.

[0016] Before various embodiments of the present disclosure are described in more detail, some aspects with respect to some terms and expressions used herein are explained.

[0017] In the present disclosure, the term “controlling” as used herein, can be understood in a broad manner and, may include operations for adapting the thickness of a ceramic layer on a substrate. The term “controlling” may encompass terms such as measuring, assessing, adjusting, adapting, equalizing, making uniform, monitoring, overseeing, comparing, correcting, and the like.

[0018] As already mentioned above, the term “thickness” shall be understood in a broad sense and, may encompass terms such as uniformity, density, width, depth, breadth, diameter, homogeneity, and the like. In particular, the term “thickness” may relate to the

distance between the surface of the ceramic layer in contact with the substrate and the surface of the ceramic layer that is opposite, between at least two different positions on the substrate.

[0019] Furthermore, the term “ceramic layer” as described herein can be understood in a broad sense and may embrace ceramic compositions. The ceramic composition of the ceramic layer may include several elements. For instance, the ceramic composition may include and/or consist of two, three, four or more elements. For instance, in the case of three elements constituting the ceramic composition, the ceramic composition may be derived from the following formula:

$$A_xB_yC_Z$$

with A being selected from a group consisting of transition metals, post-transition metals, and metalloids, with B being selected from a group of oxide, nitride, and carbide, with being C selected from the groups of A and B; x is the stoichiometry number of A, y is the stoichiometry number of B, and/or z is the stoichiometry number of Z.

[0020] For instance, in the case of two elements constituting the ceramic composition, the ceramic composition may be derived from the following formula:

$$A_xB_y$$

with A being selected from a group consisting of transition metals, post-transition metals, and metalloids, with B being selected from a group of oxide, nitride, and carbide; x is the stoichiometry number of A and/or y is the stoichiometry number of B. The above formulas can be generalized for more than three elements constituting the ceramic composition. In further embodiments, the ceramic layer may be a combination of compositions derivable from the abovementioned formulas.

[0021] Additionally, the term “ceramic layer” may embrace at least one of electrically non-conductive, very poorly conductive and a highly transparent layer including the metals aluminum, silicon, lead, zirconium, titanium, hafnium, lanthanum, magnesium, zinc, tin, cerium, yttrium, calcium, barium, strontium and combinations thereof. Despite silicon often being referred to as metalloid, in the context of the present disclosure silicon shall be

included whenever reference is made to a metal. Aluminum may be beneficial. In general, according to embodiments herein, the ceramic layer may be optimized for electrochemical cells involving strongly alkaline electrolytes by choosing particularly alkali-resistant input materials. For instance, zirconium or titanium may be used in place of aluminum as an
5 inorganic component to form the ceramic layer. The ceramic layer may include zirconium oxide or titanium oxide in place of aluminum oxide. In particular embodiments, the ceramic layer may be a highly transparent and an electrically non-conductive layer.

[0022] In further embodiments, the “ceramic layer” may include porous and non-porous layers. The term “porous” can be particularly understood in a broad manner and may
10 encompass terms such as porosity. For instance, a porosity can be determined via familiar methods, such as, e.g., by the method of mercury porosimetry and/or may be calculated from the volume and the density of the materials used on the assumption that all the pores are open pores. In the present disclosure, “porous”, such as a porous ceramic layer may relate to the accessibility of open pores. In other words, the ceramic layer can be porous
15 such that certain elements can pass through the ceramic layer. According to embodiments described herein, the ceramic layer may beneficially be a porous layer.

[0023] According to embodiments described herein, a thickness of the ceramic layer formed on the flexible substrate can be equal to or greater than 25 nm, specifically equal to or greater than 50 nm, particularly equal to or greater than 100 nm, and/or equal to or
20 smaller than 1000 nm, specifically equal to or smaller than 500 nm, particularly equal to or smaller than 150 nm. When practicing embodiments, a very high energy density in an electrochemical energy storage device can be achieved.

[0024] During ceramic material deposition, e.g. by evaporation, specifically by reactive evaporation, the ceramic layer may not be formed with full stoichiometry or formed non-
25 stoichiometry. In the context of the present disclosure, “stoichiometry”, such as a stoichiometry of the ceramic material, may be understood as the calculation of the relative quantities of reactants and products in chemical reactions. Accordingly, “non-stoichiometric” or “not full stoichiometric” can refer to cases in which the product does not include all reactants. In the example of aluminum oxide being the material of the coating
30 layer, a full stoichiometric reaction may be: $4Al + 3O_2 = 2Al_2O_3$. If the aluminum oxide is not formed with full stoichiometry or non-stoichiometric, the product of the reaction may

be, e.g., $Al_2O_{2.5}$. Accordingly, any composition of AlO_x with $x \neq 1.5$ can be considered as non-stoichiometric or not formed with full stoichiometry. In such a non-stoichiometric ceramic layer, there may be unbound excess atoms that may react with elements of the electrochemical energy storage device, specifically during charge and/or discharge of the electrochemical energy storage device. In the example of Li-ion batteries, the unbound excess atoms that may react with Li-ions traversing through the ceramic layer, such as during charge and/or discharge of the Li-ion battery. In the example of aluminum oxide as the material of the ceramic layer, the unbound excess atoms may be Al.

[0025] Furthermore, the term "substrate" as described herein, shall be understood in a broad manner and, may include substrates commonly used in at least one component of electrochemical devices such as separator, electrolyte, cathode and anode. In particular, the term "substrate" as used herein, shall particularly embrace flexible substrates, electrically insulating substrates, non-electrically insulating substrates, transparent substrates, non-transparent substrates, reflective substrates, and non-reflective substrates.

[0026] In the present disclosure, the term "transparent" can be particularly understood as relative transparency that may be the ratio and/or quotient of the transparency of the substrate and the transparency of ceramic layer arranged onto the substrate. "Non-transparent" substrates may embrace the substrates for which the relative transparency ratio may be greater than 1, particularly greater than 5. The "transparent substrates" according to the present disclosure can encompass the substrates that are not non-transparent as described herein. Further, the transparency can be measured by common methods with wavelengths that may range from the UV to IR.

[0027] Furthermore, the term "reflective" can be particularly understood as relative reflectance that may be the ratio and/or quotient of the reflectance of the substrate and the reflectance of ceramic layer arranged onto the substrate. The "non-reflective substrates" according to the present disclosure can encompass the substrates for which the relative reflectance ratio may be greater than 1, particularly greater than 5. "Reflective substrates" may embrace the substrates which are not non-reflective as described herein. Further, the reflectance may be measured by familiar methods.

[0028] In specific embodiments, the substrate may be selected to be non-transparent and non-reflective.

[0029] In further particular embodiments, the "substrate" may beneficially be devoid of at least one of the elements A and B as described herein.

5 [0030] According to embodiments described herein, the methods, apparatuses and systems described herein can be used in the context of or for the use of manufacturing electrochemical devices and/or components of electrochemical devices, such as a separator, electrolyte, cathode and anode.

[0031] As used herein, the term "electrochemical devices" shall be understood as an 10 electrochemical energy store which may be either rechargeable or non-rechargeable. The terms "accumulator" and "battery" are not distinguished in the present application. In addition, the terms "electrochemical device" and "electrochemical cell" are used synonymously hereinafter. An electrochemical cell, for instance, also covers a capacitor. In embodiments described herein, an electrochemical cell may be understood to be the 15 minimum functioning unit of the energy store. In industrial practice, a multitude of electrochemical cells may be frequently connected in series or parallel in order to increase the total energy capacity of the store. In this context, reference is made to multiple electrochemical cells. An industrially designed battery may consequently have a single electrochemical cell or a multitude of electrochemical cells connected in parallel or in 20 series.

