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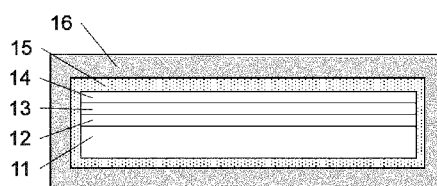
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(54) Title: SEALED SUPERCONDUCTOR TAPE

Figure 1



(57) Abstract: The present invention is in the field of sealed high-temperature superconductor tapes. It relates to a superconducting tape comprising a substrate, a buffer layer, a superconductor layer, wherein the substrate, the buffer layer and the superconductor layer are at least partially surrounded by a solder layer and wherein the solder layer is at least partially surrounded by a galvanized metal layer.



Sealed Superconductor Tape

Description

5 The present invention is in the field of sealed high-temperature superconductor tapes. High-temperature superconductors have been discovered in the 1980ies, but their commercial use is still limited. One reason is that it remains a challenge to produce superconductors of high quality and performance on a large scale at low price. For high-temperature superconductors of the second generation the superconducting material is deposited on tape-shaped substrates,
10 wherein the substrate and the superconductor are separated by a buffer layer. To reduce production cost, the substrates are often wider than the desired width of the final tape which requires a slitting step after the layers are deposited. During the slitting, the substrate and the deposited layers can get deformed and/or damaged, in particular close to the slitting zone. This can cause a deterioration of the critical current or even complete failure of the tape due to in-
15 gression of acid in a galvanization step or of cryogenic agent in the cooling bath. Various approaches to reduce the sensitivity of the tape are described in the prior art.

WO 01 / 08234 A2 discloses a method to seal the superconductor tape by embedding the tape between two wider metal tapes and a non-porous solder. However, this method cannot be ap-
20 plied if galvanized stabilizer layers are desired, for example due to cost reasons. In addition, very thin but dense stabilizers, such as below 20 μm , cannot be produced in this approach.

It was therefore an object of the present invention to provide a superconductor tape which is stable against its environment and which can be produced at low cost. The production process
25 was aimed to be flexible and easy to transfer to industrial scale.

These objects were achieved by a superconducting tape comprising a substrate, a buffer layer, a superconductor layer, wherein the substrate, the buffer layer and the superconductor layer are at least partially surrounded by a solder layer and wherein the solder layer is at least partially
30 surrounded by a galvanized metal layer.

The present invention further relates to a superconducting article comprising two superconducting tapes each comprising a substrate, a buffer layer, a superconductor layer, wherein the substrate, the buffer layer and the superconductor layer are at least partially surrounded by a solder
35 layer, and wherein the superconducting article is at least partially surrounded by a galvanized metal layer.

The present invention further relates to a process for producing a superconducting tape comprising in the following order

- 40 (a) depositing a buffer layer on a substrate,
(b) depositing a superconductor layer,
(c) immersing the substrate with the buffer layer and the superconductor layer into a liquid solder bath and thereby forming a solder layer, and
(d) electrodepositing a metal.

Preferred embodiments of the present invention can be found in the description and the claims. Combinations of different embodiments fall within the scope of the present invention.

According to the present invention, the superconductor tape contains a substrate. The substrate may be any material capable of supporting buffer and/or superconducting layers. For example, suitable substrates are disclosed in EP 830 218, EP 1 208 244, EP 1 198 846, EP 2 137 330. Often, the substrate is a metal and/or alloy strip/tape, whereby the metal and/or alloy may be nickel, silver, copper, zinc, aluminum, iron, chromium, vanadium, palladium, molybdenum, tungsten and/or their alloys. Preferably the substrate contains nickel. More preferably, the substrate contains nickel and 1 to 10 at-%, in particular 3 to 9 at-%, tungsten. Laminated metal tapes, tapes coated with a second metal like galvanic coating or any other multi-material tape with a suitable surface can also be used as substrate.

