ABSTRACT

Magnetoimpedance (MI) effect, observed in soft magnetic materials, is known for more than a decade now, yet the physics behind this phenomenon is not completely understood. New and interesting results continue to appear without a common agreement on general understanding of the phenomenon. Soft magnetic films coated over nonmagnetic wire via electrodeposition method have drawn considerable attention owing to their optimum performance to cost ratio.

It is well known that apart from the crystal structure and composition of the material, the soft magnetic properties depend on the microstructure. There are several reports that show the magnetic properties of a material with certain composition can be further enhanced by altering its microstructure. The main objective of the present work is to identify the means of control through which the microstructure can be finely controlled to create nanocrystalline grains, which can help in reduction of magnetic anisotropy as well as magnetostriction and enhance soft magnetic properties with high permeability. Several intrinsic and extrinsic parameters have been identified through which the microstructure of the soft magnetic thin films electrodeposited on non-magnetic copper wire can be controlled efficiently. Nanocrystallization and grain refinement of the magnetic films is possible with different organic additives in deposition bath. We have attempted to control the grain structure/size with organic additives like saccharin and thiourea, which in turn significantly enhance the soft magnetic properties. The reduction of crystallite size lowers the magnetocrystalline anisotropy causing an improvement in magnetic softness. This has been explained by random anisotropy model. Elemental nickel films exhibited negligible MI effect, which was attributed to the presence of magnetoelastic anisotropy. However, nickel rich NiFe alloy deposited with optimum bath composition and current density, showed highest MI effect. It is observed that the core-shell geometry also resulted in high MI values at low applied magnetic fields. A phenomenological model has been proposed to explain the role of organic additives in tailoring the microstructure. To improve the saturation magnetization of the alloy film, ternary alloy of CoNiFe was also deposited. The effect of binary and ternary film thickness on MI effect was studied and optimum thickness was found for the maximum MI response. Without the additives, MI effect was negligible (≈ 2%). But upon addition of additives like saccharin and thiourea, percentage of MI enhanced to more than 100% and optimum concentrations of saccharin (1 g/l) and thiourea (80 mg/l) were found for best MI response. Beyond this concentration, the soft magnetic properties and MI saturate in the case of saccharin but decline in the case of thiourea.

The addition of minute quantities of Cu to the magnetic films results in enhanced MI values (~ 300% in case of NiFe bath) as the soft magnetic properties improve upon reduction of grain size. This change was attributed to the role of copper atoms as nucleation centers for alloy film deposition. These nucleation centers control the growth of individual grains and restrict its size.

Keywords: Magnetoimpedance, Electrodeposited, Microstructure, Deposition parameters, Nickel, alloy, thin film