[0032] In the case of electrochemical reactions of charging and/or discharging, high porosity of the ceramic layer and/or substrate may increase the ionic conductivity. In the case of Li-ion batteries, high porosity of the ceramic layer and/or the substrate may be beneficial to enable Li-ions cycles to be transported through the pores in the ceramic layer 25 and/or substrate between the two electrodes.

[0033] In further embodiments, the substrate can be a substrate adapted to one selected from the group consisting of separators, electrolytes, cathodes and anodes.

[0034] In the case of separators, the substrate may be made from microporous polyethylene, polypropylen and/or polyolefin, and/or a lamination thereof.

[0035] In further embodiments in Li-ion batteries, optionally the electrically insulating separators can include substrates that may have a polymer material selected from the group of: polyacrylonitrile, polyester, polyamide, polyimide, polyolefin, polytetrafluoroethylene, carboxymethyl cellulose, polyacrylic acid, polyethylene, polyethylene terephthalate, polyphenyl ether, polyvinyl chloride, polyvinylidene chloride, polyvinylidene fluoride, poly(vinylidenefluoride-co-hexafluoropropylene), polylactic acid, polypropylene, polybutylene, polybutylene terephthalate, polycarbonate, polytetrafluoroethylene, polystyrene, acrylonitrile butadiene styrene, poly(methyl methacrylate), polyoxymethylene, polysulfone, styrene-acrylonitrile, styrene-butadiene rubber, ethylene vinyl acetate, styrene maleic anhydride, and combinations thereof. Any other polymer materials that are stable in, for example, the strongly reducing conditions found in lithium based electrochemical cells may be used as well. According to embodiments herein, the separator can be optimized for electrochemical cells involving strongly alkaline electrolytes by choosing particularly alkali-resistant input materials. For instance, the separator may include a polyolefin or a polyacrylonitrile in place of polyester.

[0036] In embodiments described herein, the polymer material may have a high melting point, such as greater than 200°C. Separators including polymer materials with a high melting point may be useful in electrochemical cells having a fast charging cycle.

[0037] In the case of a cathode, the flexible substrate may be made from and/or include aluminum. In this case, a cathode layer may be formed on the flexible substrate. The ceramic layer can be formed on the cathode layer. For instance, the flexible substrate in the case of a cathode can have a thickness of 5 to 12 µm and/or the cathode layer can have a thickness of up to 100 µm. Additionally or alternatively, the flexible substrate can be or include a polymer material as described herein, e.g. polyester, on which a layer of aluminum is deposited. The polymer substrate may be thinner than e.g, the aluminum substrate and/or the deposited layer of aluminum. The deposited layer of aluminum can have a thickness of about 0.5 µm to about 1 µm. When practicing embodiments, a thickness of the cathode can be reduced.

[0038] In the case of an anode, the flexible substrate may be made from and/or include copper. In this case, an anode layer may be formed on the flexible substrate. The ceramic layer can be formed on the anode layer. For instance, the flexible substrate in case of an

anode can have a thickness of 5 to 12 μm and/or the anode layer can have a thickness of up to 100 μm. Additionally or alternatively, the flexible substrate can be or include a polymer material as described herein, e.g. polyester, on which a layer of copper is deposited. The polymer substrate may be thinner than e.g, the copper substrate and/or the deposited layer
5 of copper. The deposited layer of copper can have a thickness of about 0.5 μm to about 1 μm. When practicing embodiments, a thickness of the anode can be reduced.

[0039] In the particular case of Li-ion cells, the anode may include a substrate on which a layer of lithium contained in atomic layers of crystal structures of carbon graphite (LiC_6) can be formed. Further, the cathode may include a substrate on which a layer of lithium
10 manganese oxide ($LiMnO_4$) or lithium cobalt oxide (LiCoO) can be formed.

[0040] In the present disclosure, the term “subjecting” as used herein, can be understood in a broad manner and, may encompass terms such as applying, exposing, and also expressions such as “the ceramic layer is undergoing” and the like. In the context of the disclosure, “subjecting the ceramic layer” can be performed by any device configured to
15 subject the ceramic layer to ionizing radiation.

[0041] Further, the term “position” shall be understood in a broad manner and can refer to a location that may be either a point or an area. The term “position” may encompass terms such as location, surface, region, area, site, space, place and the like. In particular, these terms shall be understood as being equivalent to each other.

20 [0042] In the present disclosure, the term “ionizing radiation” shall be understood as radiations that carry enough energy to expel at least one electron from atoms or molecules. Atoms and molecules subjected to suitable ionizing radiation can be understood as being excited and/or ionized. In particular, the term “ionizing radiation” may include at least one of gamma rays, X-rays, and short-wavelength radiation. In specific embodiments, the
25 ionizing radiation may be selected so as to excite and/or ionize at least one of the elements A and B as described herein. In further embodiments, the “ionizing radiation” shall particularly be understood as enabling transparent ceramic layers to be excited and/or ionized although the substrate may be non-transparent and/or non-reflective.

[0043] Accordingly, the term “emission” can be understood as being the energy released by ionized and/or excited atoms or molecules in response to the “ionizing radiation” as described herein. Additionally, the energy may be released in the form of a photon and/or an electron. In particular, the term “emission” may include X-ray fluorescence (XRF)
5 emissions.

[0044] Furthermore, the term “assessing”, can be understood in a broad sense and, may encompass terms such as measuring, estimating, calculating, evaluating, counting, determining and the like. The act of “assessing the thickness” can be performed by any device configured to measure the thickness of the ceramic layer on a substrate.

10 [0045] FIG. 1 shows a schematic flow chart of a method for controlling a thickness of a ceramic layer on a substrate according to embodiments described herein. As exemplarily shown in FIG.1, the method 100 for controlling a thickness of a ceramic layer on a substrate includes providing 101 a substrate having a front side and a back side. Additionally, the substrate may be coated with the ceramic layer on and/or over at least one
15 of the front side and the back side. Further, the method 100 may include subjecting 102 at least a first position L1 of the ceramic layer to ionizing radiation. The method 100 further includes detecting 103 an emission released at the at least first position L1 of the ceramic layer in response to the ionizing radiation. Additionally, the method 100 includes assessing 104 the thickness of the ceramic layer at the at least first position L1 based on the detected
20 emission.

[0046] By providing a method for controlling the thickness of a ceramic layer on a substrate, the effectiveness of the method for depositing a ceramic layer on a substrate can be enhanced. In particular, the method as described herein may beneficially provide feedbacks on the thickness of the ceramic layer at a particular position on the substrate.
25 The method as described herein may be particularly beneficial during manufacturing of at least one component of an electrochemical device such as a separator, electrolyte, cathode and anode. Particularly, the method described herein may enable to control the quality of the component being manufactured in-situ, e.g. the thickness and/or uniformity of the ceramic layer. Further, by providing a method as described herein, subsequent operations
30 for the manufacturing of at least one component in the electrochemical industry can be enhanced.

[0047] More particularly, by providing the method as described herein, the thickness of the ceramic layer can be beneficially controlled especially in the case of a variable deposition rate and/or a variable evaporation rate during the depositing of the ceramic layer on the substrate. The term “variable” can be particularly understood as the deposition rate and/or evaporation rate that vary over the time and/or the deposition area. Further, the term “variable” may encompass terms such as inconstant, changing and the like. For instance, during deposition of the ceramic material, especially by evaporation, the crucible can get stuck with evaporated material and, the deposition and/or evaporation rate may in turn vary.