The substrate can be textured or non-textured, preferably it is textured, i.e. it has a textured surface, in particular a cube textured surface with a degree of cube texture of at least 90 %, such as at least 95 %. The degree of cube texture in a rectangular object, for example a sheet or tape, of a polycrystalline material generally means that the percentage of grains with a deviation of their crystallographic axes from the principal axes of the rectangular object is equal or less than 16 °. The substrates are typically 20 to 200 µm thick, preferably 40 to 100 µm. The length of the substrate usually substantially resembles the length of the superconductor tape.

The surface of the substrate can have a roughness in a relatively wide range, for example with root-mean-squared roughness (rms) according to DIN EN ISO 4287 and 4288 of 5 to 50 nm, such as 10 to 30 nm. The roughness refers to an area of 10 x 10 µm within the boundaries of a crystallite grain of the substrate surface, so that the grain boundaries of the metal substrate do not influence the specified roughness measurement. However, it is also possible to use rougher and thus less expensive substrates. In this case, the buffer layer can serve as planarization layer.

According to the present invention the superconductor tape contains a buffer layer. In the context of the present invention, a buffer layer is any layer between the substrate and the superconductor layer which serves to planarize the substrate and/or separates the substrate from the superconductor layer against diffusion of atoms from the one to the other and/or transfers texture from the substrate to the superconductor layer.

It is possible that the superconductor tape contains one buffer layer or more than one buffer layers, preferably, the superconductor tape contains more than one buffer layer, for example two, three or four buffer layers, in particular two buffer layers. If the superconductor tape contains more than one buffer layer, at least one of the buffer layers has the characteristics described herein, preferably the buffer layer in closest proximity to the substrate has the characteristics described herein, in particular all buffer layers have the characteristics described herein.

Preferably, the buffer layer contains a metal oxide, such as TbO_x, GaO_x, CeO₂, yttria-stabilized zirconia (YSZ), Y₂O₃, LaAlO₃, La₂Zr₂O₇, SrTiO₃, CaTiO₃, Gd₂O₃, LaNiO₃, LaCuO₃, SrRuO₃, NdGaO₃, NdAlO₃, CeGdO and/or some nitrides as known to those skilled in the art. Preferably,

the buffer layer contains at least one rare earth metal, i.e. Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, preferably the buffer layer contains an oxide containing at least one rare earth metal. Preferred buffer layer materials are yttrium-stabilized zirconium oxide (YSZ); zirconates, such as gadolinium zirconate, lanthanum zirconate; titanates, such as strontium titanate; and simple oxides, such as cerium oxide, or magnesium oxide. More preferably the buffer layer contains lanthanum zirconate, cerium oxide, yttrium oxide, magnesium oxide, strontium titanate and/or rare-earth-metal-doped cerium oxide such as gadolinium-doped cerium oxide. Even more preferably the buffer layer contains lanthanum zirconate and/or cerium oxide. In the context of the present invention, a region of substantially the same composition is regarded as one buffer layer, even though it may be made by stacking several layers of about the same composition.

Preferably, the buffer layer has a thickness of 50 to 400 nm, more preferably 100 to 350 nm, in particular 150 to 300 nm. The buffer layer preferably covers the whole surface of the substrate on one side, which means at least 95 % of the surface, more preferably at least 99 % of the surface. Preferably, the surface of the buffer layer facing towards the superconductor layer has a low roughness such as a rms of less than 50 nm, more preferably less than 30 nm, in particular less than 20 nm.

The surface of the buffer layer is preferably textured, in particular cube-textured. The degree of texture is preferably at least 90 %, more preferably at least 96 %, in particular at least 98 %. The degree of cube texture in a rectangular object, for example a sheet or tape, of a polycrystalline material generally means that the percentage of grains with a deviation of their crystallographic axes from the principal axes of the rectangular object is equal or less than 16 °.

