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(54) **Electrically conductive metal/plastic hybrid comprising a polymer material, a first metal and metal particles of a second metal embedded in the first metal and method of producing such**

Elektrisch leitfähige Metall-/Kunststoffmischung mit einem Polymermaterial, einem ersten Metall und Metallpartikel eines zweiten Metalls eingebettet in das erste Metall und Herstellungsverfahren dafür

Hybride métallique/plastique électriquement conducteur comportant un matériau polymère, premier métal et particules métalliques d'un second métal intégré dans le premier métal et son procédé de production

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(73) Proprietors:
- **Tyco Electronics Corporation**
  Berwyn, PA 19312 (US)
- **Tyco Electronics AMP GmbH**
  64625 Bensheim (DE)

(72) Inventors:
- **Schmidt, Helge**
  67346 Speyer (DE)
- **Freckmann, Dominique**
  50226 Frechen (DE)

(74) Representative: **Grünecker, Kinkeldey,**
Stockmair & Schwanhäusser
Leopoldstrasse 4
80802 München (DE)

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WO-A1-98/08362 **US-A1- 2007 012 900**

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Description

[0001] The invention relates to an electrically conductive metal/plastic hybrid which comprises a matrix of a polymer material, a network embedded in the matrix and made of a metal, the metal having a first melting temperature, and metal particles within the network having a second melting temperature, the second melting temperature being higher than the first melting temperature. Further, the invention relates to a method of producing such a metal/plastic hybrid.

[0002] Metal/plastic hybrids of the afore-mentioned type are known from the prior art, but in order to achieve high electric conductivity, contain high percentages of the higher melting point metal particles. As these higher melting point metals are usually very dense, the entire metal/plastic hybrid is very dense too. Further, the metals used for the higher melting point metal particles can be expensive, which increases the price for the metal/plastic hybrid. Additionally, these metals generally have a high heat capacity, which makes the resulting metal/plastic hybrid difficult to process, in particular in a molding process.

[0003] In the document WO 98/08362, a metal plastic hybrid material is described. The material consists of four constituents: a metal powder with a high melting point, a second metal powder with a low melting point, an epoxy resin and a cross-linking agent. The cross-linking agent is at the same time an anti-oxidant for the metals. The cross-linking agent removes oxides from the metals and at the same time cross-links the epoxy resin, to form a solid material. The compound is optimized for the formation of thin layers of material to replace conductive strip lines on printed circuit boards. The compound is used as an ink for printing of conductive strip lines. However, the compound only works due to the interplay of the four constituents and a formation of complex three dimensional structure using injection molding techniques is rather complicated when epoxy resin is used.

[0004] Thus, the object of the invention is to provide a metal/plastic hybrid which exhibits a lower density. A further object of the invention is to provide a metal/plastic hybrid that is cheaper. An even further object of the invention is to provide a metal/plastic hybrid that is easy to process, in particular in a molding process.

[0005] According to the invention, the object is achieved by using a polymer material that is a thermoplastic material and by using metal particles that contain aluminium as the higher melting point metal particles.

[0006] By using aluminium as a material for the metal particles, the density of the resulting metal/plastic hybrid can be reduced considerably. Additionally, aluminium is usually cheaper than the metals often used for the metal particles, like for example copper, nickel, iron or silver. Furthermore, as aluminium has a low heat capacity, metal/plastic hybrids containing aluminium are easy to process and finer structures can be produced due to the lower volumetric heat capacity of the resulting metal/plastic hybrid. In particular, two-step processes can be conducted more easily, as negative effects of heat can be minimised. Especially if delicate and small structures are supposed to be created, the lower heat capacity can enable better results.

[0007] As aluminium and compounds containing aluminium are less toxic than the materials generally employed in metal/plastic hybrids, a health and environmental benefit can result.

[0008] The solution according to the invention may be combined in any way with one or several of the following further advantageous embodiments respectively.

[0009] In a first advantageous development of the invention, the metal particles contain primarily aluminium, that means, aluminium is the main component.

[0010] In a development of the invention, the metal particles consist only of aluminium and unavoidable impurities. The percentage of impurities is preferably less than 3%, more preferably less than 1 % of the weight.

