Low-Stress High Performance Soft Magnetic Materials For MEMS From Additive-Free Chloride Baths

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MEMS devices such as microactuators, sensors, micromotors, and frictionless microgears require the use of both hard and soft magnetic materials because electromagnetically-actuated MEMS are more stable for high force and large actuation gap applications. Moreover, they are less susceptible to malfunction when subjected to adverse environments [1-3].

There are many different ways to deposit and integrate magnetic materials into MEMS. Electrochemical processes including electrodeposition and electroless deposition are well-suited to fulfill the requirements of high yield and cost effective processes. Due to these advantages, electroplated soft magnetic materials such as NiFe and CoNiFe have been widely used as recording head materials for computer hard drive industries [4]. In the case of magnetic-MEMS, the magnetic layer thickness can vary from a few nanometers to a few mm depending on the applications. Magnetic thin films must also have good adhesion, low-stress, corrosion resistance, and be thermally stable with excellent magnetic properties.

The most commonly used magnetic materials in MEMS are soft magnetic materials, such as permalloy (19%Ni-81%Fe alloy). The combination of relatively high magnetic saturation ($M_S \approx 1$ T), low coercivity (low hysteresis loss), good corrosion resistance, and near zero magnetostriction (i.e. magnetic properties not affected by film stress) has led to the use of electrodeposited permalloy films in macroscopic and microscopic sensors, actuators, and systems.

Residual stress in the electrodeposited films is an important factor for MEMS devices because, unlike in the data storage application, the thickness of magnetic films in MEMS can range from nanometers (e.g. NEMS devices) to few millimeters thick (e.g. LIGA devices). In many cases, this film stress could exceed the strength of the film, resulting in cracking, deformation of devices, and interfacial failure.

Low-stress high magnetic saturation (upto 2.3 T) soft magnetic materials (i.e. CoFe and FeCoNi) were developed from additive-free acidic chloride baths. The effect of electrolyte compositions, operating temperatures, current density on film compositions and magnetic properties were systematic investigated. Figure 1 and 2 show the internal stress and magnetic saturation, and morphology of CoFe films. Increasing operating temperature promotes grain growth minimizing internal stress and reducing coercivity.

References:

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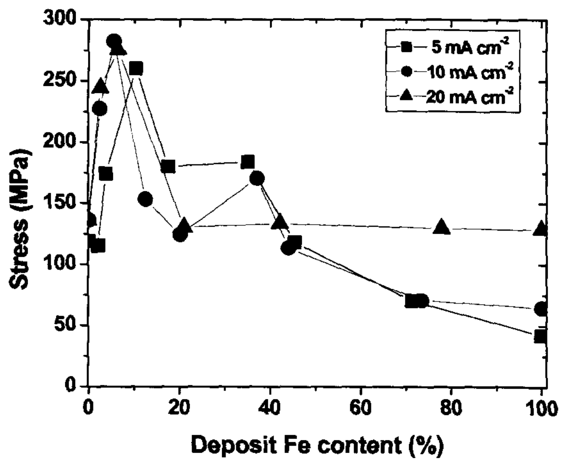

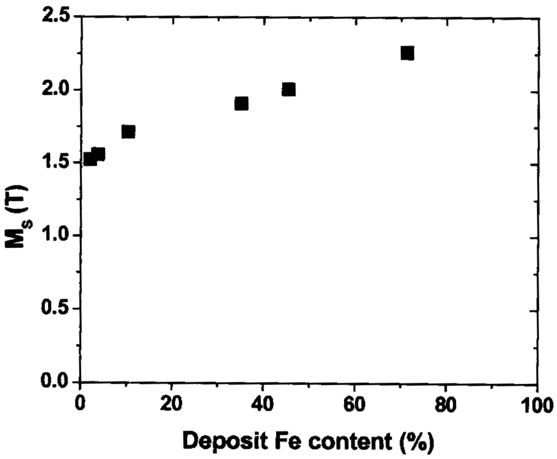

Figure 1. Internal stress and magnetic saturation of electrodeposited CoFe films from additive-free acidic chloride baths: Magnetic saturation (M_s) of 2.26 T with stress of 70 MPa was achieved.

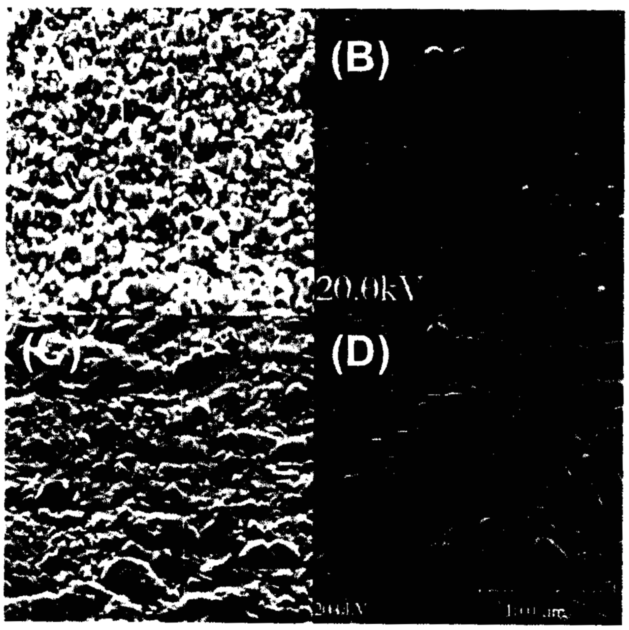

Figure 2. SEM micrographs of electrodeposited CoFe films at 5 mA cm^{-2}: (A) 2.1 %Fe, 115 MPa (B) 10.4 %Fe, 260 MPa, (C)17.8 %Fe, 180 MPa and (D)71.3% Fe, 70 MPa