Preferably, the superconducting tape contains a shield layer on the substrate on the side opposite to the superconductor layer. The description of composition and the thickness of the buffer layer also applies to the shield layer. The composition of the shield layer can be the same or different to that of the buffer layer, preferably it is the same. The thickness of the shield layer can be the same or different to that of the buffer layer, preferably it is the same. However, usually, the shield layer does not require a high degree of texture in contrast to the buffer layer.

The superconductor tape according to the present invention further contains a superconductor layer. Preferably, the superconductor layer contains a compound of the formula $RE_xBa_yCu_3O_{7-\delta}$. RE stands for one or more than one rare earth metal, preferably yttrium, dysprosium, holmium, erbium, gadolinium, europium, samarium, neodymium, praseodymium, or lanthanum, in particular yttrium. An example, in which RE stands for more than one rare earth metals is $RE = Y_{0.9}Gd_{0.1}$. The index x assumes a value of 0.9 to 1.8, preferably 1.2 to 1.5. The index y assumes a value of 1.4 to 2.2, preferably 1.5 to 1.9. The index δ assumes a value of 0.1 to 1.0, preferably 0.2 to 0.5. The superconductor layer preferably has a thickness of 200 nm to 5 μm , more preferably 400 nm to 3.5 μm , for example 1 to 2 μm .

Preferably, the superconductor layer contains residual amounts of fluorine arising from the precursor composition. The fluorine content of the superconductor layer can be 0.001 to 2 at.-%, preferably 0.01 to 1.8 at.-%, in particular 0.1 to 1.2 at.-%.

The superconductor layer preferably further contains non-conductive particles which act as pinning centers and can minimize the critical current density loss upon application of magnetic fields. Typical pinning centers contain ZrO_2 , stabilized ZrO_2 , HfO_2 , Ta_2O_5 , SrTiO_3 , BaZrO_3 , $\text{La}_2\text{Zr}_2\text{O}_7$, CeO_2 , BaCeO_3 , Y_2O_3 or RE_2O_3 , in which RE stand for one or more rare earth metals.

5 Usually, the particles have an average diameter of 1 to 100 nm, preferably 2 to 20 nm.

The superconducting layer preferably has a low surface roughness, for example a root-mean-squared roughness (rms) according to DIN EN ISO 4287 and 4288 of less than 150 nm or even less than 100 nm, such as less than 50 nm. The superconducting layer typically has a re-

10 sistance close to zero at low temperatures, preferably up to a temperature of at least 77 K. Preferably, the superconductor layer has a critical current density at 77 K without externally applied magnetic field of at least 1.0 MA/cm^2 , more preferably at least 1.5 MA/cm^2 . Preferably, the critical current density decreases by less than 30 % if a magnetic field of 0.1 T is applied perpendicular to the surface of the superconductor layer, more preferably it decreases by less than
15 20 %. Preferably, the critical current density decreases by less than 15 % if a magnetic field of 0.1 T is applied parallel to the surface of the superconductor layer, more preferably it decreases by less than 10 %.

According to the present invention, the substrate, the buffer layer and the superconductor layer
20 are at least partially surrounded by a solder layer. Preferably, the solder layer has an electric conductivity of at least 10^2 S/m , more preferably at least 10^3 S/m , in particular at least 10^4 S/m . Typical solder materials can be used, preferably tin or indium alloys such as Sn-Pb, Sn-Ag, Sn-Cu, Sn-Bi, Sn-Ag-Cu, Sn-Ag-Bi, In-Sn, In-Ag, In-Pb, In-Pb-Ag. Examples are 60 wt.-% Sn – 40 wt.-% Pb or 52 wt.-% In – 48 wt.-% Sn. Preferably, the solder layer contains silver, more prefer-
25 ably the solder layer contains 0.4 to 4 wt.-% Ag. The melting point of the solder is preferably not more than 300°C , in particular not more than 250°C . Usually, the solder layer surrounds the substrate, the buffer layer and the superconductor layer only partially, preferably, they are surrounded by the solder layer to an extent of at least 90 %, more preferably at least 95 %, in particular at least 99 % or fully. The extent refers to the percentage of the outer surface of the sub-
30 strate, the buffer layer and the superconductor layer which is covered by the solder layer.