[0011] The metal particles containing aluminium can be coated with a second metal. Preferably, the coating of the metal particles takes place before the particles are mixed into the low melting point metal. Such a coating can help to make better contact between the metal particles and the low melting point metal, e.g. by reducing or removing oxide layers, which might be present on the outside of the metal particles. In particular, the coating can contain metals that can also be found in the low melting point metal. In a very particular case, the coating of the metal particles contains only one element and the low melting point metal is a mixture of this element and other elements.

[0012] The coating of the metal particles containing aluminium can be achieved with several methods. Preferentially, the metal particles are coated with a chemical method, for example by galvanizing. However, other methods of coating, for example Physical Vapour Deposition (PVD), Atomic Layer Deposition (ALD) or sputtering, can also be used.

[0013] In a preferential development of the invention, the coating for the metal particles containing aluminium can be zinc. Zinc is a common coating material for many metals, in particular for aluminium. Therefore, several processes for generating such a zinc coating are widely known and corresponding substances or devices are easily available. Furthermore, a pool of knowledge, e.g. process parameters for achieving certain thicknesses, is already available. Such a coating can for example be achieved by wet chemical methods or by physical methods. As aluminium and zinc tend to form mixed crystals, an intimate connection between the two, and a good sticking of the zinc to the metal particle containing aluminium can be obtained.

[0014] In another advantageous development of the invention, tin is used as a coating material for the metal particles. Aluminium and tin do not mix in the solid phase, so diffusion of the coating metal into the aluminium particle can be avoided by using tin. Tin is often employed

as a component of the low melting point metal. Hence, using tin as a coating material can help to make a good contact between the particles and the low melting point metal. The tin coating can be applied by several methods, for example chemically or physically.

[0015] In a further advantageous development of the invention, the metal particles containing aluminium can contain two or even more coating layers. For example the metal particles containing aluminium can be coated with zinc in a first step, and with tin in a second step. Due to the intennixing of aluminium and zinc in the solid phase, the zinc will stick easily to the aluminium particles. As zinc and tin can form a eutectic system, further processing of such particles at temperatures as low as about 200°C can be made possible. Due to the low temperature, the production of the metal/plastic hybrid is further facilitated, in particular if tin is used as a component of the low melting point metal. Furthermore, tin will not diffuse into the aluminium particles.

[0016] In a further advantageous embodiment of the invention, the metal particles are coated with tin in a first step and with zinc in a second step. In particular if the metal/plastic hybrid is processed at a higher temperature, such a combination can be advantageous. In case the low melting point metal contains tin, using zinc as the second layer helps to make good contact between the metal particle and the low melting point metal.

[0017] By using a material that is employed in solders, e.g. tin, as a coating material, it is facilitated that contact is made, for example by soldering, to this metal/plastic hybrid, as the additional solder for contacting will readily make contact with the coating material.

[0018] In a further development of the invention, a coating layer of the metal particles contains the low melting point metal. If enough of the low melting point metal is applied onto the metal particles, the step of adding further low melting point metal in another step can be avoided and the metal particles can be mixed with the polymer material directly.

[0019] In another advantageous development of the invention, copper can be used as a first or additional coating material for the metal particles containing aluminium. As it might be difficult to apply copper by chemical methods, a deposition by physical methods is preferred in this case.

[0020] In an even further advantageous development of the invention, the polymer material can be a thermoplastic and the first metal can melt in the range of 100°C to 400°C.

[0021] In an advantageous development of the invention, in particular if the metal particles containing aluminium are not coated, the addition of flux to the metal/plastic hybrid can help to make good contact between the metal particles containing aluminium and the low melting point metal, as such a flux can remove oxide layers which might be present on the metal particles containing aluminium and can additionally improve the flowing properties of the low melting point metal in the liquid phase.

[0022] Shaped bodies, especially electric or electronic elements, comprising at least in part the metal/plastic hybrid according to the invention, can be used for a big range of applications. In particular, they can be used in electric circuits, as electric or electromagnetic shieldings, as moldable plugs, housings, radio frequency (RF) connectors or antennas.

