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(54) Electric conductor made of aluminium with a magnetic outer surface and method for its production

Elektrischer Leiter aus Aluminium mit einer magnetischen Oberfläche und Methode zu dessen Herstellung

Conducteur électrique en aluminium avec une surface magnétique et méthode pour fabrication

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method of providing an electric conductor made of aluminium or enclosed by an aluminium layer with a magnetic outer layer. The invention also relates to a corresponding conductor made of aluminium or enclosed by an aluminium layer, provided with a magnetic outer layer.

[0002] The conductor may be made of solid aluminium or by any other metal provided with an outer layer of aluminium or an aluminium alloy. Such an outer layer of aluminium may or may not be electrically in contact with the conductor.

[0003] Typically the conductor is a conductor for intermediate and high voltage applications, wherein intermediate voltage is referred to as from about 1 kV up to about 40 kV, and high voltage is referred to as from about 40 kV up to about 150 kV.

[0004] Preferably, the conductor is an air-cooled overhead transmission wire. However, other conductors are not excluded from the scope of the invention.

BACKGROUND OF THE INVENTION

[0005] As is well known, an aluminium conductor may be used in a wire or cable for power transmission. Alternatively, a layer of aluminium may be applied to enclose a conductor core made of a material other than aluminium. A shield made of a ferromagnetic material may be provided around the periphery of said wire or cable in order to screen off the electric field generated by the wire or cable upon transmission of current through the latter. According to prior art, the shield may be comprised by a solid layer of such a ferromagnetic material or by any kind of wiring of such a material. The layer or winding may be applied directly onto the outer surface of the aluminium conductor or onto an intermediate layer of any other material, such as a polymer layer.

THE OBJECT OF THE INVENTION

[0006] The object of the invention is to provide an alternative method of providing an aluminium conductor or a conductor enclosed in an aluminium layer with a shield of a magnetic material for the purpose of screening off an electric field generated by said conductor upon operation thereof. Said method should provide a cost effective alternative to contemporary methods of prior art. It should also promote the generation of a shield that adheres well to the aluminium conductor.

[0007] The object of the invention is also to present an aluminium conductor provided with an outer shield of a magnetic material, by which the shield adheres well to the aluminium conductor, and may be produced cost effectively in comparison to corresponding contemporary aluminium conductors of prior art.

SUMMARY OF THE INVENTION

[0008] The object of the invention is achieved by the method initially defined, characterised in that it includes the steps of: anodising the outer surface of said conductor or enclosing layer, thereby generating a porous outer alumina layer, and filling at least a part of said pores with magnetic particles. The electrolyte in which the anodising takes place may be an oxalic, sulphuric or phosphoric solution. For example, hexagonally ordered pore arrays may be obtained under a constant anodic potential in phosphoric acid.

[0009] "Particles" is referred to as any kind of particles, including nano-particles. Anodising parameters such as current density, voltage, temperature, time, pH, etc, may be adjusted in order to provide the alumina layer with pores of suitable size, size distribution with regard to the size, size distribution and requested concentration of the magnetic particles. Magnetic properties of the magnetic anodic film can be controlled by changing morphology of the pores in the anodic film. Porous anodic alumina films may, for example, be generated in nitric acid electrolytes. Preferably, the pores are regular and uniform, with a diameter of tens of a nm up to approximately 50 nm. They may have an inter-pore distance of approximately 100-400 nm.

[0010] The filling of the pores may be conducted by means of an electrochemical process in which the alumina layer is submersed in a bath containing said magnetic particles. The process may be an anodic process. For example, Fe (iron) may be electrodeposited into the pores of an anodic film using a mixed solution (pH=3.8) of $FeSO_4(NH_4)SO_4.6H_2O$ (0,20 mol/l) and H_3BO_4 (0,48 mol/l) at 20 °C with constant voltage of 10 V, and Co may be electrodeposited into the pores using a mixed solution (pH=4.5) of $CoSO_4.7H_2O$ (0.10 mol/l) and H_3BO_4 (0.48 mol/l).

[0011] According to a preferred embodiment of the invention, the filling of the pores is followed by a sealing thereof, preferably in a subsequent electrochemical process in which a sealing material is deposited onto the alumina layer. By sealing the pores, the magnetic particles are entrapped and, thereby, less sensitive to outer affection and less prone to leak out of the pores.

[0012] The object of the invention is also achieved by means of the conductor initially defined, characterised in that said magnetic layer comprises a porous alumina layer, the pores of which are at least partly filled with a magnetic material. Preferably, if the conductor is made of, or based on, aluminium, the porous alumina layer is built on the conductor itself. If, on the other hand, the conductor is based on a material other than aluminium and enclosed in an aluminium layer, the porous alumina layer should be built on said enclosing aluminium layer. The aluminium layer may or may not be part of the conductor. For example, it may be separated from the conductor any electrically insulating layer, e.g. a polymer layer. The magnetic layer may, but need not, be the outmost layer

of a wire or cable to which the conductor belongs.

[0013] According to a preferred embodiment, said pores are sealed towards the surrounding environment by a material other than said magnetic material. Possibly, the sealing of the pores is obtained through a further anodising of the alumina layer, by which the anodising conditions are chosen such that a barrier layer of alumina is produced on top of the porous layer filled with magnetic material.

[0014] The anodising of the conductor, as well as the deposition of the magnetic material and the subsequent sealing of the pores may be a batch process or a continuous process.

EXAMPLE

[0015] According to one embodiment of the invention, a conductor made of an aluminium alloy is subjected to an anodising process in a nitric acid electrolyte by which a layer of porous alumina is generated on the surface of the conductor. A hexagonal porous structure is obtained. The pores are open.

