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

(57) A method of providing an electric conductor made of aluminium or enclosed by an aluminium layer with a magnetic outer surface. The method of the invention includes the steps of: anodising the outer surface of

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

EP 1 870 907 A1

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 $\text{FeSO}_4(\text{NH}_4)\text{SO}_4 \cdot 6\text{H}_2\text{O}$ (0,20 mol/l) and H_3BO_3 (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 $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$ (0.10 mol/l) and H_3BO_3 (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 $\text{FeSO}_4(\text{NH}_4)\text{SO}_4 \cdot 6\text{H}_2\text{O}$ (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.

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 method according to any one of claims 2-6, **characterised in that** the pores are sealed with a material other than said magnetic material.
8. 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.
9. A conductor according to claim 8, **characterised in that** said pores are sealed towards the surrounding environment by a material other than said magnetic material.
10. A conductor according to claim 8 or 9, **characterised in that** it is an air-cooled overhead transmission wire.

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.



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 06 44 6001

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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			TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 27 November 2006	Examiner Marsitzky, Dirk
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 06 44 6001

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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