[0023] The invention will be described hereinafter in greater detail and in an exemplary manner using advantageous embodiments and with reference to the drawings. The described embodiments are only possible configuration in which, however, the individual features as described above, can be provided independently of one another or can be omitted. In the drawings:

Fig. 1 is a schematic sectional view of a first embodiment of a metal/plastic hybrid according to the invention;

Fig. 2 is a schematic sectional view of a second embodiment of a metal/plastic hybrid according to the invention.

[0024] In Fig. 1 a metal/plastic hybrid 1 according to the invention is depicted in a sectional view. Metal particles 2 according to the invention are formed as metal particles containing aluminium 3, which are embedded in a low melting point metal 4. The metal particles 2 can have a basically spherical shape. However, they can have any other shape, in particular, they might be filaments, cubes, flakes, rods, coins or the like. The metal particles 2 together with the low melting point metal 4 form an electrically conductive phase and can form an electrically conductive network within the metal/plastic hybrid 1, such that the entire metal/plastic hybrid 1 is electrically conductive. Herein, as usual, metals are defined by being electrically conductive. Thus, a metal can be elementary, an alloy, a compound or a mixture with metal. The metal/plastic hybrid 1 can also comprise a polymer material 5 which can comprise one or more plastic materials, which can be plastically deformable at elevated temperatures, for instance thermoplastics or resins.

[0025] According to the invention, the metal particles 2 contain aluminium, in particular aluminium can be the main or the only component. However, other elements may also be present in the metal particles. By using aluminium as one of the components of the metal particles 2, the density of the metal particles 2 can be lowered. A further advantage of aluminium is, that it is usually cheaper than other metals employed for producing metal/plastic hybrids, like for example copper, nickel, iron or silver.

[0026] As an additional advantage, aluminium has a low heat capacity, which can help to facilitate the production of parts that comprise such a metal/plastic hybrid 1. In particular, if other components of the part are affected negatively by heat, using a metal/plastic hybrid 1 according to the invention can help to make manufacturing this

part easier, with less effort and time, thus saving money and additionally saving energy, as less energy is required to heat the metal/plastic hybrid 1 according to the invention. Furthermore, very fine structures can be produced with the metal/plastic hybrid according to the invention due to its low heat capacity. In particular, processes in which a second part can be affected negatively by heat or temperature, or in which using a lower temperature or less heat is advantageous, can be carried out more efficiently, with less discard, faster and with less energy.

[0027] In an advantageous embodiment of the invention, the metal/plastic hybrid 1 might also contain flux. Flux can help to remove oxide layers which can be on the aluminium particles and which can make it difficult or impossible to establish a connection between the metal particles 2 and the low melting point metal 4. Furthermore, such a flux can give a higher viscosity of the low melting point metal 4, which further improves the interconnection between the metal particles 2 and the low melting point metal 4.

[0028] The sizes of the metal particles 2 can in a preferential embodiment be smaller than 200 μm. In case very fine structures are supposed to be manufactured, the size of the metal particles 2 can be lowered further. However, if for example a higher volume to surface ratio is desired, the size of the particles containing aluminium 3 can be increased. For more efficient packing and therefore a higher loading of metal particles and/or easier processing, also mixtures of various particle sizes, e.g. fine and coarse, can be used.

[0029] Although in Fig. 1 the metal particles containing aluminium 3 are not covered by a coating layer 6 around the particle in their final state in the metal/plastic hybrid 1, it can be advantageous to coat the metal particles containing aluminium 3 during the process of manufacturing. For example, the metal particles containing aluminium 3, which might exhibit oxide layers on the outside, can be coated with tin. Such a coating can for instance be achieved with wet chemical methods like galvanization or by physical methods like Physical Vapour Deposition (PVD). As tin is often contained in the low melting point metal 4 of the metal/plastic hybrid 1, the coating layer 6 of tin can intermix with the tin in the low melting point metal 4. Such a coating step can help to make a better contact between the metal particles comprising aluminium 3 and the low melting point metal 4.

[0030] In an advantageous embodiment of the invention, one of the coating layers 6 contains the low melting point metal 4, preferably in large quantities. Thus, the addition of low melting point metal 4 or the intermixing of the metal particles 2 with the low melting point metal 4 can be avoided, as the coating layer 6 provides enough low melting point metal 4. Hence, these coated particles can be blended with or into the polymer material, skipping one step in the manufacturing process.