Preferably, the solder layer has an average thickness of 0.1 to 20 μm , more preferably 0.5 to 10 μm , in particular 1 to 5 μm . The average thickness refers to the number average of the dimension of the solder layer at any point it touches any underlying layer to the galvanized metal lay-
35 er. If the solder layer does not fully surround the underlying layers, only those parts are taken into account where the solder layer actually covers an underlying layer, so the remaining area is not counted as 0 μm .

According to the present invention, the solder layer is at least partially surrounded by a galva-
40 nized metal layer, preferably, the solder layer is surrounded by the galvanized metal layer to an extent of at least 90 %, more preferably at least 95 %, in particular at least 99 % or fully. Preferably, the galvanized metal layer stands in direct contact to the solder layer. The galvanized metal layer typically has a low electrical resistance, preferably lower than $1 \mu\Omega\text{m}$ at room temperature, more preferably lower than $0.2 \mu\Omega\text{m}$ at room temperature, in particular lower than 0.05
45 $\mu\Omega\text{m}$ at room temperature. The galvanized metal layer comprises at least one metal, preferably

copper, silver, tin, zinc, in particular copper. The galvanized metal layer can also contain more than one metal, for example two, typically as an alloy such as bronze. Preferably, the galvanized metal contains at least 50 at-% copper, tin or zinc, more preferably at least 65 at-%, in particular at least 85 at-%. Preferably, the galvanized metal has an average thickness of 0.5 to 100 μm , more preferably 1 to 70 μm , in particular 3 to 50 μm .

In contrast to a soldered metal tape as stabilizer layer, a galvanized metal layer has a several advantages: There are no seams through which during operation of the superconductor tape nitrogen can enter the tape. Further, the parts around the edges or any irregular shapes which are caused by the slitting process get rounded, which is well-known as dog-bone effect. This decreases the electric field strength even if the galvanized layer is relatively thin.

Preferably, the superconductor tape contains a noble metal layer. A noble metal layer in the context of the present invention is a layer containing at least 50 wt.-% of Ag, Pd, Rh, Ru, Os, Ir, Pt, Au, or a mixture of these, preferably at least 70 wt.-%, in particular at least 90 wt.-%. A noble metal layer avoids the degradation of the superconductor layer when any subsequent layer is deposited. The noble metal layer can be between the superconductor layer and the solder layer. Preferably, the superconductor tape contains a second noble metal layer between the substrate and the solder layer on the side of the substrate opposite to the superconductor layer. Preferably, the noble metal comprising layer contains silver. Silver has the additional advantage that it can act as catalyst for increasing the oxygen content of the superconductor layer. Preferably, the noble metal layer has a thickness of 0.1 to 10 μm , more preferably 0.2 to 5 μm , in particular 0.5 to 2 μm . Sometimes, substantial parts of the noble metal layer, in particular if it contains silver, dissolve in the solder layer, making it difficult to distinguish between noble metal layer and solder layer. Preferably, the noble metal layer and the solder layer have a combined average thickness of 2 to 15 μm , more preferably 4 to 10 μm , in particular 6 to 8 μm . Preferably, the noble metal layer and the solder layer together have an average silver content of not more than 25 at.-%, more preferably not more than 20 at.-%, in particular not more than 15 at.-%. Preferably, the superconductor tape has a length of at least 10 m, preferably at least 50 m, more preferably at least 100 m, in particular at least 200 m. Usually, the superconductor tape has a length of not more than 1 km. The superconductor tape can have various widths, for example 4 mm, 10 mm, or 12 mm.

