Complex CuNiFe films obtained by TVA method

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Development of new magnetic materials, especially of those who present GMR effect are intensively studied by many research teams. GMR effect occurs in thin films structure composed by ferro-magnetic metal deposits alternatively. Electrical resistance has a significant decrease in the presence of magnetic field. Granular thin films which presents GMR effect have interesting properties and a series of applications. We can list here magnetic sensor, the reading heads. Nanocrystalline magnetic grains in these films are included in the nonmagnetic matrix. The interesting properties appear only when magnetic grains are isolated in nonmagnetic matrix. To obtain thin films we use 2 TVA guns, one of them to evaporate an alloy 80%Ni - 20%Fe, and the other to evaporate the Cu anode. Deposited films present a uniformity in what concerns the thickness and dispersion of the nanograins from the film. The diameter calculated is determined by mediation of distances between two lines tangent to the contour of the particle measured for angles from 15 to 15 degrees. Complex nanostructures obtained by TVA method have special morphological properties with grain with size below 10 nm. The electron diffraction shows the presence of Cu in cubic phase. Electric and magnetic responses are in concordance with the theory of granular solids. The measurements show that magneto-optical effects are increased when the films are deposited on Si.

(Received September 8, 2011; accepted June 6, 2012)

Keywords: Thin films, Magnetoresistivity, TVA-method

1. Introduction

Granular layers based on Co, Ni, Fe, such as CoFeNi, CoCuNi, FeCoCu, CoNiAg, NiFeCu systems, represent promising alternatives for sensors and magnetic recording medias industry [1-5].

For granular system CoNiCu it has been reported in literature [6] an increasing of the value MR from 0,41% at the samples heat untreated to 5,09% at the samples heat treated at 400°C. Y.O.Zhang and others [7] have been reported a Mr increase at room temperature until 6,2% once with decreasing Ni concentration in granular layers of CoNiCu.

Granular ferromagnetic layers are composite materials wich usually are made from nanometric grains Fe, Co, Ni, fixed into a metal nonmagnetic immiscible matrix. (Au, Ag, Cu).

An appropriate composition for the composit layer NiFeCu used for manufacture of magnetic sensors includes: Ni between 45%-80%, Fe between 5%-20% and Cu between 10%-50% (8). In this system, Ni atoms can form solid solutions with both Cu and Fe atoms, that way being possible formation of grains from mixed alloys Cu-Ni and Fe-Ni.

There have been made and reported in the scientific literature intensive studies for connecting the GMR response to the structural properties (for example the crystalline structure, the interface granular underlayer-layer, the form, density and size of the particles, the intergranular density etc

Excellent magnetic properties have been reached, such as susceptibilities from 10 until hundreds of 10 until densities of saturation flux of arround 1T, and coercivities of only scores of Oe.

2. Experimental

In the present study were deposited granular layers de NiFeCu with TVA method, usind two guns TVA which vaporise two anodes, one of them consisting of an alloy 80%Ni and the other of Cu.The NiFeCu films' adhesion deposited by TVA method to underlayer was:

a) The proper cleaning of silicon wafers underlayers respectively the glass with 0,8mm thickness before the deposition with cleaning chemicals (acetone and alcohol) in ultrasonic bath.

b) Luminescent discharge before starting the deposition process.

This discharge has been made in residual air because the oxygen's presence was necessary for burning the debris on underlayers.

c) By the bombardment with a big energy and metallic ions' flow (NiFeCu) of the underlayers.

To achieve the above mentioned condition b), before the vacuum limit is reached in the reaction chamber (usually at a pressure of 10-3 torr) is being applied a voltage of kilovolts between the anode and the samples form the table. In this case, ignites a glow discharge between samples, which along with chamber walls which plays the role of cathode, and anode placed at a high voltage. There is a spray combined with oxidation and degassing of samples by using the air still present in the room. This pretreatment of samples was performed for 20 minutes, after which opened the acces to the diffusion pump. Residual pressure drops below the voltage applied to the anode so that be able to mantain glow descharge around the room deposit, and the glow discharge is extinguished.