[0031] By using low melting material like brazing solders or leads as a coating material, connecting the material to external parts is made easier.

[0032] In Fig. 2 another advantageous embodiment of the invention is depicted. In this schematic sectional view the metal/plastic hybrid 1 according to the invention comprises metal particles which contain aluminium 3 with an additional coating layer 6 located on the interface between the metal particles containing aluminium 3 and the low melting point metal 4. Furthermore, a polymer material 5, for example a thermoplastic material or a resin, can be seen.

[0033] Again, the preferred size range of the metal particles containing aluminium 3 is below 200 μm. However, by varying the size of the metal particles containing aluminium 3 at a constant thickness of the coating layer 6, the ratio of the coating material to the material of the metal particle containing aluminium 3 can be varied.

[0034] In the first embodiment of the invention, aluminium is the main component of the metal particles, further reducing the density of the metal particles.

[0035] In a preferential embodiment of the invention, aluminium is the only component in the metal particles 2. Such simple particles can easily be manufactured or be purchased readily, which reduces manufacturing time and costs.

[0036] In a preferential embodiment of the invention, the metal particles containing aluminium 3 have a coating layer 6 containing zinc. Such a zinc coating can be achieved by several methods, for example by wet chemical methods like galvanization or by physical methods. Such methods are already known and widely used so that a wide knowledge of these processes exists and substances for this process are easily available. As aluminium and zinc can easily intermix by forming mixed crystals, a tight and intimate contact between the aluminium in the metal particle and the coating layer 6 is generated.

[0037] In many cases, tin is a component of the low melting point metal, which makes using zinc as a coating layer 6 even more advantageous, as zinc and tin can form a eutectic system with a melting point as low as about 200°C. Such a low melting point helps to minimize the energy used for the production process of the metal/plastic hybrid 1. Furthermore, manufacturing time and effort is also decreased by such a low melting point.

[0038] In another advantageous embodiment of the invention, tin is used as a coating layer 6 for the metal particles containing aluminium 3. As aluminium and tin do not intermix in the solid phase, a diffusion of the tin into the aluminium of the metal particle containing aluminium 3 over time is avoided. Thus, constant properties of the metal/plastic hybrid 1 during the lifetime of a part manufactured from this metal/plastic hybrid 1 can be expected. Furthermore, as tin is used as a component of the low melting point metal 4 in many cases, an easy contacting of the metal particles containing the aluminium 3 to the low melting point metal can be facilitated. The coating of the metal particles containing aluminium 3 with tin can be accomplished with a variety of methods such as chemical methods or physical methods.

[0039] In an even more advantageous embodiment of the invention, the metal particles containing aluminium 3 can be coated with more than one coating layer 6. For instance the first coating layer might be zinc, which forms mixed crystals with the aluminium and thus a good contact to the other components is established. A second layer might be made from tin, which can form a eutectic system with zinc, having a low melting point and giving a good connection of the zinc to the tin layer. As tin is often used as a component of the low melting point metal 4, a good contact between the second layer and the low melting point metal 4 is also provided by using tin as a second coating layer 6. The second coating layer 6 might only exist in the process of manufacturing the metal/plastic hybrid, in particular if the low melting point metal 4 contains tin as a component.

[0040] Copper can also be used as a coating layer 6. If copper is used as a coating material, a physical coating process like Physical Vapour Deposition (PVD) might be preferred, as applying copper by chemical methods like wet chemical methods could be difficult.

[0041] Parts or shaped bodies manufactured from or comprising at least partially a metal/plastic hybrid 1 according to the invention could be used in a variety of applications. Due to the electric conductivity of such a metal/plastic hybrid 1 it can easily be used in electric circuits, in particular if electric circuits or electric parts are supposed to be manufactured by methods that include plastic forming, especially at elevated temperatures, of these electric circuits or parts. Further, this method is very advantageous in 2-step-processes like a 2K or 2-shot molding process, as the metal/plastic hybrid 1 according to the invention has a low heat capacity, which allows for faster and more efficient processing with less energy and more precision. Parts made from this metal/plastic hybrid 1 could also be used as shieldings for electric or electromagnetic fields. Another exemplary application of a part made from such a metal/plastic hybrid 1 could be a plug molded onto a conductive element of an electric circuit, a radio frequency (RF) connector, an antenna or a casing.

