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METHOD OF MAKING FERRIMAGNETIC FILMS BY CATHODIC SPUTTERING

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ABSTRACT OF THE DISCLOSURE

Ferrimagnetic films are deposited by cathodic sputtering from a source cathode of ferrimagnetic oxide compounds which were first fired in a reducing atmosphere to lower the resistivity.

This application is a continuation of copending application Ser. No. 394,603, filed Sept. 4, 1964, now abandoned.

The present invention relates to the field of cathodic sputtering and can be advantageously used to prepare cathodes or negative electrodes which are employed for the sputtering of ferrimagnetic materials in glow discharge environments.

The sputtering process is a form of cathodic disintegration performed under low pressure in the presence of a filling gas, usually argon. In the cathodic sputtering process, the negative electrode is bombarded with positive ions present as a result of the filling gas becoming ionized. This bombardment of the electrode by the positive ions causes an ejection of particles from the electrode which may be deposited in the form of a film onto the positive electrode or onto a substrate placed between the negative and positive electrodes. Such sputtered ferrimagnetic films find use as computer elements and in thin film circuit applications.

For the particles to be ejected continuously from the negative electrode in a glow discharge, the electrode itself must be capable of carrying a current large enough to sustain the discharge. Unfortunately, only in some very few instances can the cathodic sputtering process be directly applied to ferrimagnetic oxides, since most of these have a very high resistivity which would permit little or no flow of current through the electrode.

Thus, the main problem involved in the cathodic sputtering of ferrimagnetic materials has been the preparation of targets for the positive ions that have a sufficiently low resistivity to enable them to be successfully used as negative electrodes.

Applicants have discovered that electrodes of ferrimagnetic material that contain ferric ions can have their resistivity decreased sufficiently to render them suitable for cathodic sputtering at substantially room temperature by first preparing the material in the form of an electrode and then firing the form in the presence of a reducing atmosphere.

In arriving at their invention, applicants have hypothesized that by analogy with the ferric oxide-magnetite system, it can be supposed that the introduction into a ferrimagnetic oxide lattice of a proportion of ferrous ion would be accompanied by a decrease in resistivity. Applicants corroborated this hypothesis in connection with the zone refining of yttrium iron garnet by radio frequency induction heating. It is well known that pure yttrium iron garnet has a high resistivity. The iron in this compound is in the

form of ferric ion and it has been found by the applicants that as the proportion of iron in the form of ferrous ion increases, the resistivity of the compound decreases. By increasing the proportion of iron in the form of ferrous ion in a ferrimagnetic material, according to this belief, the resistivity of the material can be decreased sufficiently for it to be useful in cathodic sputtering techniques. In any event, firing the electrode in the presence of the reducing atmosphere does decrease the resistivity sufficiently whether or not this hypothesis is correct.

A negative electrode or target of ferrimagnetic material may be prepared by the usual ceramic techniques from the component metal oxides of the desired material. The preparation by ceramic techniques is well known in the art and comprises thoroughly mixing the various oxides that will form the ferrimagnetic material, calcining this mixture, grinding to produce the desired fineness of powder, pressing the powder to the desired shape and firing the compressed compact to produce a dense, hard, ceramic. The sputtering target or negative electrode made by the above procedure may be pressed into the form of a thin slab with shape and dimensions appropriate to the electrode assembly into which it is to be incorporated.

As stated above applicants' believe that at least a portion of the iron in ferric form is reduced to iron in the ferrous form to bring about a decrease in resistivity of the target material. In the preparation of a yttrium iron garnet electrode suitable for use as a target, the firing of the compressed compact was carried out in a stream of hydrogen gas for about two hours at 1000° C. It has been found that any suitable reducing atmosphere may be used and that neither the time required nor the temperature are critical factors. Although no accurate measurements of resistivity have been made on these materials, it has been found that the resistance of particular cathodes has been decreased from hundreds of thousands of ohms to the range of tens of ohms. The decrease has been sufficient to enable these materials to be employed as targets for ion bombardment in the cathodic sputtering process.

Yttrium iron garnet, nickel ferrite, hexagonal barium iron oxide and cobalt ferrite are examples of ferrimagnetic materials which have been successfully tried. The applicants do not wish to be limited to these specific ferrimagnetic materials because the invention is applicable to other high resistivity ferrimagnetic materials which contain ferric ions and which may be reduced to decrease resistivity of the electrode sufficiently to render it suitable for use in cathodic sputtering techniques.

We claim:

1. In a process for the cathodic sputtering of ferrimagnetic films in a glow discharge environment wherein a cathode is bombarded with positive ions causing an ejection of particles from said cathode, the improvement which comprises:

(a) preparing a ferrimagnetic oxide compound forming a ceramic cathode, said compound containing a sufficient amount of ferric ions such that the resistivity of said cathode is too high to permit the cathode to carry enough current to sustain a glow discharge during sputtering;

(b) rendering said cathode capable of carrying enough current to sustain a glow discharge during sputtering by firing said cathode in the presence of a reducing gas to reduce at least a portion of the ferric ion content in said ferrimagnetic compound to ferrous ion, thereby decreasing the resistivity of said ferrimagnetic compound;

(c) and using said so rendered cathode in said sputtering process of ferrimagnetic films.

2. The process of claim 1, wherein the electrode material is selected from the group consisting of yttrium iron garnet, nickel ferrite, hexagonal barium iron oxide and cobalt ferrite.

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