Next we present experimental conditions for obtaining layers of NiFeCu:

Anod1: graphite crucible filled with 80% Ni20% Fe alloy;

Anod2: graphite crucible filled with pure Cu material;

Substrates: 5 industrial glass plates and 6 Si plates Fe = 1g; Ni = 4g; Cu = 7,5g;

Distances between anodes and the probe for the sample thickness: $d_{probe-NiFe}$ = 40cm and $d_{probe-Cu}$ = 40cm;

Distances between anodes and the center of the substrate support system: $d_{substrate-NiFe}$ = 39cm and $d_{substrate-Cu}$ = 39cm;

Correction factors:

$(d_{probe-NiFe} + d_{probe-Cu})$:2=40,5 cm x

$(d_{substrate-NiFe} + d_{substrate-Cu})$:2=39cm y

$$\left(\frac{x}{y}\right)^2 = \left(\frac{40,5}{39}\right)^2 = (1,03)^2 = 1,06$$

Densities: Fe = 7,86g/cm^3, Ni = 8,9g/cm^3, Cu = 8,93g/cm^3;

Average density: 8,56g/cm^3;

$I_{filament}$ = 51A; $I_{filamentCu}$ = 49A; P_{lucru} = 6,6x10^{-6}Torr

Deposition time was 14 minutes;

Thickness was measured by Cressington monitor = 200nm.

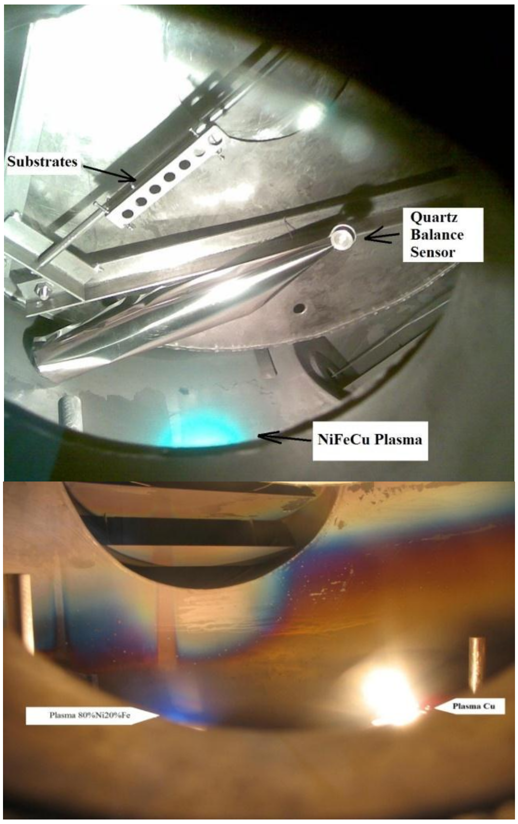

Fig. 1. Simultaneous evaporation system using one (up) or two (down) TVA guns.

Table 1. Intensity and voltage of the discharge in NiFe vapors.

$I_{discharge}$ (A)	$U_{discharge}$ (V)
1,3	590
1,5	629

Table 2. Intensity and voltage of the ischarge in Cu vapors.

$I_{discharge}$ (A)	$U_{discharge}$ (V)
0,5	700
0,58	740

For deposing the NiFe+Cu films were ignited the discharges in NiFe vapors and separately (simultaneously) in Cu vapors (Fig. 1). Control of relative concentrations between the theree components of the layer was achieved by choosing the electrical parameters of stable operations in vapor NiFe, or also by positioning the samples at appropriate distances from the two sources of plasma.

3. Results and discussion

Morphology and structure investigations were performed using a transmission electron microscope TEM Philips CM 129 ST operating at 100kV.

Magneto-optical measurements were made with a Moke device which measures the angle of rotation of optical vibration plan of a laser radiation reflected (Kerr rotation) as a function of magnetic field applied to samples of the composite layer.

The magnetic resitive ratio

$$MR(B) = \frac{R(B) - R(0)}{R(0)}$$

was measured as a function of field B applied at the room temperature through a classical method and uses the configuration in 4 points. A magnetic field of up to 1 T was applied perpendicular on the layout of the sample.

In Fig. 2 are shown TEM images of the NiFe Cu granular layer deposited on glass and silicon, where you can see the existence of crystal clusters with 3-8nm dimensions.