Claims

1. Electrically conductive metal/plastic hybrid (1) which comprises a matrix of a polymer material (5), a network embedded in the matrix and made of a metal, the metal having a first melting temperature, and metal particles (2) within the network having a second melting temperature, the second melting temperature being higher than the first melting temperature, **characterised in that** the polymer material (5) is a thermoplastic material and that the metal particles (2) contain aluminium.

2. Metal/plastic hybrid (1) according to claim 1, **characterized in that** the metal particles (2) consist primarily of aluminium.

3. Metal/plastic hybrid (1) according to claim 1 or 2, **characterized in that** the metal particles (2) contain solely aluminium, apart from impurities, which constitute preferably less than 3 weight-%, more preferable less than 1 weight-% of the particles.

4. Metal/plastic hybrid (1) according to any of claims 1 to 3, **characterised in that** the metal particles (2) containing aluminium are coated with at least one coating layer (6) of a metal.

5. Metal/plastic hybrid (1) according to claim 4, **characterised in that** at least one coating layer (6) contains tin.

6. Metal/plastic hybrid (1) according to any one of claims 4 or 5, **characterised in that** at least one coating layer (6) contains zinc.

7. Electric or electronic element which comprises at least one electrically conductive section, made at least in part from a metal/plastic hybrid (1) according to any one of claims 1 to 6.

8. Method for producing an electrically conductive metal/plastic hybrid (1), the method comprising the step of bringing a first metal and a polymer together, so that a network of metal in a polymer matrix results, **characterized in that** the polymer material (5) is a thermoplastic material and that metal particles containing aluminium and the first metal are brought together, so that the metal particles are embedded in the metal network afterwards.

9. Method for producing an electrically conductive metal/plastic hybrid (1) according to claim 8, **characterised in that** the method comprises a step of coating the metal particles containing aluminium (3) with a coating layer (6) of a metal.

10. Method for producing an electrically conductive metal/plastic hybrid (1) according to claim 9, **characterised in that** the coating layer (6) of the metal particles containing aluminium (3) contains tin.

11. Method for producing an electrically conductive metal/plastic hybrid (1) according to claim 9 or 10, **characterised in that** the coating layer (6) of the metal particles containing aluminium (3) contains zinc.

Patentansprüche

1. Elektrisch leitfähiger Metall-Kunststoff-Hybrid (1), der eine Matrix aus einem Polymermaterial (5), ein in der Matrix eingebettetes und aus einem Metall her-

gestelltes Netzwerk, wobei das Metall eine erste Schmelztemperatur aufweist, und Metallteilchen (2) innerhalb des Netzwerks umfasst, die eine zweite Schmelztemperatur aufweisen, wobei die zweite Schmelztemperatur höher ist als die erste Schmelztemperatur, **dadurch gekennzeichnet, dass** das Polymermaterial (5) ein thermoplastisches Material ist und dass die Metallteilchen (2) Aluminium enthalten.

2. Metall-Kunststoff-Hybrid (1) nach Anspruch 1, **dadurch gekennzeichnet, dass** die Metallteilchen (2) hauptsächlich aus Aluminium bestehen.

3. Metall-Kunststoff-Hybrid (1) nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die Metallteilchen (2) ausschließlich Aluminium, außer Verunreinigungen, enthalten, die bevorzugt weniger als 3 Gew.-%, noch bevorzugter weniger als 1 Gew.-%, der Teilchen ausmachen.

4. Metall-Kunststoff-Hybrid (1) nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet, dass** die Metallteilchen (2), die Aluminium enthalten, mit mindestens einer Beschichtungsschicht (6) aus einem Metall beschichtet sind.

5. Metall-Kunststoff-Hybrid (1) nach Anspruch 4, **dadurch gekennzeichnet, dass** mindestens eine Beschichtungsschicht (6) Zinn enthält.