[0048] In further embodiments of the present disclosure, the method may further include providing a predetermined thickness for the ceramic layer to be deposited onto and/or over the substrate. In particular in embodiments of the present disclosure, the predetermined thickness can be the thickness of the ceramic layer to be deposited during depositing. In this case, the method of the present disclosure can be understood as an in-situ control of the thickness of the ceramic layer deposited onto and/or over the substrate. The expression “in-situ control” can be understood as a preliminary quality control during depositing. By providing a preliminary and/or in-situ control of the thickness of the ceramic layer, the method as described herein may beneficially enhance the process of manufacturing at least one component of an electrochemical device. In further embodiments, the predetermined thickness can be the thickness of the ceramic layer of an end product that may be subjected to final quality control. In this case, the method as described herein can beneficially provide a quality control of the product to be manufactured such as a component of electrochemical devices.

[0049] According to embodiments described herein, the predetermined thickness of the ceramic layer can be equal to or greater than 25 nm, specifically equal to or greater than 50 nm, particularly equal to or greater than 100 nm, and/or equal to or smaller than 1000 nm, specifically equal to or smaller than 500 nm, particularly equal to or smaller than 150 nm. Further, the predetermined thickness can depend on the nature of the substrate onto which the ceramic layer is deposited. In the case of substrates for a separator, the predetermined thickness of the ceramic layer as described herein may be substantially equal to 100 nm. In the case of substrates for a cathode and/or an anode, the predetermined

thickness of the ceramic layer as described herein may be substantially equal to 50 nm. The term "substantially" can be understood as to encompass deviations of the predetermined thickness, e.g. up to 10% from an exact predetermined thickness, especially up to 5%.

[0050] In further embodiments the thickness of the ceramic layer to be achieved can include a tolerance. In particular embodiments, the thickness can include a tolerance that may be the tolerance of the intended ceramic layer to be deposited onto and/or over the substrate during depositing. This tolerance may be understood as an "in-situ tolerance". In further embodiments, the thickness can include a tolerance that may be the tolerance of the intended ceramic layer deposited on and/or over the substrate within the product such as a component of an electrochemical device.

[0051] The tolerance of the ceramic layer thickness can depend on different parameters such as the nature of the substrates on which the ceramic layer is deposited. In particular embodiments the tolerance can range from 5% to 10%.

[0052] Additionally, the method may include comparing the thickness of the ceramic layer at a first position L1 with a predetermined thickness in light of a tolerance as described herein (not shown in FIG.1) so as to verify the compliance with manufacturing constraints. The term "in light of" as described herein, can be particularly understood as the term "within", or the expression "plus or minus". In other words, the tolerance as described herein may be considered as a range having the predetermined thickness as a mean value.

[0053] FIG. 2 shows a schematic flow chart of embodiments of the method described with reference to FIG.1, further including at least a second position L2 of the ceramic layer on the substrate. As exemplarily shown in FIG. 2, the method 200 further includes subjecting 201 at least a second position L2 of the ceramic layer to ionizing radiation. Further, the at least second position L2 may particularly be different from the at least first position L1. By providing a second position L2 on the ceramic layer, the method 200 as described herein, can beneficially cover different positions on the ceramic layer and optionally a larger area. Further, providing a second position L2 of the ceramic layer may accelerate the controlling of the thickness of the ceramic layer onto and/or over substantially the entire length of the substrate. In this case, the term "substantially" can be

particularly understood as to encompass deviations of up to 10% from an entire length of the substrate, especially of up to 5%. The second position L2 of the ceramic layer may beneficially enable the uniformity during ceramic layer deposition.

[0054] In further embodiments (not shown in FIG. 2), the method of the present 5 disclosure, may include three or more different positions different from one another. The benefits as described herein can beneficially provide at least the benefits as described herein, and may even improve those benefits to some extent.

[0055] As illustrated in FIG.2, the method 200 may include detecting 202 an emission released at the at least second position L2 of the ceramic layer in response to ionizing 10 radiation. Detecting 103 and detecting 202 may be performed either simultaneously or at different points in time. The method 200 may further include assessing 203 the thickness of the ceramic layer at the at least second position L2. In particular, assessing 104 and assessing 203 may be performed either simultaneously or at different points in time.

[0056] In further embodiments that can be combined with any embodiments described 15 herein, the method 200 may include comparing 204 the thickness at the at least first position L1 of the ceramic layer with the thickness at the at least second position L2 of the ceramic layer. Further, the method 200 may include adjusting 205 the thickness of the ceramic layer at the at least first position L1 to the thickness of the ceramic layer at the at least second position L2.

20 [0057] The term “adjusting” as described herein, shall be particularly understood as meaning equalizing, and also “making uniform”. In other words, after adjusting 205 the thickness of the ceramic layer at the at least first position L1 may beneficially correspond to the thickness of the ceramic layer at the at least second position L2.

[0058] Furthermore, at least one of the combinations subjecting 102 and subjecting 202, 25 detecting 103 and detecting 202, and assessing 104 and assessing 203 may be performed either simultaneously or at different points in time.

[0059] By providing a method that may include comparing 204 and adjusting 205 as described herein, the depositing of a ceramic layer on a substrate may be enhanced. Further, the reproducibility and repeatability of depositing a ceramic layer on a substrate

can be ensured. Accordingly, compared to common methods for depositing a ceramic layer on a substrate, the method of the embodiments described herein, may improve the quality of components for electrochemical devices.

[0060] More particularly, by providing the method as described herein, the thickness of the ceramic layer can be beneficially controlled especially in the case of a deposition rate and/or an evaporation rate being non-constant during the depositing of the ceramic layer on the substrate. Even more particularly, the method as described herein can adjust the depositing of the ceramic layer on the substrate so as to form a ceramic layer with a constant thickness on and/or over substantially the entire substrate. In this case, the term "substantially" can be particularly understood as to encompass deviations of up to 10% from an entire length of the substrate, especially of up to 5%. By forming a ceramic layer having a constant thickness, the method as described herein may further enhance the uniformity of the ceramic layer on and/or over the substrate.

[0061] According to further embodiments that can be combined with any embodiments described herein, the method may include adjusting a thickness of the ceramic layer in a region of the ceramic layer to at least one of the thickness of the ceramic layer at the at least first position L1 and the thickness of the ceramic layer at the at least second position L2 (not shown in FIG. 2). The term "region" as described herein, shall be particularly understood as an at least third position of the ceramic layer. Furthermore, the term "adjusting" shall be understood as described herein, namely equalizing, "making uniform" and the like. In those specific embodiments, the method may provide at least the benefits as described herein.

[0062] According to further embodiments (not shown in FIG. 2), the method may include providing a predetermined thickness in light of a tolerance. Additionally, the method may include comparing the thickness of the ceramic layer at the at least first position L1 with the predetermined thickness in light of the tolerance. Further, the method may include comparing the thickness of the ceramic layer at the at least second position L2 with the predetermined thickness in light of the tolerance.

