Electrodeposition of Iron-group Multilayer Thin Films and Nanowires

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Electrodeposition of multilayers with adjacent ferromagnetic materials separated by a nonmagnetic, nanometric spacer material, can be antiferromagnetically coupled in thin films giving rise to giant magnetoresistance (GMR) when the current travels parallel to the multilayer plane (CIP). A variety of electrodeposited iron-group (Ni, Fe, Co) elemental and alloy compositional multilayer systems have been examined.[1] Dry processes have produced multilayers with GMR values that surpass electrodeposited ones, however, the impetus to explore the electrodeposition process is based on its cost-effective advantage and applicability to deposit multilayers into deep recessed areas for nanowire designs.

Nanowires are of interest due to the GMR in the current perpendicular to the multilayer plane (CPP) mode. Several systems of nanostructured multilayers have been deposited in the form of nanowires. They include, for example, Co/Cu,[2-4] Ni/Cu,[5] CoNi/Cu[6] and NiFe/Cu[2]. Recently, our laboratory has also demonstrated the fabrication of CoNiFe/Cu multilayered nanowires[7] in alumina templates. The choice to study the CoNiFeCu system is to have the flexibility to tailor the magnetic property by varying composition.

In this study, we provide an overview of our recent work in the electrodeposition of different combinations of the CoNiFeCu multilayered system. Room temperature magnetoresistance is reported for CoCu/Cu, CoNiCu/Cu, CoNiFeCu/Cu and CoAu/Au thin films. Nanowires have also been fabricated for the CoNiCu/Cu and CoNiFeCu/Cu multilayered materials in porous alumina templates. A demonstration of a multilayered nanotube is also presented from porous templates.

Experimental

Sulfate-sulfamate electrolytes were used with boric acid. The influence of Triton X-100 was evaluated for CoCu/Cu multilayers. Deposits were fabricated on a variety of substrates including 316 stainless steel, Au, Cu silicon and alumina templates with a sputtered Au seed layer. A non-cyanide bath was developed for a CoAu/Au electrolyte.[8] Electrodeposition was carried out on both a rotating disk electrode (RDE) and on a flat plate under stagnant conditions. The flat plate cell holder consisted of two pieces of PEEK that sandwiched the sample, with a window exposing the electrode. The electrode was recessed 1 cm from the plastic holder surface. GMR was characterized with a Quantum Design PPMS measurement system using the standard 4-probe AC technique at 27 Hz.

Results and Discussion

Variable multilayer sizes were investigated in the different systems. An example of a comparison of similar GMR values obtained with a thin film (CIP mode) with a 100-200 nm diameter nanowire array multilayer deposition (CPP mode) is shown in Figures 1 and 2 for the CoNiFeCu/Cu and CoNiCu/Cu systems, respectively. In both cases there is a dramatic decrease in the saturation field with the nanowire array. Larger diameter porous templates (800 nm) resulted in multilayered tubes.

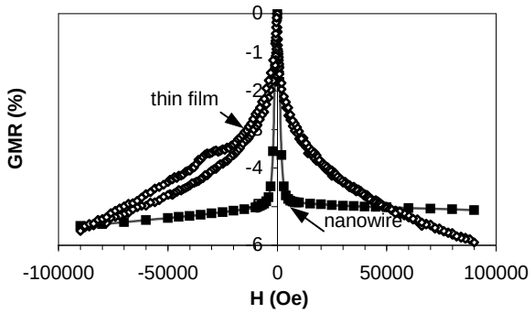

Fig 1. CoNiFeCu/Cu multilayers with similar GMR % plated as a thin film and a nanowire array

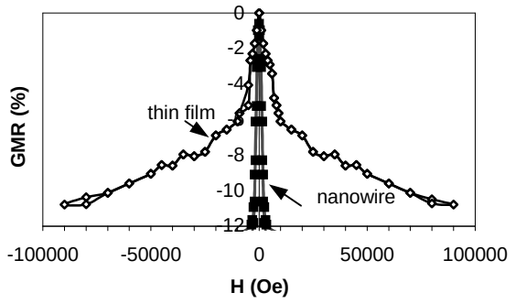

Fig 2. CoNiCu/Cu multilayers with similar GMR % plated as a thin film and a nanowire array

Multilayers of Co/Cu and Co/Au, with impurities of the more noble metal in the magnetic layer, were also realized. Similar GMR behavior was obtained on a Cu (200) foil with values exceeding 10 % at high fields. A critical feature was that the GMR dropped an order of magnitude if the substrate was removed.

Detailed experimental conditions will be presented.

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