An example of a superconductor tape is shown in figure 1. A substrate 11, a buffer layer 12, a superconductor layer 13 and a noble metal layer 14 are surrounded by a solder layer 15 which is surrounded by a galvanized metal layer 16. Often, the solder layer 15 also fills gaps at the edges between substrate 11 and buffer layer 12 and/or between buffer layer 12 and superconductor layer 13 and/or superconductor layer 13 and noble metal layer 14. These gaps can occur if the substrate with the buffer layer and the superconductor layer are slit. The advantage of solder layer 15 is that the superconductor layer 13 is hermetically sealed against the electrolyte bath during galvanization which often contains sulfuric acid. Also, the galvanized layer 16 is more homogeneous and thus seals the superconductor layer against ingress of cryogenic agent which can destroy the whole tape if its evaporation temperature is exceeded. In this way, the superconducting tape preferably retains at least 95 % of its critical current at 77 K after ten times cooling to liquid nitrogen and thawing back to room temperature.

The present invention further relates to a superconducting article comprising two superconducting tapes each comprising a substrate, a buffer layer, a superconductor layer, wherein the substrate, the buffer layer and the superconductor layer are at least partially surrounded by a solder layer, and wherein the superconducting article is at least surrounded by a galvanized metal layer. The substrate, the buffer layer, the superconductor layer, the solder layer and the galvanized layer are as described above including preferred embodiments unless explicitly described differently below.

The two tapes can be arranged in different ways: they can be arranged head-to-head with the same orientation of substrate, buffer layer and superconductor layer or they can be arranged by overlapping for a small fraction of their length, wherein the superconductor layers are in close proximity, or they can be overlapped along their complete length wherein either the two superconductor layers are in close proximity or the substrates are in close proximity. Preferably, the two superconducting tapes further comprise one or two noble metal layers as described above.

Preferably, the superconducting article further comprises a third superconducting tape which is arranged to bridge the gap between the two superconducting tapes. The third superconducting tape is often a short piece of a superconductor tape comprising a substrate, a buffer layer and a superconductor layer. These layers can be of the same composition as those in the first and the second superconducting tapes or of different, preferably the same. The third superconducting tape is usually attached to the first and the second superconducting tape by a solder layer. Preferably, the third superconducting tape is arranged such that the superconductor layer faces the superconductor layers of the first and the second superconductor tape.

Preferably, a metal tape is in between the superconducting splice and the two superconducting tapes. Preferably, the metal tape has an electric resistance of 10 to 200 % of the galvanized metal layer, more preferably 20 to 150 % in particular 30 to 100 %. Preferably, the metal tape contains copper, for example the metal in the metal tape is copper, brass or bronze, in particular soft-annealed copper. Preferably, the metal tape has an average thickness of 10 to 200 μm , more preferably 30 to 100 μm , in particular 45 to 60 μm , such as 50 μm . Preferably, the thickness at the ends with regard to the length of the superconducting splice is lower than in the central part, preferably the thickness at the end is 10 to 50 % of the thickness in the center. Preferably, the width of the metal tape is 50 to 100 % of the width of the two superconducting tapes, in particular 80 to 100 %. Preferably, the length of the metal tape is 80 to 200 % of the length of the superconducting splice, more preferably 90 to 150 %, in particular 100 to 120 %.

It is possible that the two superconducting tapes are attached to each other by the same solder as the solder layer surrounding the substrate, a buffer layer, a superconductor layer of the superconducting tapes or by different ones. If they are attached to each other by a different solder, it is possible that the two superconducting tapes are attached to each other by a solder having a lower or higher melting point than the solder layer surrounding the substrate, a buffer layer, a superconductor layer of the superconducting tapes. Preferably the two superconducting tapes are attached to each other by a solder having a lower melting point than the solder layer surrounding the substrate, a buffer layer, a superconductor layer of the superconducting tapes.