[0063] In particular embodiments, the method may include adjusting the thickness of the ceramic layer according to one of the following cases (1) to (3):

(1) one of the thicknesses of the thickness of the ceramic layer assessed at the at least first position L1 and the thickness of the ceramic layer assessed at the at least second position L2 is within the predetermined thickness in light of the tolerance and the other one of the thicknesses of the thickness of ceramic layer assessed at the at least first position L1 and the thickness of the ceramic layer assessed at the at least second position L2 is outside the predetermined thickness in light of the tolerance:

adjusting the thickness that is outside the predetermined thickness in light of the tolerance, specifically to a value included within the predetermined thickness in light of the tolerance;

(2) the thickness of the ceramic layer at the at least first position L1 and the thickness of the ceramic layer at the at least second position L2 are both within the predetermined thickness in light of the tolerance;

either (2a) not adjusting;

or (2b) determining which of the thicknesses of the thickness of the ceramic layer assessed at the at least first position L1 and the thickness of the ceramic layer assessed at the at least second position L2 is closer to the predetermined thickness, the other one being further removed from the predetermined thickness;

adjusting the thickness that is the further removed from the predetermined thickness Y to the thickness that is closer to the predetermined thickness;

(3) the thickness of the ceramic layer assessed at the at least first position L1 and the thickness of the ceramic layer assessed at the at least second position L2 are both outside the predetermined thickness in light of the tolerance;

adjusting until at least one of the thicknesses of the thickness of the assessed ceramic layer at the at least first position L1 and the thickness of the ceramic layer at the at least second position L2 is within the predetermined thickness in light of the tolerance;

optionally further adjusting according to (1) or (2).

[0064] In further embodiments (not shown in FIG. 2), the method may involve three or more positions of the ceramic layer on the substrate.

[0065] According to other embodiments, the method may further include providing a substrate having a front side and a back side. Additionally, the method may include forming a ceramic layer on at least one of the front side and back side of the substrate (not shown in FIG. 2). In particular, the ceramic layer can be formed by any common methods, more particularly may be formed by reactive evaporation such as PVD, CVD and the like.

[0066] In other specific embodiments, the ceramic layer may be formed of at least a first forming position F1 and of at least a second forming position F2 (not shown in FIG. 2). The at least first forming position F1 may particularly correspond to the at least first position L1. The at least second forming position F2 may particularly correspond to the at least second position L2. In specific embodiments, the at least first forming position F1 may particularly correspond to the at least first position L1 and the at least second forming position F2 may particularly correspond to the at least second position L2.

[0067] In the context of the present disclosure, a corresponding position, such as a forming position corresponding to a position towards which the ionizing radiation can be directed to, can be understood as corresponding in at least one dimensional direction, e.g. of the flexible substrate and/or the ceramic layer. In particular, the first forming position F1 may correspond to the first position L1 in a length direction of the substrate, i.e. along a transport direction of the substrate, in that the first forming position F1 and the first position L1 are aligned with each other along the transport direction and/or spaced from each other along the length direction. Further, first forming position F1 may correspond to the first position L1 in a width direction of the substrate, i.e. perpendicular to the transport direction of the substrate, in that the first forming position F1 and the first position L1 are arranged at the same width. The same may also correspondingly apply for the second forming position F2 and the second position L2 and any further respective positions.

[0068] FIG. 3 shows a schematic view of a roll-to-roll system for manufacturing at least one component of electrochemical devices. As exemplarily shown in FIG. 3, the roll-to-roll system 300 can include a loading/unloading chamber 301. The loading/unloading chamber 301 can be configured to load/unload the flexible substrate 302 into and/or from

the roll-to-roll system 300. According to embodiments described herein, the loading/unloading chamber may be held under vacuum during processing of the flexible substrate 302. A vacuum device 303, such as a vacuum pump, can be provided to evacuate the loading/unloading chamber 301.

5 [0069] According to embodiments described herein, the loading/unloading chamber 301 can include an un-winding module 304 and/or a re-winding module 305. The un-winding module 304 can include an unwind roll for unwinding the flexible substrate 302. During processing, the flexible substrate 302 may be un-wound (indicated by arrow 323) and/or guided by one or more guide rolls 306 to a coating drum 307. After being processed, the
10 flexible substrate 302 may be wounded (arrow 324) on a re-wind roll in the re-winding module 305.

[0070] Further, the loading/unloading chamber 301 may include a tension module 308, for instance, including one or more tension rollers. Additionally or alternatively, the loading/unloading chamber 301 may also include a pivot device 319, such as, for instance,
15 a pivot arm. The pivot device 319 can be configured to be moveable with respect to the re-winding module 305.

[0071] According to embodiments described herein, the un-winding module 304, the re-winding module 305, the guide rolls 306, the pivot device 319, and tension module 308 can be part of the substrate transport mechanism and/or the roller assembly.

20 [0072] According to embodiments described herein, the roll-to-roll system 300 can include an evaporation chamber 309. The evaporation chamber 309 can include the deposition module 310. The evaporation chamber 309 may be evacuated by the vacuum device 303 that may also be used to evacuate the loading/unloading chamber 301. Additionally or alternatively, the evaporation chamber 309 may have a vacuum device that
25 is separate from the vacuum device 303 that may also be used to evacuate the loading/unloading chamber 301.

[0073] As exemplarily shown in FIG. 3, the deposition module 310 may include an evaporation device 311. The evaporation device 311 can be configured to evaporate a metal. According to embodiments described herein, the evaporation device may include

one or more evaporation boats. The evaporation device can further include one or more wires to be fed into the evaporation device. Specifically, there can be one wire for each evaporation boat. The one or more wires can include and/or be made of the material to be evaporated. Specifically, the one or more wires can supply the material to be evaporated.

5 [0074] According to embodiments described herein, the evaporation source can include one or more electrode beam sources. The one or more electrode beam sources can provide one or more electrode beams to evaporate the material to be evaporated. According to embodiments described herein, the evaporation device 311 may be one or more inductively heated crucibles. The inductively heated crucible may, for instance, be configured for
10 evaporating a metal in a vacuum environment by RF induction-heating, in particular by MF induction-heating. Further, the metal may be provided in crucibles that are exchangeable, such as, for example in one or more graphite vessels. The exchangeable crucible may include an insulating material that surrounds the crucible. One or more induction coils may be wrapped around the crucible and the insulating material. According
15 to embodiments described herein, the one or more inductive coils may be water cooled. Where exchangeable crucibles are used, no wire needs to be fed into the evaporation device 311. The exchangeable crucibles may be pre-loaded with a metal and may be replaced or refilled periodically. By providing the metal in batches the amount of metal being evaporated can be beneficially controlled.

20 [0075] In contrast to common evaporation methods that use resistance heating of crucibles to evaporate metals, using an inductively heated crucible allows for the heating process to be generated inside of the crucible and not by an external source via heat conduction. The inductively heated crucible has the benefit that all the walls of the crucible are heated very rapidly and evenly. The evaporation temperature of the metal may be
25 controlled more closely than with common resistance heated crucibles. When using an inductively heated crucible, the crucible may not necessarily be heated above the evaporation temperature of the metal. When practicing embodiments, a more controlled and efficient evaporation of the metal in order for the ceramic layer formed on a flexible substrate to be more homogenous may be provided. Close control of the temperature of the
30 crucible may also prevent/reduce pinholes and through-hole defects in the ceramic layer by

diminishing the likelihood of splashing of the evaporating metal. Pinhole and through-hole defects in separators may cause shorts in electrochemical cells.

[0076] According to embodiments described herein, the inductively heated crucible may, for instance, be surrounded by one or more induction coils (not shown in the FIGS.). The induction coils may be an integral part of the inductively heated crucible. Further, the induction coils and the inductively heated crucible may be provided as separate parts. Providing the inductively heated crucible and the induction coils separately may allow for easy maintenance of the evaporation apparatus.

