United States Patent [19]

Schoen, Jr.

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[54] **METHOD FOR ELECTRICALLY INSULATING MAGNETOSTRICTIVE MATERIAL**

[75] Inventor: **Oscar W. Schoen, Jr.**, Corona, Calif.

[73] Assignee: **The United States of America as represented by the Secretary of the Navy**, Washington, D.C.

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[52] **U.S. Cl.** **29/609**, 29/602, 117/217, 117/234, 148/6.35, 335/215, 336/20, 336/213

[51] **Int. Cl.** **H01f 7/06**

[58] **Field of Search** 29/602, 605, 609; 336/20, 213, 206; 335/215; 148/6.35; 117/234, 217; 340/11

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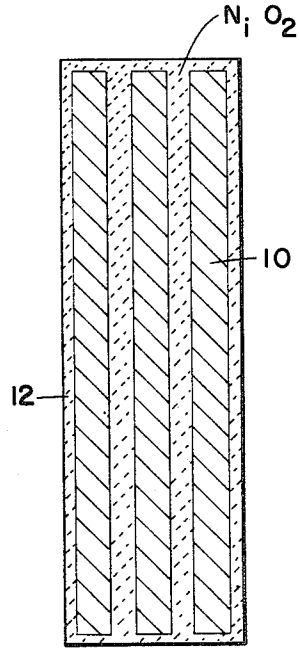
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Primary Examiner—Charles W. Lanham
Assistant Examiner—Carl E. Hall
Attorney—Richard S. Sciascia, J. M. St. Amand & Q. Baxter Warner

[57] **ABSTRACT**

A process of electrochemically plating and annealing in a protective atmosphere the surface of ferrous material used in the construction of underwater transducer scrolls and transformer cores to insulate sheets and plates from each other. The process also eliminates work hardening of the material due to handling, and increases operating and production efficiency.

6 Claims, 5 Drawing Figures



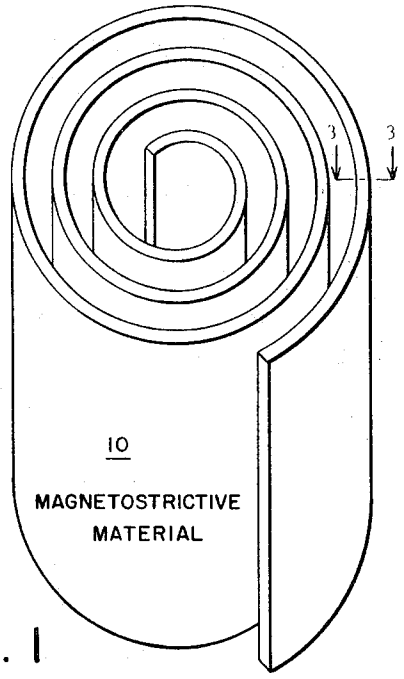


FIG. 1

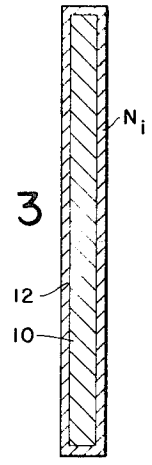


FIG. 3

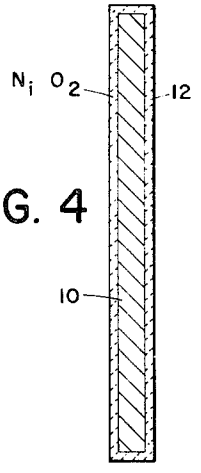


FIG. 4

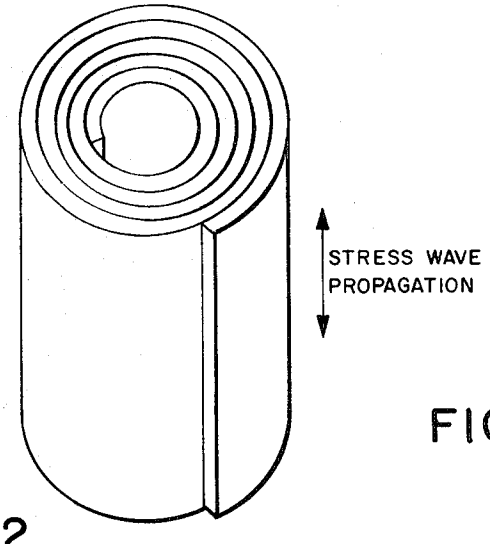


FIG. 2

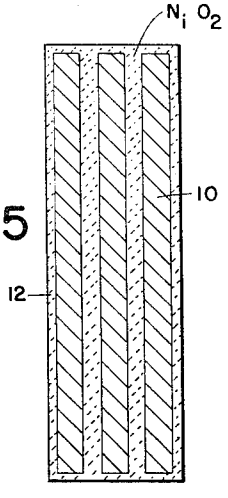


FIG. 5

METHOD FOR ELECTRICALLY INSULATING MAGNETOSTRICTIVE MATERIAL

BACKGROUND OF THE INVENTION

The present invention relates to metal vibrators, magnetostrictive transducers and the like, and more particularly to an improved method for electrically insulating adjacent laminations of magnetostrictive materials.

Metal vibrators (materials exhibiting the magnetostrictive effect) are usually laminated structures because eddy currents must be kept small. Since it is preferable to construct a resonator so that stress waves propagate parallel to the lamination surfaces rather than across lamination boundaries, tubes which are to be used as longitudinal resonators should be constructed as scrolls rather than as ring stacks.