The smallest sides of the two superconducting tapes in the superconducting article form an angle α with the length of the tape as for example shown in figure 3, where a top view on the two superconducting tapes 10 and 20 is depicted. Usually, the angle α is 90° or approximately 90°. However, if the smallest side surfaces of the two superconducting tapes are in contact to each other, the angle α is preferably lower than 90°, for example 20° to 80°, more preferably 30° to 70°, for example 45°. In this way, the superconducting article is mechanically more stable and the resistance over the joint between the two superconducting tapes is lower.

An example for a superconducting article is shown in Figure 2. A first superconductor tape 10 comprising a substrate 11, a buffer layer 12, a superconductor layer 13 and a noble metal layer 14 is arranged head-to-head with the same orientation of substrate as a second superconductor tape 20 comprising a substrate 21, a buffer layer 22, a superconductor layer 23 and a noble metal layer 24. The gap between the two superconducting tapes is bridged by a superconducting splice 30 comprising a substrate 31, a buffer layer 32, a superconductor layer 33 and a noble metal layer 34. The superconductor layer 33 of splice 30 is oriented such that it faces the superconductor layers 13, 23 of the superconductor tapes 10, 20. A metal tape 17 is in between the splice 30 and the two superconductor tapes 10, 20. The two superconductor tapes 10, 20, the splice 30 and the metal tape 17 are surrounded by a solder layer 15 which is surrounded by a galvanized metal layer 16.

The present invention further relates to a process for producing a superconducting tape. The details about the substrate, the buffer layer, the superconductor layer, the solder layer and the galvanized metal layer including the preferred embodiments described for the superconductor tape above equally apply for the process.

The deposition of the buffer layer in step (a) can be achieved in various ways for example by ion-beam assisted deposition (IBAD), inclined substrate deposition (ISD), or chemical solution deposition (CSD). CSD is preferred, in particular by inkjet printing, roller coating or slot die coating.

The deposition of the superconductor layer in step (b) can be achieved in various ways for example by chemical vapor deposition (CVD), pulsed-laser deposition (PLD), or CSD. Preferably, the superconductor layer is deposited by CSD. Preferably, an ink containing a rare earth-containing compound, a barium-containing compound, a copper-containing compound and an alcohol are deposited and heated as for example described in WO 2016 / 150 781 A1. Preferably, the superconductor layer is deposited on the buffer layer, i.e. there is no other layer in between the buffer layer and the superconductor layer. Preferably, both the buffer layer and the superconductor layer are deposited by CSD.

Preferably, after step (b) a noble metal layer is deposited onto the superconductor layer. This can be achieved in various ways, such as CVD, PLD, or CSD. CSD is preferred, for example as disclosed in WO 2008 / 000 485 A1.

Preferably, in between step (a) and (b) or between step (b) and (c) the substrate with the deposited layers is slit along the longest dimension. This can, for example, be done by a slit roller apparatus as disclosed by US 3 831 502.

- 5 The substrate with the buffer layer and the superconductor layer are immersed into a liquid solder bath thereby forming a solder layer in step (c). The liquid solder bath is preferably at a temperature of 10 to 50 °C above the melting point of the solder. Preferably, the substrate with the buffer layer and the superconductor layer are immersed into a liquid solder bath for 1 to 20 s, more preferably, for 2 to 10 s, in particular for 3 to 5 s. Preferably, the substrate with the buffer
10 layer and the superconductor layer are immersed into a liquid solder bath by continuously drawing at a speed of 500 to 2000 m/s, more preferably at 800 to 1000 m/s. The length of the solder bath is adjusted accordingly. Preferably, a solder-forming flux is used which fits the solder as known to the skilled person of soldering. Excess solder is removed after immersion to obtain the desired thickness. It is possible that the substrate with the buffer layer and the superconductor
15 layer are immersed into a liquid solder bath once or more than once, for example twice. It is possible that the substrate with the buffer layer and the superconductor layer are immersed fully into a liquid solder bath or only partially, for example the edge.