[0077] According to embodiments described herein, a power source 312 (see in FIG. 4) may be provided. The power source 312 may be connected to the induction coils. The power source can be an AC power source that can be configured to provide electricity with a low voltage and high current and high frequency. Further, a reaction power may be increased, for instance, by including a resonant circuit. According to embodiments described herein, in addition or alternatively to electrically conductive materials, the inductively heated crucible may, for instance, include ferromagnetic materials. Magnetic materials may, for instance, improve the induction heat process and may allow for a better control of the evaporation temperature of metal.

[0078] According to embodiments described herein, the coating drum 307 of the roll-to-roll system 300 may separate the loading/unloading chamber 301 from the evaporation chamber 309. The coating drum 307 can be configured to guide the flexible substrate 302 into the evaporation chamber 309. The coating drum 307 can be arranged in the processing system so that the flexible substrate 302 can pass over the evaporation device 311. According to embodiments described herein, the coating drum 307 may be cooled.

[0079] The deposition module 310 may include a plasma source 313 configured to produce a plasma 321 between the evaporation device 311 and the coating drum 307. The plasma source 313 may, for instance, be an electron beam device configured to ignite a plasma 321 with an electron beam. According to further embodiments herein, the plasma source may be a hollow anode deposition plasma source. The plasma 321 may help to prevent/reduce pinholes and through-hole defects in the porous coating on the substrate by further diminishing the likelihood of splashing of the evaporating metal. The plasma may

also further excite the particles of the evaporated metal. According to embodiments described herein, the plasma may increase the density and uniformity of the porous coating deposited on the flexible substrate.

[0080] According to embodiments described herein, the deposition module 310 can include a gas supply for supplying a process gas. The gas supply can include a gas introduction device 314. The gas introduction device 314 can be arranged for controllably introducing the process gas into the deposition module 310 and/or the evaporation chamber 309. The gas introduction device may, for instance, include a nozzle and a supply tube connected to, for example, a process gas supply for providing the process gas into the deposition module 310 and/or evaporation chamber 309.

[0081] The process gas can be a reactive gas. Specifically, the process gas can be a reactive gas that reacts with the metal evaporated by the evaporation device 311. For instance, the process gas can be and/or include oxygen, ozone, argon and combinations thereof.

[0082] For the case of oxygen being included in the process gas, the oxygen gas may, for example, react with the evaporated metal to form the ceramic layer on the flexible substrate 302. The components of the electrochemical energy storage device, such as the separator or separator film, the cathode and the anode, may include AlO_y. A metal such as aluminum may be evaporated by the inductively heated crucible and oxygen may be supplied to the evaporated metal via the gas introduction device.

[0083] According to embodiments described herein, the roll-to-roll system 300 can include a gas assembly 316. The gas assembly 316 can be configured to supply an oxidation gas, such as oxygen. According to embodiments described herein, the roll-to-roll system 300 can include a heating assembly (not shown). The heating assembly can be configured to elevate a temperature of at least one of the supplied oxidation gas, the flexible substrate 302 and the ceramic layer.

[0084] According to embodiments described herein, the roll-to-roll system 300 can include a suction device 317. The suction device 317 can be configured to suck excess oxidation gas, i.e. oxidation gas that is not used to oxide the ceramic layer. The suction

device 317 can be arranged, with respect to the flexible substrate 302, opposite the gas assembly 316. Accordingly, process gas supplied by the gas assembly 316 can be provided to the ceramic layer, traverse the flexible substrate 302, and be sucked by the suction device 317, that may beneficially prevent pollution of the roll-to-roll system 300.

5 [0085] According to embodiments herein, the roll-to-roll system 300 may include a processing system 318 (shown in FIGS 3-5). The processing system 318 may be adapted to acquire a monitoring signal including information on at least one of the thickness and/or uniformity and the composition of the ceramic layer deposited on the substrate.

[0086] FIG. 4 shows an enlarged section 400 of the roll-to-roll system 300 according to 10 FIG. 3, including the processing system 318 for controlling a thickness of a ceramic layer on a substrate. As exemplarily shown in FIG. 4, the process system 318 includes at least one radiation unit 401 configured to emit ionizing radiation as described herein. The ionizing radiation is directed towards at least a first position L1 of the ceramic layer. Additionally, the processing system 318 includes at least a first sensor 402 arranged at a 15 first position S1 within the at least one radiation unit 401. Further, the at least first sensor 402 is configured to detect an emission released at the at least first position L1 of the ceramic layer in response to the ionizing radiation. The processing system 318 further includes at least one controller 403 configured to assess the thickness of the ceramic layer at the at least first position L1 based on the detected emission.

20 [0087] In further embodiments, the at least first sensor can be arranged anywhere in the radiation unit. In particular embodiments, the at least first sensor may be arranged in a parallel plane to the plane defined by the ceramic layer. In particular, the at least first sensor may be arranged in a plane facing the surface of the substrate deprived of ceramic material. More particularly, the at least first sensor may be arranged so as to face the at 25 least first position L1.

[0088] In a particular embodiment, the processing system illustrated in FIG. 4 is configured to operate the method for controlling the thickness of a ceramic layer on a substrate according to FIG. 1.

[0089] FIG. 5 shows a processing system according to embodiments of FIG. 4; the at least one radiation unit 401 may be further configured to emit ionizing radiation as described herein, towards at least a second position L2 of the ceramic layer. In particular, the at least second position L2 of the ceramic layer may be beneficially different from the at least first position L1 of the ceramic layer. The processing system 318 may further include at least a second sensor 404 arranged at a second position S2 within the at least one radiation unit 401. In particular, the second position S2 may beneficially be different from the first position S1. Additionally, the at least second sensor 404 may be configured to detect an emission released at the at least second position L2 of the ceramic layer in response to the ionizing radiation. Further, the at least one controller 403 may be further configured to assess the thickness of the ceramic layer at the at least second position L2 based on the detected emission.

[0090] In further embodiments, the at least second sensor can be arranged anywhere in the radiation unit. In particular embodiments, the at least second sensor may be arranged in a parallel plane to the plane defined by the ceramic layer. In particular, the at least second sensor may be arranged in a plane facing the surface of the substrate deprived from ceramic material. More particularly, the at least second sensor may be arranged so as to face the at least first position L2. In specific embodiments, the at least first sensor may be arranged so as to face the at least first position L1 and the at least second sensor may be arranged so as to face the at least second position L2.

[0091] In further embodiments, the at least one controller 403 may be configured to compare the thickness of the ceramic layer at the at least first position L1 with the thickness of the ceramic layer at the at least second position L2. In particular embodiments, the at least one controller may be configured to compare at least one of the thickness of the ceramic layer at the at least first position L1 and the thickness of the ceramic layer at the at least second position L2 with a predetermined thickness in light of a tolerance as described herein.

[0092] Further, the at least one controller may be configured to adjust the thickness of the ceramic layer at the at least first position L1 to the thickness of the ceramic layer at the at least second position L2.

[0093] In further embodiments, the at least one controller can be beneficially configured to adjust a thickness of the ceramic layer in a region of the ceramic layer as described herein, to at least one of the thickness of the ceramic layer at the at least first position L1 and the thickness of the ceramic layer at the at least second position L2.

5 [0094] In a particular embodiment, the processing system illustrated in FIG. 5 is configured to operate the method for controlling the thickness of a ceramic layer on a substrate according to FIG. 2.