In previous methods, metal laminations have been annealed in a protective atmosphere by running them through a predetermined heat cycle which was found to enhance the desired magnetostrictive properties. Cold working of the material after anneal had to be avoided if the full benefits of the anneal are to be retained.

In building up laminated structures, electrical insulation between laminations must be maintained in order to keep eddy current effects low, and the laminations kept free of burrs which could cause shorting. Organic adhesives have been used to effect consolidation of the laminations. To maintain insulation it has been necessary at times to pre-coat the laminations before consolidating them, or to use a filler in the adhesive.

For the case of 2V Permendur, which is an iron-cobalt alloy frequently used where high saturation requirements justify its rather high costs, laminations must be separated by a gap (as in some transformer cores) or by some form of epoxy-type potting compound applied after annealing (as in underwater sound transducer scroll type applications). In such case, a scroll, for example, is placed within a container and annealed within a protective, non-oxidizing atmosphere while it is loosely wound and after annealing the potting or insulating compound is poured into the container, covering the scroll. The scroll is then wound tightly and maintained under tension while the potting compound cures. The net effect on the scroll material is some degree of cold working (work hardening) and induced internal stresses. Also, air bubbles and bare spots may exist in the potting compound, between laminations, after the scroll is wound, resulting in a non-acceptable device.

The prior method of annealing a scroll, cooling and applying liquid potting compound, and further winding (tightening) the scroll and maintaining tension until the potting compound has hardened results in the deleterious effects of: work hardening during handling and tightening of the scroll, resulting in a reduction of operating efficiency; the creation of bubbles or dry spots between adjacent scroll layers, resulting in poor coupling between laminations and/or electrical short circuits during operation, further reducing operating efficiency and possibly requiring the scroll to be scrapped.

The present invention, which is for an improved method of electrically insulating magnetostrictive material, involves coating the surface of a scroll magnetostrictive material with metallic nickel and annealing in an air or oxygen enriched atmosphere to convert the nickel to non-conducting nickel oxide. The scroll is then allowed to cool and is tightly wound, and while maintaining tension, is reannealed in order to eliminate the work-hardening induced during the winding procedure. The scroll again is allowed to cool so that it may be potted. This process eliminates all of the deleterious effects of the prior methods.

Increasing the efficiency of underwater sound transducer construction techniques, procedures and processes is significant from a cost standpoint. The present invention can lower the rejection rate of defective transducers, solve existing problems in applying insulating layers to transducer laminations, and increase the operating efficiency of individual transducer units.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows transducer scroll prior to winding.

FIG. 2 shows a transducer scroll as in FIG. 1 after being tightly wound.

FIG. 3 shows a cross section taken along line 3—3 of FIG. 1 after plating and prior to annealing.

FIG. 4 is a cross-sectional view as in FIG. 3 taken after annealing.

FIG. 5 is a cross-sectional view of two adjacent sections as in FIG. 4 after winding and a second annealing.

In referring to the drawings like references refer to like components in each of the figures.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the example described herein, 2V Permendur, an iron alloy with approximately 50 percent cobalt is used; its oxide is electrically conductive. Various other magnetostrictive materials whose oxides are electrically conductive are suitable, and the following process will apply to them. The improved process involves coating, by electroplating for example, the surface of a loosely wound scroll **10**, as shown in FIG. **1**, of 2V Permendur with metallic nickel **12** so that a layer 0.001 to 0.005 inch in thickness is deposited over the entire surface of the metal.

The thickness of the deposited nickel coating **12**, as shown in FIG. **3**, will depend on the radius of curvature of the scroll, i.e., — smaller radii require thinner coatings to preclude cracking of the deposited layer of nickel. The nickel coated scroll **10** is then annealed in an air or oxygen enriched atmosphere. During the annealing process the nickel coating **12** is changed to non-conducting nickel-oxide as shown in FIG. **4**. After annealing, scroll **10** is wound tightly, without the need for a separate application of epoxy-type potting compound to insulate and mechanically bind or consolidate the scroll. After the scroll is tightly wound, as shown in FIG. **2**, the nickel-oxide coating forms an electrically non-conductive, insulating partition between conducting layers or laminations **10** of the scroll, as illustrated in FIG. **5**. Then the scroll is again annealed in order to eliminate the work-hardening and internal stresses induced during winding. After this second anneal the scroll can be immersed in an epoxy type potting compound in order to effect consolidation. It should be noted that the potting compound is not needed or used to insulate the layers. Further annealing cannot be ac-

complished after application of the potting compound due to temperature limitations of the compound.

While 2V Permendur material was used as an example, any material which does not produce an electrically non-conductive oxide after annealing and which can be nickel plated may benefit from this described process.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A method for making a magnetostrictive device, comprising:

a. coating a sheet of magnetostrictive material with metal nickel,

b. annealing said sheet coated with nickel in an oxygen rich atmosphere to convert said nickel coating to non-conducting nickel oxide,

c. rolling said nickel oxide coated sheet into a scroll having a plurality of adjacent layers wherein said nickel oxide coating insulates and separates the layers of magnetostrictive material,

d. re-annealing said scroll to eliminate any work hardening and internal stresses.

2. A method as in claim **1** wherein said nickel coating is from 0.001 inch to 0.005 inch in thickness.

3. A method as in claim **1** wherein said magnetostrictive material is a ferrous material which can be nickel plated.

4. A method as in claim **1** wherein said magnetostrictive material is an iron alloy with approximately 50 percent cobalt.

5. A method as in claim **1** wherein said magnetostrictive material is any magnetostrictive material whose oxide is electrically conductive.

6. A method as in claim **1** wherein said layers, after re-annealing, are encased in a potting material for consolidating them into a compact assembly.

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