In some cases, in particular if the solder layer is thin, some residual holes or cracks can be present which still allow deterioration of the superconductor layer upon galvanization. Therefore,
20 the solder layer can be treated mechanically after cooling to about room temperature, for example by rolling to close any residual holes or cracks. Alternatively, a thin layer of a resin which can be hardened below the melting point of the solder can be applied to the solder layer, for example a UV resin.

25 Electrodeposition in step (d) is usually done in an electrolyte bath containing a soluble salt of the metal to be deposited, for example copper (II) sulfate if copper is used as metal, and an acid, for example sulfuric acid. Depending on the desired thickness of the galvanized layer, the electric current and the time of the galvanization is adjusted. Typical values for the electric current density are 1 to 20 A/dm² with regard to the surface of the superconductor tape which is in
30 contact with the electrolyte bath at a certain time, preferably 2 to 15 A/dm², in particular 2.5 to 10 A/dm², for example 3 to 5 A/dm². If the current is pulsed, the preferred values relate to the time average current value, i.e. the currents during the pulse can higher than the given values. It can be advantageous to use multiple electrolyte baths in which different electric current is applied. Preferably, in the first bath the lowest electric current density is applied. Preferably, typical
35 additives for electrodeposition are used such as surfactants. Preferably before step (d) the substrate with the deposited layers is cleaned and/or activated.

The process according to the present invention is preferably performed on several subsequent
40 reel-to-reel apparatuses. As the process of the present invention is very robust, the superconducting tape can be made at high speeds, such as 30 to 200 m/s.

Claims

1. A superconducting tape comprising a substrate, a buffer layer, a superconductor layer,
5 wherein the substrate, the buffer layer and the superconductor layer are at least partially surrounded by a solder layer and wherein the solder layer is at least partially surrounded by a galvanized metal layer.
2. The superconducting tape according to claim 1, wherein the solder layer has an average
10 thickness of 1 to 5 μm .
3. The superconducting tape according to claim 1 or 2, wherein the substrate, the buffer layer and the superconductor layer are surrounded by the solder layer to an extent of at least
15 90 %.
4. The superconducting tape according to any of the claims 1 to 3, wherein a noble metal containing layer is in between the superconductor layer and the solder layer.
5. The superconducting tape according to claim 4, wherein a second noble metal layer is
20 between the substrate and the solder layer on the side of the substrate opposite to the superconductor layer.
6. The superconducting tape according to any of the claims 1 to 5, wherein a second buffer layer is on the substrate on the side opposite to the superconductor layer.
- 25 7. The superconducting tape according to any of the claims 1 to 6, wherein the galvanized metal layer has an average thickness of 3 to 50 μm .
8. The superconducting tape according to any of the claims 1 to 7, wherein the superconducting tape retains at least 95 % of its critical current at 77 K after ten times cooling to
30 liquid nitrogen and thawing back to room temperature.
9. A superconducting article comprising two superconducting tapes each comprising a substrate, a buffer layer, a superconductor layer, wherein the substrate, the buffer layer and the superconductor layer are at least partially surrounded by a solder layer, and wherein
35 the superconducting article is at least partially surrounded by a galvanized metal layer.
10. The superconducting article according to claim 8, wherein the superconducting article comprises a third superconducting tape which is arranged to bridge the gap between the
40 two superconducting tapes.
11. The superconducting article according to claim 9, wherein a metal tape is in between the bridging superconducting tape and the two superconducting tapes.
- 45 12. The superconducting article according to any of the claims 8 to 10, wherein the two superconducting tapes are attached to each other by a solder having a lower melting point

than the solder layer surrounding the substrate, a buffer layer, a superconductor layer of the superconducting tapes.

- 5 13. A process for producing a superconducting tape comprising in the following order
- (a) depositing a buffer layer on a substrate,
 - (b) depositing a superconductor layer,
 - (c) immersing the substrate with the buffer layer and the superconductor layer into a liquid solder bath and thereby forming a solder layer, and
 - (d) electrodepositing a metal.
- 10 14. The process according to claim 12, wherein step (a) and (b) or between step (b) and (c) the substrate with the deposited layers is slit along the longest dimension.
- 15 15. The process according to claim 12 or 13, wherein the buffer layer and/or the superconductor layer is deposited by chemical solution deposition.