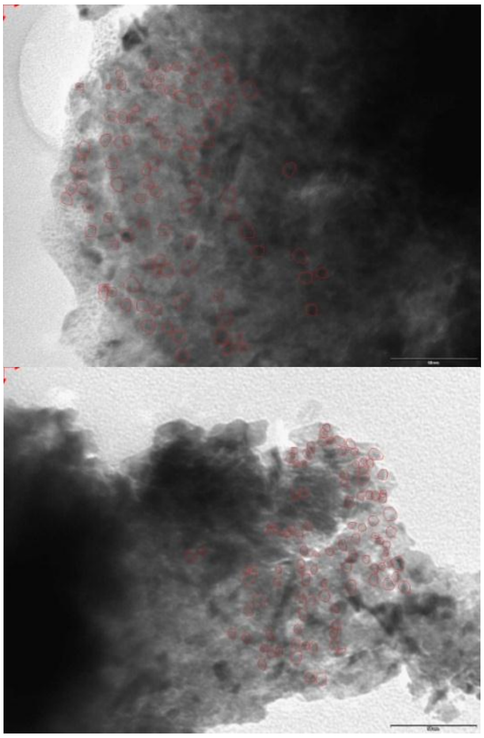

Fig. 2. TEM images of NiFeCu layer deposited on silicon underlayer (up) and on glass underlayer (down).

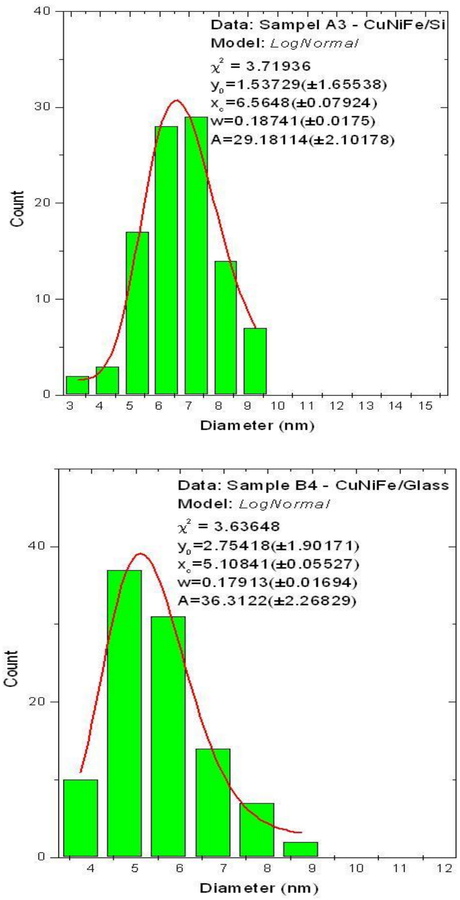

Fig. 3. Distribution of average size of crystallites for NiFeCu samples deposited on silicon (up) and on glass (down).

Distribution after size of crystallites, obtained by measuring the diameter of a few tens of crystalline aggregates (indentified in Fig. 2) is shown in Fig. 3. Grain size distribution was fixed at a lognormal curve. The average size of crystallites Dm was found being about 5nm samples deposited on glass and about 7nm for samples deposited on silicon.

Fig. 4 shows MR variation as a function of applied field on NiFeCu sample deposited on Si underlayer , recorded at room temperature in the working geometry CIP (current in the sample plane), choosing the value of 25mA constant current. It could been seen a maximum value of 1,38 % MR ration to a value of 0,06T of applied field , the saturation started at about 0,15 T.

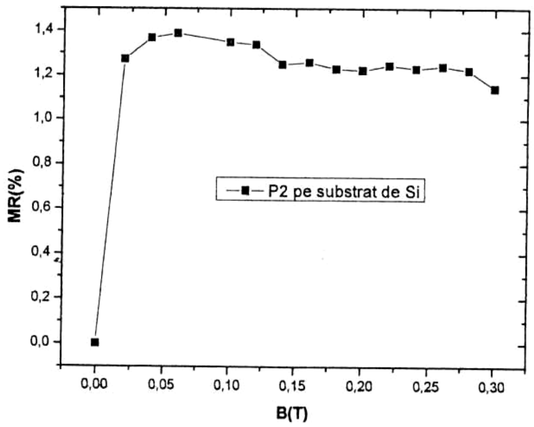

Fig. 4. MR effect at room temperature for NiFeCu sample deposited on Si in CIP geometry, using a current of 25mA.

4. Conclusions

Nanostructures obtained both on glass and silicon have special morphological proprieties with grains of sizes below 10 nm. Deposited films show a uniformity in terms of thickness and dispersion film nanograins. Electric and magnetic responses are in concordance with the theory of granular solids. The measurements show that magneto-optical effects are increased when the films are deposited on Si. Nanograins' diameter was calculated by distances average between two lines tangent to the contour of the particle measured for angles of 15 to 15 degrees.

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