[0095] In further embodiments, the controller 403 may be connected to at least one of the deposition module 310, the gas introduction device 314, the plasma source 313 and the 10 power source 312. According to embodiments described herein, the controller 403 can be configured to adjust at least one of a power provided to the deposition module 310, power provided to the plasma source 313, and/or an amount of the processing gas and/or an orientation of a gas flow of the processing gas introduced into the deposition module 310 by the gas introduction device 314.

15 [0096] According to embodiments described herein, the gas introduction device 314 may be arranged to provide a gas flow of the process gas in a direction approximatively parallel to an evaporation direction 322 of the metal. According to embodiments described herein, the orientation of the gas flow provided by the gas introduction device may be adjusted depending on at least one of the uniformity and composition of the ceramic layer. When 20 practicing embodiments, a more efficient reaction between the reactive gas and the evaporated metal for forming the ceramic layer can be ensured. Arranging the gas introduction device 314 to introduce a reactive gas in a direction essentially parallel to the evaporation direction 322 of the metal from the evaporation device 311 may also help to better control the coating process by being able to more accurately control the amount of 25 process gas which interacts with the evaporated metal.

[0097] According to embodiments described herein, the plasma 321 may be guided in a direction essentially perpendicular to the evaporation direction 322 of the metal. When practicing embodiments, splashing of the evaporating metal may be prevented and/or pinhole defects of the ceramic layer can be reduced.

[0098] The method and processing system as described herein may be performed and operated respectively, by way of hardware components, a computer programmed by appropriate software, by any combination of the two or in any other manner.

[0099] While the foregoing is directed to embodiments of the disclosure, other and
5 further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

[00100] In particular, this written description uses examples to disclose the disclosure, including the best mode, and also to enable to practice the described subject-matter, including making and using any devices or systems and performing any incorporated
10 methods. While various specific embodiments have been disclosed in the foregoing, mutually non-exclusive features of the embodiments described above may be combined with each other. The patentable scope is defined by the claims, and other examples are intended to be within the scope of the claims if the claims have structural elements that do not differ from the literal language of the claims, or if the claims include equivalent
15 structural elements with insubstantial differences from the literal language of the claims.

CLAIMS

1. Method (100,200) for controlling a thickness of a ceramic layer on a substrate, comprising:

providing (101) a substrate having a front side and a back side, the substrate being coated
5 with the ceramic layer on at least one of the front side and the back side;

subjecting (102) at least a first position L1 of the ceramic layer to ionizing radiation;

detecting (103) an emission released at the at least first position L1 of the ceramic layer in response to the ionizing radiation; and

assessing (104) the thickness of the ceramic layer at the at least first position L1 based on
10 the detected emission.

2. Method (200) for controlling a thickness of a ceramic layer on a substrate according to claim 1, comprising:

subjecting (201) at least a second position L2 of the ceramic layer to ionizing radiation; the
15 at least second position L2 being different from the at least first position L1;

detecting (202) an emission released at the at least second position L2 of the ceramic layer in response to the ionizing radiation; and

assessing (203) the thickness of the ceramic layer at the at least second position L2.

20 3. Method (200) for controlling a thickness of a ceramic layer on a substrate according to claim 2, further comprising:

comparing (204) the thickness at the at least first position L1 with the thickness at the at least second position L2 ; and

adjusting (205) the thickness of the ceramic layer at the at least first position L1 to the thickness of the ceramic layer at the at least second position L2.

4. Method (100) for controlling a thickness of a ceramic layer on a substrate according to claim 3, further comprising adjusting a thickness of the ceramic layer in a region corresponding to at least one of the thickness of the ceramic layer at the at least first position L1 and the thickness of the ceramic layer at the at least second position L2.

5. Method (100,200) for controlling a thickness of a ceramic layer on a substrate according to any of claims 1-4, providing a substrate includes:

providing a substrate having a front side and a back side; and

forming a ceramic layer on the substrate.

6. Method (100) for controlling a thickness of a ceramic layer on a substrate according to any of claims 1-5, wherein the ceramic layer is formed by reactive evaporation.

7. Method (200) for controlling a thickness of a ceramic layer on a substrate according to any of claims 1-6, wherein the ceramic layer is formed of at least a first forming position F1 and a second forming position F2, the first forming position F1 corresponding to the at least first position L1 of the ceramic layer and the second forming position F2 corresponding to the at least second position L2 of the ceramic layer.

8. Method (100, 200) for controlling a thickness of a ceramic layer on a substrate according to any of claims 1-7, wherein the ceramic layer is one of the ceramic composition selected from the following formula:

A_xB_y

with A being selected from the group consisting of transition metals, post-transition metals, and metalloids;

with B being selected from the group of oxide, nitride, carbide; and

5 x is the stoichiometry number of A and y is the stoichiometry number of B.

9. Method (100, 200) for controlling a thickness of a ceramic layer on a substrate according to claim 8, wherein the ionizing radiation is configured to ionize at least one of A and B.

10

10. Processing system (318) for controlling a thickness of a ceramic layer on a substrate, comprising:

- at least one radiation unit (401) configured to emit ionizing radiation towards at least a first position L1 of the ceramic layer;

15 - at least a first sensor (402) being arranged at a first position S1 within the at least one radiation unit (401); the at least first sensor (402) being configured to detect an emission released at the at least first position L1 of the ceramic layer in response to the ionizing radiation; and

- at least one controller (403) configured to assess the thickness of the ceramic layer
20 at at least a first position L1 based on the detected emission.

11. Processing system (318) for controlling a thickness of a ceramic layer on a substrate according to claim 10, further comprising:

- the at least one radiation unit (401) being further configured to emit ionizing radiation
25 towards at least a second position L2 of the ceramic layer; and

- at least a second sensor (404) being arranged at a second position S2 within the at least one radiation unit (401),

the at least second sensor (404) being configured to an emission released at least at a second position L2 of the ceramic layer in response to ionizing radiation, and

5 - the at least one controller (403) being further configured for assessing the thickness of the ceramic layer at the at least second position L2 based on the detected emission.

12. Processing system (318) for controlling a thickness of a ceramic layer on a substrate according to claim 10 or 11, the at least one controller (403) being configured to:

10 compare the thicknesses of the thickness of the ceramic layer at the at least first position L1 with the thickness of the ceramic layer at the at least second position L2; and

adjust the thickness of the ceramic layer at the at least first position L1 to the thickness of the ceramic layer at the at least second position L2.

15 13. Processing system (318) for controlling a thickness of a ceramic layer on a substrate according to any of claims 10-12, wherein the at least one controller (403) is configured to adjust a thickness of the ceramic layer in a region corresponding to at least one of the thickness of the ceramic layer at the at least first position L1 and the thickness of the ceramic layer at the at least second position L2.

20

14. Roll-to-roll system comprising at least one processing system according to any of claims 10-13.

15. Processing system (318) comprising at least one radiation unit (401), at least a first
25 sensor (402), at least second sensor (404) and at least one controller (403).