6. Metall-Kunststoff-Hybrid (1) nach einem der Ansprüche 4 oder 5, **dadurch gekennzeichnet, dass** mindestens eine Beschichtungsschicht (6) Zink enthält.

7. Elektrisches oder elektronisches Element, das mindestens einen elektrisch leitfähigen Abschnitt umfasst, der mindestens teilweise aus einem Metall-Kunststoff-Hybrid (1) nach einem der Ansprüche 1 bis 6 hergestellt ist.

8. Verfahren zur Herstellung eines elektrisch leitfähigen Metall-Kunststoff-Hybrids (1), wobei das Verfahren den Schritt des Zusammenbringens eines ersten Metalls und eines Polymers umfasst, so dass ein Netzwerk von Metall in einer Polymermatrix resultiert, **dadurch gekennzeichnet, dass** das Polymermaterial (5) ein thermoplastisches Material ist und dass die Metallteilchen, die Aluminium enthalten, und das erste Metall zusammengebracht werden, so dass die Metallteilchen nachher in dem Metallnetzwerk eingebettet sind.

9. Verfahren zur Herstellung eines elektrisch leitfähigen Metall-Kunststoff-Hybrids (1) nach Anspruch 8, **dadurch gekennzeichnet, dass** das Verfahren einen Schritt des Beschichtens der Metallteilchen, die Aluminium (3) enthalten, mit einer Beschichtungsschicht (6) aus einem Metall umfasst.

10. Verfahren zur Herstellung eines elektrisch leitfähigen Metall-Kunststoff-Hybrids (1) nach Anspruch 9, **dadurch gekennzeichnet, dass** die Beschichtungsschicht (6) der Metallteilchen, die Aluminium (3) enthalten, Zinn enthält.

11. Verfahren zur Herstellung eines elektrisch leitfähigen Metall-Kunststoff-Hybrids (1) nach Anspruch 9 oder 10, **dadurch gekennzeichnet, dass** die Beschichtungsschicht (6) der Metallteilchen, die Aluminium (3) enthalten, Zink enthält.

Revendications

1. Hybride métal/plastique électriquement conducteur (1) qui comprend une matrice d'un matériau polymère (5), un réseau enchâssé dans la matrice et constitué d'un métal, le métal ayant une première température de fusion, et des particules métalliques (2) au sein du réseau ayant une seconde température de fusion, la seconde température de fusion étant supérieure à la première température de fusion, **caractérisé en ce que** le matériau polymère (5) est un matériau thermoplastique et que les particules métalliques (2) contiennent de l'aluminium.

2. Hybride métal/plastique (1) selon la revendication 1, **caractérisé en ce que** les particules métalliques (2) sont principalement constituées d'aluminium.

3. Hybride métal/plastique (1) selon la revendication 1 ou 2, **caractérisé en ce que** les particules métalliques (2) contiennent uniquement de l'aluminium, à part des impuretés, qui constituent de préférence moins de 3 % en poids, de manière plus préférable moins de 1 % en poids des particules.

4. Hybride métal/plastique (1) selon l'une quelconque des revendications 1 à 3, **caractérisé en ce que** les particules métalliques (2) contenant de l'aluminium sont revêtues d'au moins une couche de revêtement (6) d'un métal.

5. Hybride métal/plastique (1) selon la revendication 4, **caractérisé en ce que** au moins une couche de revêtement (6) contient de l'étain.

6. Hybride métal/plastique (1) selon l'une quelconque des revendications 4 ou 5, **caractérisé en ce que** au moins une couche de revêtement (6) contient du zinc.

7. Élément électrique ou électronique qui comprend au moins une section électriquement conductrice, constituée au moins en partie d'un hybride mé-

tal/plastique (1) selon l'une quelconque des revendications 1 à 6.

8. Procédé de production d'un hybride métal/plastique électriquement conducteur (1), le procédé comprenant l'étape de mise en contact d'un premier métal et d'un polymère, de sorte qu'un réseau métallique dans une matrice polymère résulte, **caractérisé en ce que** le matériau polymère (5) est un matériau thermoplastique et **en ce que** les particules métalliques contenant de l'aluminium et le premier métal sont mis en contact, de sorte que les particules métalliques soient enchâssées par la suite dans le réseau métallique.

