

MAGNETIC PROPERTIES OF NANOSTRUCTURED CONIP ELECTRODEPOSITS

D.-Y. Park, N. V. Myung, M. Schwartz, and K. Nobe
Department of Chemical Engineering
University of California, Los Angeles
CA 90095-1592

INTRODUCTION

Numerous studies have been carried out to develop ternary CoNiP magnetic thin films because of their hard magnetic properties with potential applications, including high density recording media [1-2] and microelectromechanical system (MEMS) devices [3-4]. Electrochemical processes (electrodeposition and electroless deposition) have many advantages over vacuum processes: low cost, easy scale up and maintenance, low operating temperature, and the ability to "tailor" deposit structure and properties.

Since Iwasaki and Nakamura proposed the potential of high density recording media by perpendicular magnetic recording [5], the electroless deposition process has been studied by a number of investigators to develop CoNiP magnetic thin films for perpendicular magnetic recording media [2, 6]. However, few electrodeposition studies have been conducted on perpendicular magnetic recording media [7]. Hard and soft magnetic materials have recently been incorporated into MEMS devices, including microactuators, sensors, micromotors and frictionless microgears. Electromagnetically-actuated MEMS are more stable for high force and large gap applications, more robust in harsh (dust and humidity) environments, and can be actuated with low cost voltage controllers [4].

The purpose of the present work is to study the effect of electrodeposition parameters on the magnetic properties of CoNiP thin films from chloride baths, and to apply this information to incorporate hard magnetic films into MEMS.

EXPERIMENTAL PROCEDURE

CoNiP thin film alloys were electrodeposited from chloride baths. NaCl and boric acid were used as supporting electrolyte and pH buffer, respectively. Saccharin was added to reduce the deposit stress. Solution pH was adjusted with KOH or HCl; experiments were conducted at 10mA/cm² and room temperature without stirring. Current density of 10 mA/cm² was used to produce electrodeposited CoNiP films with coercivities of H_{C,⊥} > 1600 and H_{C,∥} > 800, squareness of S_∥ > ~ 0.4 and S_⊥ > ~ 0.2.

The effect of the solution Co⁺²/Ni⁺² ratio on the deposit composition of CoNiP was investigated by varying the Co⁺² concentration from 0.10 M to 0.206 M, with Ni⁺² concentrations set at 0.2 M. The effect of NaH₂PO₂ concentration on the deposit P content and magnetic properties was also examined by varying the NaH₂PO₂ concentration from 0.009 M to 0.283 M with Ni⁺² and Co⁺² concentrations set at 0.2 M and 0.206 M, respectively. Co⁺² concentrations were varied to produce CoNiP electrodeposits with nanocrystalline grain size (30-70nm). CoNiP films were electrodeposited on brass substrates and nickel sheet was used as soluble anodes.

Magnetic properties such as magnetic saturation (M_s), coercivity (H_c), squareness (S=M_r/M_s) and BH_{max} were determined using a vibrating sample magnetometer. Microstructures of CoNiP electrodeposits were examined with a scanning electron microscope and an optical microscope. X-ray diffractometer (XRD) with Cu K_α radiation was used for the identification of the existing phases and the measurement of grain size.

RESULTS AND DISCUSSION

Magnetic CoNiP alloys were electrodeposited using chloride baths to investigate the dependence of the magnetic properties on electrodeposition parameters. Magnetic properties were strongly influenced by Co²⁺ and NaH₂PO₂ concentrations, deposit thickness and solution pH. Coercivity (H_{C,⊥} and H_{C,∥}) increased with increasing deposit P content as shown in Fig. 1. The backscattered electron image revealed a finely-columnar structure of CoNiP electrodeposits as shown in Fig. 2. The electrodeposits from solutions containing low concentrations of NaH₂PO₂ (0.009 M) exhibited hcp structures with (100), (101) and (110) planes. Higher concentrations (≥ 0.028 M) resulted in deposits with nanocrystalline grains in the 46-60 nm range and preferred (002) planes, the intensity of which increased with increasing solution pH; these conditions appear to be closely related to increased deposit coercivity.

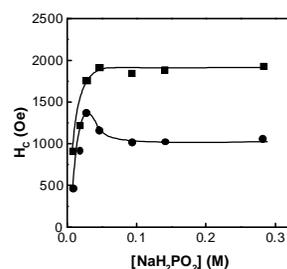


Fig. 1 Coercivity (H_c) dependence of CoNiP electrodeposits on NaH₂PO₂ concentration.

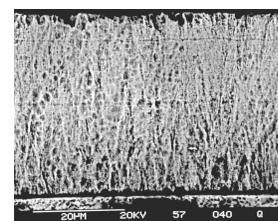


Fig. 2 Microstructures of CoNiP deposit cross sections with 0.028 M NaH₂PO₂ concentration, 10 mA/cm² and pH 3.

ACKNOWLEDGEMENT

This work was supported by the DARPA MEMS program DAB63-99-1-2000.

REFERENCES

1. Y. Nakamura, *J. Magn. Magn. Mater.*, 200, 634 (1999).
2. T. Homma, Y. Kita and T. Osaka, *J. Electrochem. Soc.*, 147 (1), 160 (2000).
3. T.-S. Chin, *J. Magn. Magn. Mater.*, 209, 75 (2000).
4. J. W. Judy and R. S. Muller, *J. Microelectromechanical Sys.*, 6 (3), 249 (1997).
5. S. Iwasaki and Y. Nakamura, *IEEE Trans. Magn. MAG-13*, 1272 (1977).
6. T. Homma, Y. Sezai and T. Osaka, *Electrochim. Acta*, 42 (20-22), 3041 (1997).
7. C. Byun, G. C. Rauch, D. J. Young and C. A. Klepper, *J. Appl. Phys.*, 73 (10), 5575 (1993).