DRAWINGS

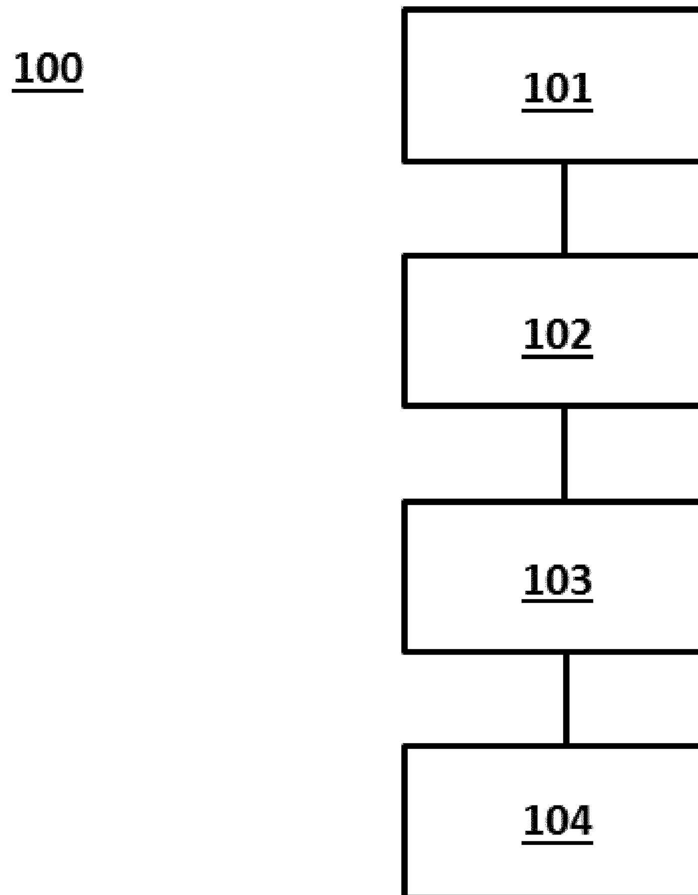

FIG.1

200

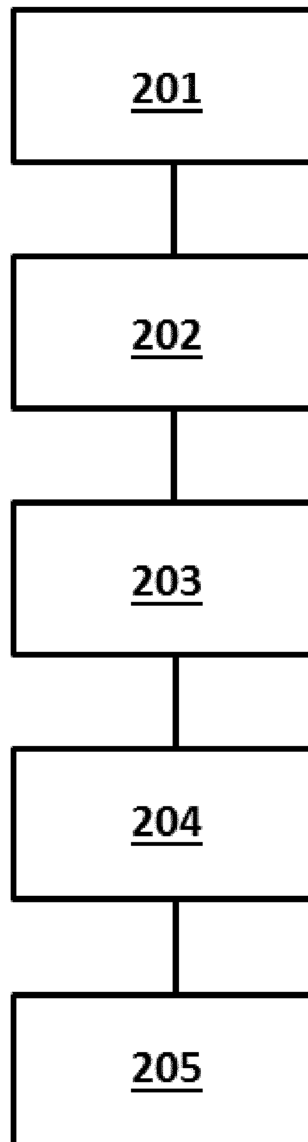

FIG.2

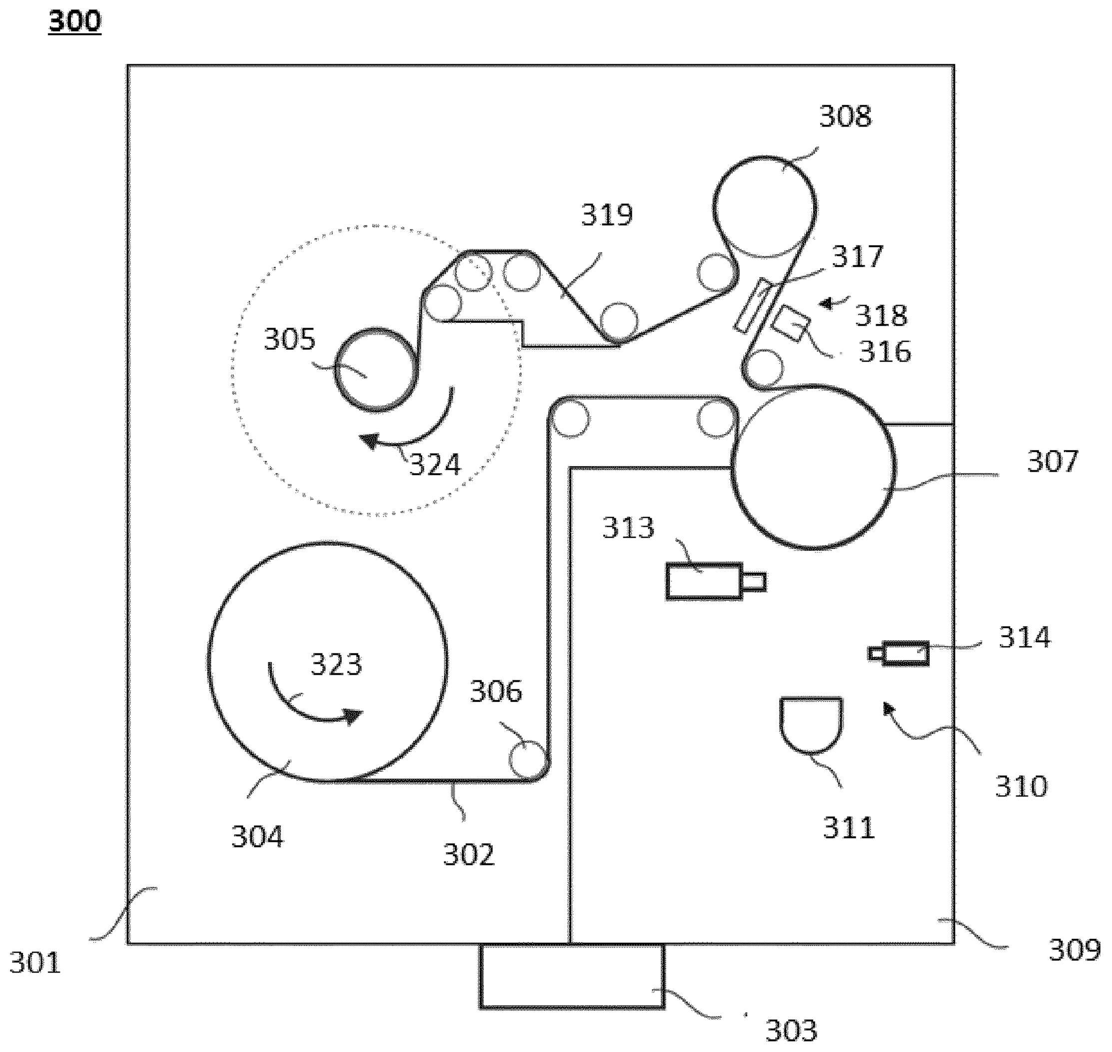

FIG. 3

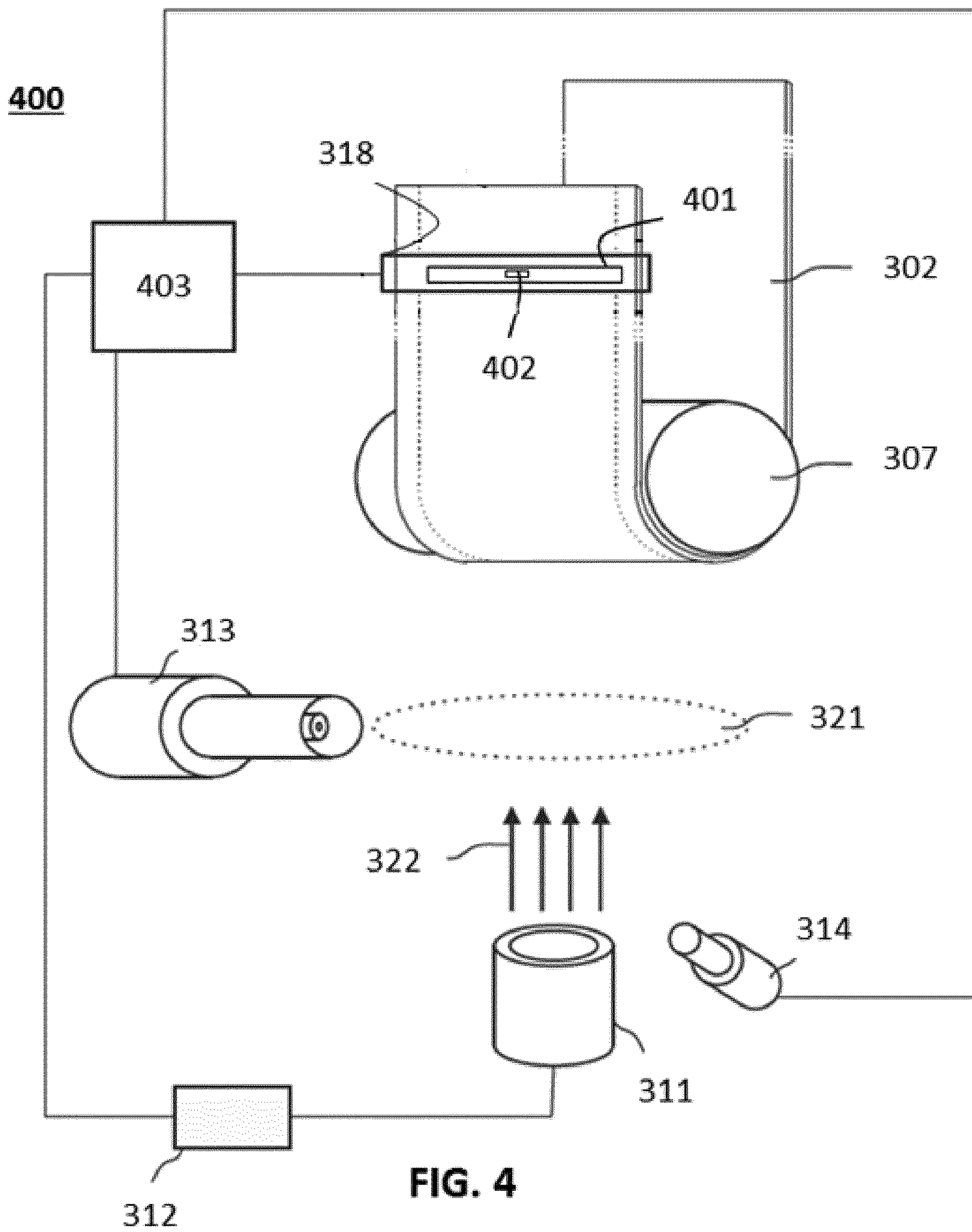

FIG. 4

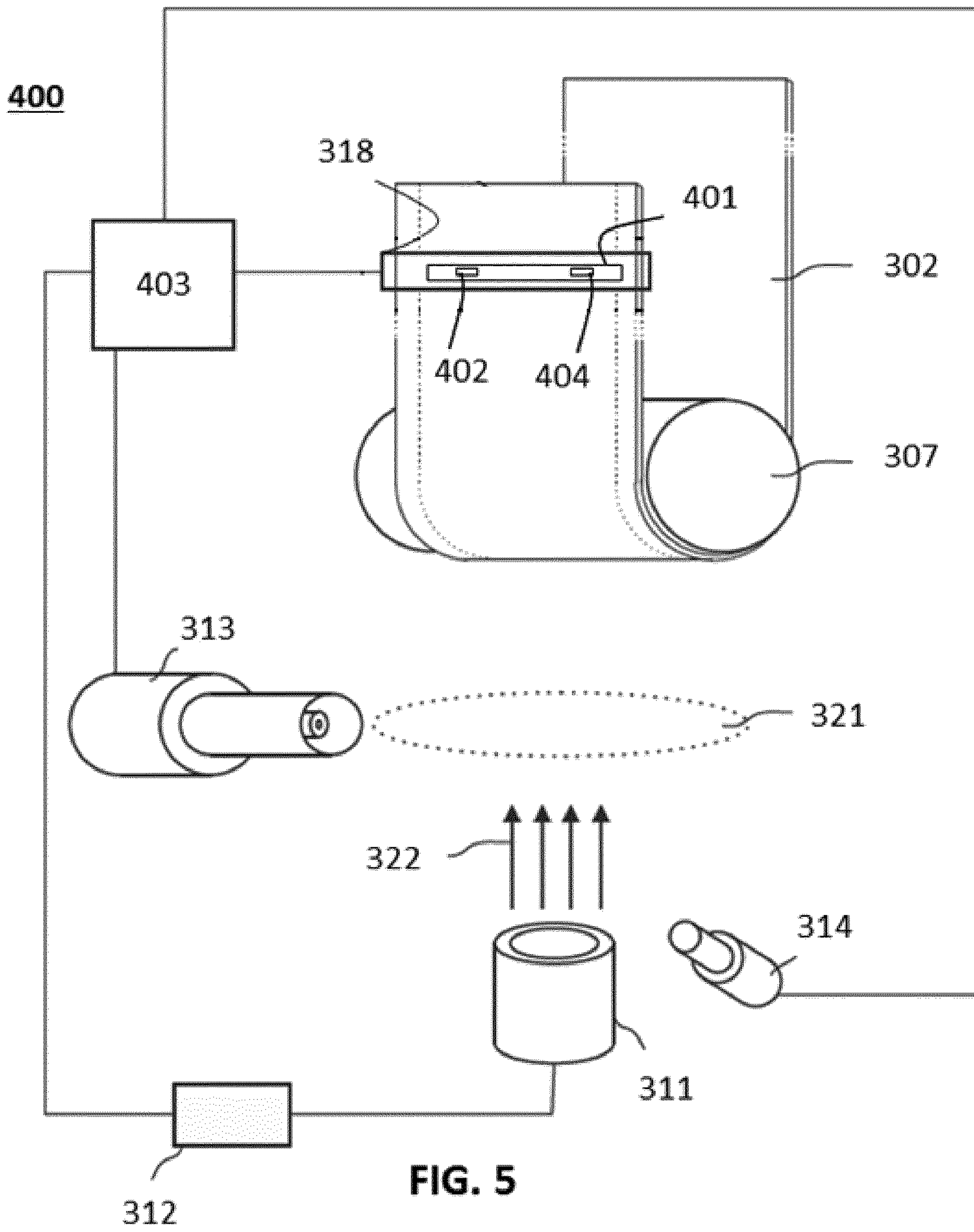

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/073778

A. CLASSIFICATION OF SUBJECT MATTER

INV. C23C14/08 C23C14/06 C23C14/00 C23C14/26 C23C14/56
C23C14/54 C23C16/40 C23C16/34 C23C16/54 C23C16/52
H01M2/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C23C H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 028 174 A1 (TOYO BOSEKI [JP]) 16 August 2000 (2000-08-16) paragraph [0013]; figure 1 paragraph [0062] - paragraph [0065] paragraph [0077] tables 7,8,11,12 paragraph [0073] paragraphs [0035], [0036]	1-15
X	JP H06 330318 A (TOYO BOSEKI) 29 November 1994 (1994-11-29)	1,5,6, 8-10,14
Y	paragraphs [0016], [0024] paragraph [0026]; figure 1 paragraph [0024]	2-4
Y	EP 2 168 643 A1 (APPLIED MATERIALS INC [US]) 31 March 2010 (2010-03-31) paragraph [0020]; figure 1	2-4

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"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)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"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

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Date of the actual completion of the international search	Date of mailing of the international search report
31 May 2018	18/06/2018

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International application No
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