9. Procédé de production d'un hybride métal/plastique électriquement conducteur (1) selon la revendication 8, **caractérisé en ce que** le procédé comprend une étape de revêtement des particules métalliques contenant l'aluminium (3) avec une couche de revêtement (6) d'un métal.

10. Procédé de production d'un hybride métal/plastique électriquement conducteur (1) selon la revendication 9, **caractérisé en ce que** la couche de revêtement (6) des particules métalliques contenant l'aluminium (3) contient de l'étain.

11. Procédé de production d'un hybride métal/plastique électriquement conducteur (1) selon la revendication 9 ou 10, **caractérisé en ce que** la couche de revêtement (6) des particules métalliques contenant l'aluminium (3) contient du zinc.

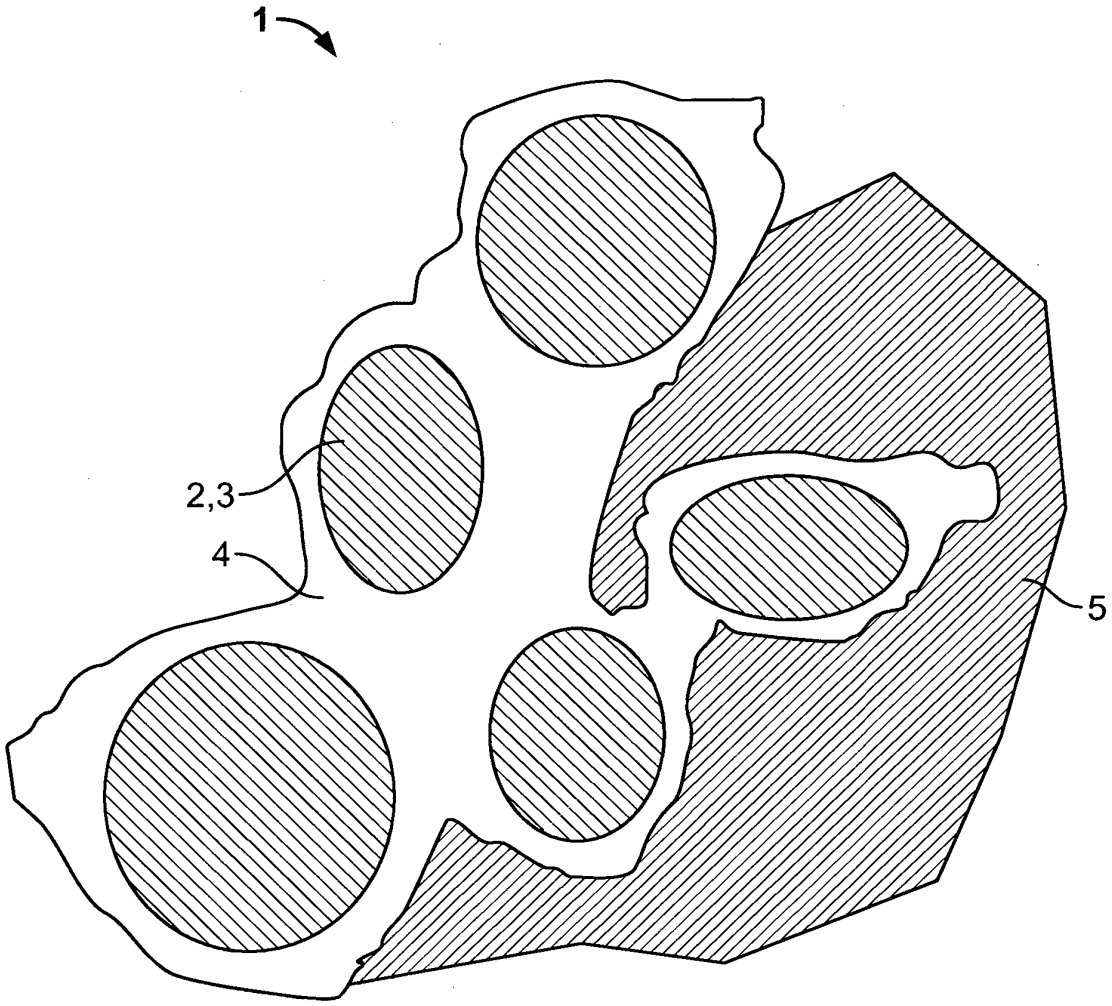


Fig. 1

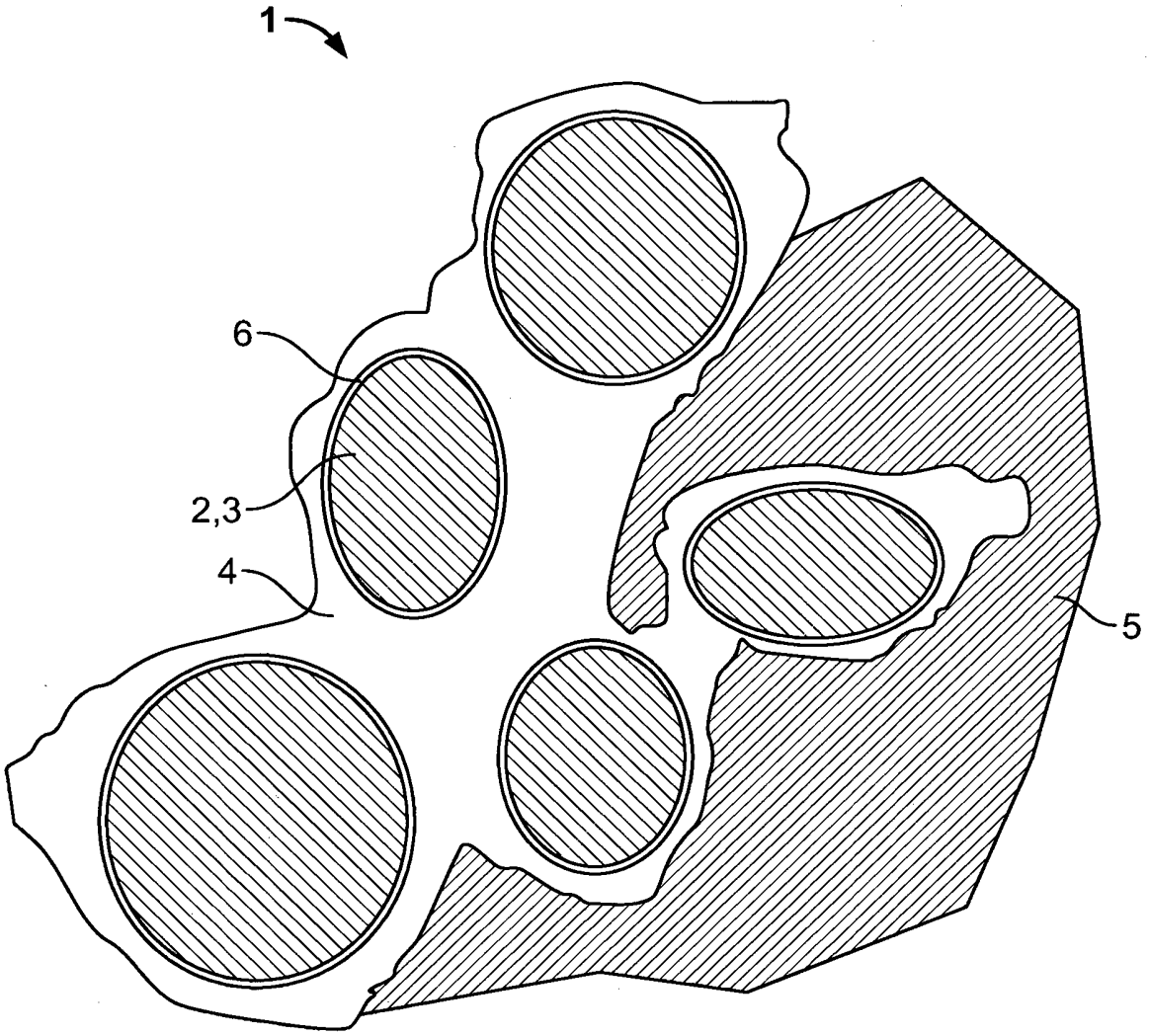


Fig. 2

REFERENCES CITED IN THE DESCRIPTION

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