The influence of soft magnetic layer thickness on the inductance and resistance of NiFe/Cu composite wires

Ning Ning, Xiaoping Li

National University of Singapore, Singapore

Giant magneto-impedance (GMI) effect has attracted much interest because of its applications in weak magnetic field sensing. GMI effect in $Ni_{80}Fe_{20}$/Cu composite wire has been found to be more significant over homogenous bulk structures e.g. amorphous wire, due to its non-ferromagnetic and conductive core structure. Recently, GMI effect was reported to use in the micro composite wire based tunable inductor [1], which further extends the applications of GMI phenomenon. With a further understanding of the tunable properties of inductance L and resistance R_s in the micro composite wires, the tunability of L and R_s of such composite wire inductor in relation to the magnetic coating layer thickness t_m, is presented in this paper.

Specimens of $Ni_{80}Fe_{20}$/Cu composite wires were produced by electroplating a layer of $Ni_{80}Fe_{20}$ with varying thickness t_m of 1 - 7 µm, onto a Cu wire of 20 µm in diameter and 2 cm in length. The resultant L and R_s of the wires, under the application of a range of biasing magnetic field H_{ext} (from 0 to 43 Oe), were measured and characterized as a function of t_m (see Fig.1). The change of L and R_s with increase of frequency f, H_{ext} and t_m may be due to the change of dominating magnetization process (from domain displacement to moment rotation). It can be explained by that during the electroplating process, as t_m increased, the circumferential magnetic flux density was getting weaker and the direction of the easy axis was getting away from the circumferential direction. Another important factor to consider is the eddy-current effect. The change of t_m changes the eddy current distribution within the conductor, which in turn leads to the change of L and R_s. The external magnetic field changes the relative permeability of the magnetic layer, which changes the eddy current loss as well.

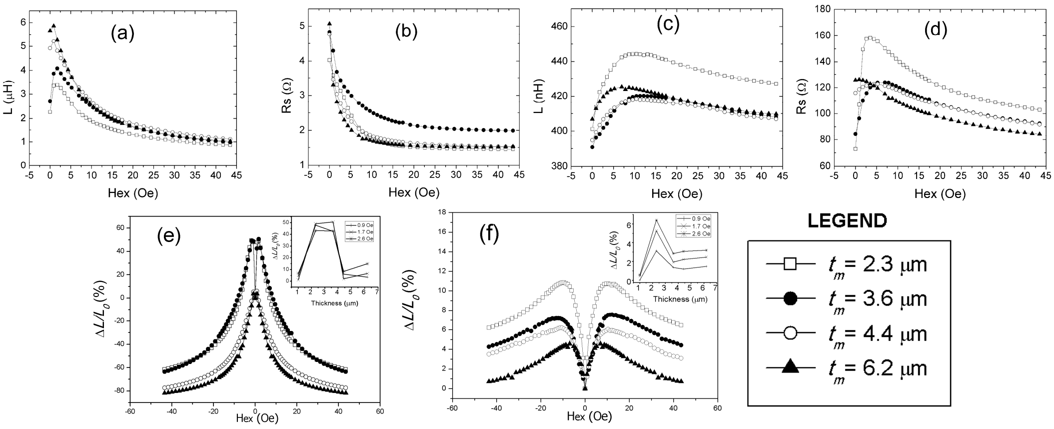

Fig. 1: (a) L *vs* H_{ex} at 100 kHz; (b) R_s *vs* H_{ex} at 100 kHz; (c) L *vs* H_{ex} at 100 MHz; (d) R_s *vs* H_{ex} at 100 kHz; (e) $\Delta L/L_0$ *vs* H_{ex} at 100 kHz; (f) $\Delta L/L_0$ *vs* H_{ex} at 100 MHz. $\Delta L/L_0 = (L – L_0) / L_0$, where L_0 is the inductance at zero basing field.

The results indicate that there is a critical thickness for the coating layer, below which the tunability of L under a weak bias magnetic field is high (up to 50.6% at 100 kHz and 5.3% at 100 MHz, when H_{ext} is 1.7 Oe) and is proportional to t_m, and above which the tunability of L under a weak bias field is low (up to 6.6% at 100 kHz and 2.5% at 100 MHz, when H_{ext} is 1.7 Oe) and is inversely proportional to t_m. To the tunability of L of composite wire inductors, the increase of t_m has an equivalent effect as decreasing the operating frequency.

[1] N. Ning, X. P. Li, *et al*, *IEEE Trans. Magn.*, 42 (2006), 1585-1590

Corresponding author e-mail: mpelixp@nus.edu.sg