Figures

Figure 1

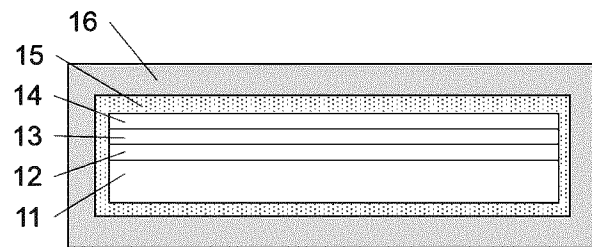


Figure 2

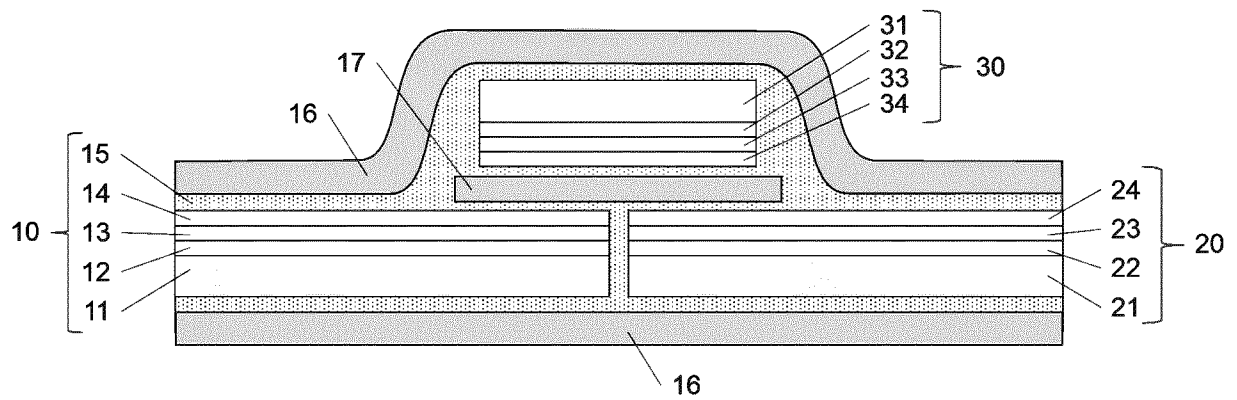
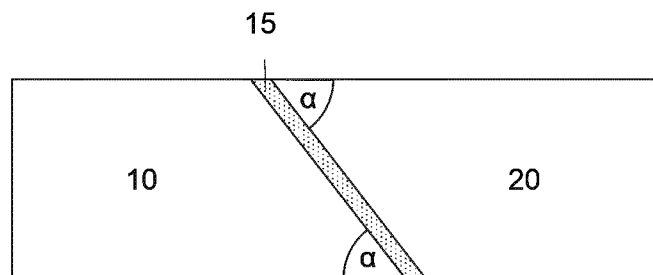


Figure 3



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/059852

A. CLASSIFICATION OF SUBJECT MATTER INV. H01L39/02 H01L39/14 H01L39/24 ADD.		
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) H01L		
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	US 2012/065074 A1 (XIE YI-YUAN [US] ET AL) 15 March 2012 (2012-03-15)	1-5, 7-11,13
Y	paragraph [0035] - paragraph [0045];	6
A	figures 2,5 -----	12
Y	US 2010/173784 A1 (LEE HEE-GYOUN [KR] ET AL) 8 July 2010 (2010-07-08)	6
A	figure 3C -----	1-5,7-15
☐ Further documents are listed in the continuation of Box C. ☒ 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 "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 "&" document member of the same patent family		
Date of the actual completion of the international search	Date of mailing of the international search report	
25 June 2020	03/07/2020	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Koskinen, Timo	

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Information on patent family members

International application No

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