[0016] Subsequently, the conductor is placed in a bath containing a mixed solution (pH=3.8) of $FeSO_4(NH_4)SO_4.6H_2O$ (0,20 mol/l) and H_3BO_4 (0,48 mol/l) with a temperature of 20 °C. A constant voltage of 10 V is applied in order to achieve a deposition of Fe into the pores of the alumina layer. After a time sufficient for the filling of the pores with the magnetic material, the electro-deposition of Fe is ended.

[0017] Finally, the alumina layer is sealed through a further anodising process, in which the process parameters have been changed in order to promote the generation of a barrier layer of alumina on top of the already generated, porous layer.

Claims

1. A method of providing an electric conductor made of aluminium or enclosed by an aluminium layer with a magnetic outer surface, **characterised in that** it includes the steps of:

   anodising the outer surface of said conductor or aluminium layer, thereby generating a porous outer alumina layer, and
   filling at least a part of said pores with magnetic particles.

2. A method according to claim 1, **characterised in that**, subsequently to the filling of the pores, the at least partly filled pores are sealed.

3. A method according to any one of claims 1-2, **characterised in that** said magnetic particles comprise nano-particles.

4. A method according to any one of claims 1-3, **characterised in that** the filling of the pores comprises the steps submersing the alumina layer in a bath containing said magnetic particles, and subjecting the alumina layer to an electrochemical process in said bath.

5. A method according to claim 4, **characterised in that** said electrochemical process is an anodic process.

6. A method according to claim 4 or 5, **characterised in that** said magnetic particles comprises a ferromagnetic material that is electrodeposited into the pores of the alumina layer.

7. A conductor made of aluminium or enclosed by an aluminium layer, and provided with a magnetic outer layer, **characterised in that** said magnetic outer layer comprises a porous alumina layer, the pores of which are at least partly filled with a magnetic material.

8. A conductor according to claim 7, **characterised in that** it is an air-cooled overhead transmission wire.

Patentansprüche

1. Ein Verfahren zum Bereitstellen eines elektrischen Leiters, der aus Aluminium hergestellt ist oder von einer Aluminiumschicht eingeschlossen wird, mit einer magnetischen äußeren Oberfläche, **dadurch gekennzeichnet, dass** das Verfahren die Schritte umfasst:

   Anodisieren der äußeren Oberfläche des Leiters oder der Aluminiumschicht, dabei Generieren einer porösen, äußeren Aluminiumschicht, und Füllen von zumindest einem Teil der Poren mit magnetischen Partikeln.

2. Ein Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** nach dem Füllen der Poren die zumindest teilweise gefüllten Poren abgedichtet werden.

3. Ein Verfahren nach einem der Ansprüche 1 bis 2, **dadurch gekennzeichnet, dass** die magnetischen Partikel Nanopartikel umfassen.

4. Ein Verfahren nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet, dass** das Füllen der Poren die Schritte umfasst Tauchen der Aluminiumschicht in ein Bad, das die magnetischen Partikel enthält, und Aussetzen der Aluminiumschicht einem elektrochemischen Prozess in dem Bad.

5. Verfahren nach Anspruch 4, **dadurch gekennzeichnet, dass** der elektrochemische Prozess ein anodischer Prozess ist.

6. Verfahren nach einem der Ansprüche 4 oder 5, **dadurch gekennzeichnet, dass** die magnetischen Partikel ein ferromagnetisches Material umfassen, das durch Galvanisieren in die Poren der Aluminiumschicht abgeschieden wird.

7. Ein Leiter, der aus Aluminium hergestellt ist oder von einer Aluminiumschicht umgeben wird, und der mit einer magnetischen äußeren Schicht bereitgestellt wird, **dadurch gekennzeichnet, dass** die magnetische äußere Schicht eine poröse Aluminiumschicht umfasst, deren Poren zumindest teilweise mit einem magnetischen Material gefüllt sind.

8. Ein Leiter nach Anspruch 7, **dadurch gekennzeichnet, dass** er eine luftgekühlte Oberleitung für die Übertragung ist.

Revendications

1. Procédé pour munir un conducteur électrique en aluminium ou entouré d'une couche d'aluminium d'une surface extérieure magnétique, **caractérisé en ce qu'**il comprend les stades :

   d'anodisation de la surface extérieure du conducteur ou de la couche d'aluminium en produisant ainsi une couche extérieure poreuse d'alumine, et
   de remplissage d'au moins une partie de ses pores par des particules magnétiques.

2. Procédé suivant la revendication 1, **caractérisé en ce qu'**à la suite du remplissage des pores, les pores remplies au moins en partie sont scellées.

3. Procédé suivant l'une quelconque des revendications 1 à 2, **caractérisé en ce que** les particules magnétiques comprennent des nano-particules.

4. Procédé suivant l'une quelconque des revendications 1 à 3, **caractérisé en ce que** le remplissage des pores comprend les stades de submersion de la couche d'alumine dans un bain contenant les particules magnétiques et la soumission de la couche d'alumine à une opération électrochimique dans le bain.

5. Procédé suivant la revendication 4, **caractérisé en ce que** l'opération électrochimique est une opération anodique.

6. Procédé suivant la revendication 4 ou 5, **caractérisé en ce que** les particules magnétiques comprennent un matériau ferromagnétique qui est électrodéposé dans les pores de la couche d'alumine.

7. Conducteur en aluminium ou entouré d'une couche d'aluminium et muni d'une couche magnétique extérieure, **caractérisé en ce que** la couche magnétique extérieure comprend une couche poreuse d'alumine, dont les pores sont emplis au moins en partie d'un matériau magnétique.

8. Conducteur suivant la revendication 7, **caractérisé en ce que** c'est un câble de transmission aérien à refroidissement par air.