2 Ⅱ (특별강연)

Recent Advances in Micro-Magnetic Devices

東北大学電気通信研究所 山口正洋、荒井賢一
連絡所：山口正洋 (YAMAGUCHI, Masahiro)
〒980-77 宮城県仙台市青葉区片平 2-1-1、日本
東北大学 電気通信研究所 助教授
TEL: +81-22-217-5488, FAX: +81-22-217-5489
e-mail: yamaguti@riec.tohoku.ac.jp

There is a need for practical magnetic thin/thick film inductors and transformers, increasing with the rapid market growth of personal electronic equipments. Not only in Japan but in US, Germany and recently in Korea, basic properties and applications for dc-to-dc converters, LC filters, fluxgate magnetometers, etc. have been discussed. The technology area of Micro-Magnetic Devices involves materials, processes, design/simulation and packaging as shown in Fig. 1.

We microfabricated magnetic metallic thin-film inductors and YIG film inductors and analyzed their inductance and ac resistance in 1 MHz - 1 GHz range. The frequency characteristics are governed by a number of material parameters and structural parameters as shown in Fig. 2.

Reduction of the eddy currents and the coil resistance are of major concern for metallic thin-film inductors from as low frequency as a few MHz in order to obtain high-Q (quality factor) and low-loss micro core. The skin depth, $\delta = (2\rho/\mu\omega)^{1/2}$ (ρ: resistivity, μ: permeability, ω: angular frequency) is an useful guideline to achieve eddy current reduction. Toshiba Co. and NTT Co. announced very recently the commercialization of a 1W class planar dc-to-dc converter using a microfabricated thin/thick film inductor. Both parties utilize laminated sputter-deposited magnetic films in order to reduce eddy current losses. Electro-deposited films are also useful for thick coil fabrication which help dc resistance reduction. The planar dc-to-dc converter application will be going on because a portable electronic equipment require different supply voltages depending on the function of circuit blocks involved in the equipment.

A potential use of thin film inductors and transformers is LC filters for noise suppression and signal processing. Their frequency range may cover 1 MHz - 3 GHz. We made a thin-film LC filter with cut-off frequency of 50 MHz using NiFeCuMo film. Its advantages over air-core LC filter were size reduction and low insertion losses. Currently the filters with cut-off frequency of 1 GHz -3 GHz have a potential for personal handy phones (PHS), etc. In this frequency range, ferrite films and high resistivity films can be main candidates if we take account of eddy currents, ferromagnetic resonance and anisotropy dispersion in the magnetic films. The LC resonance and wave-length resonance should be considered in device design.

Micro-Magnetic Devices are coming up to the stage of practical applications. Interactive discussions with Micro Electro Mechanical Systems (MEMS), magnetic high frequency measurement techniques and semiconductor microelectronics will help the development of practical devices very much.

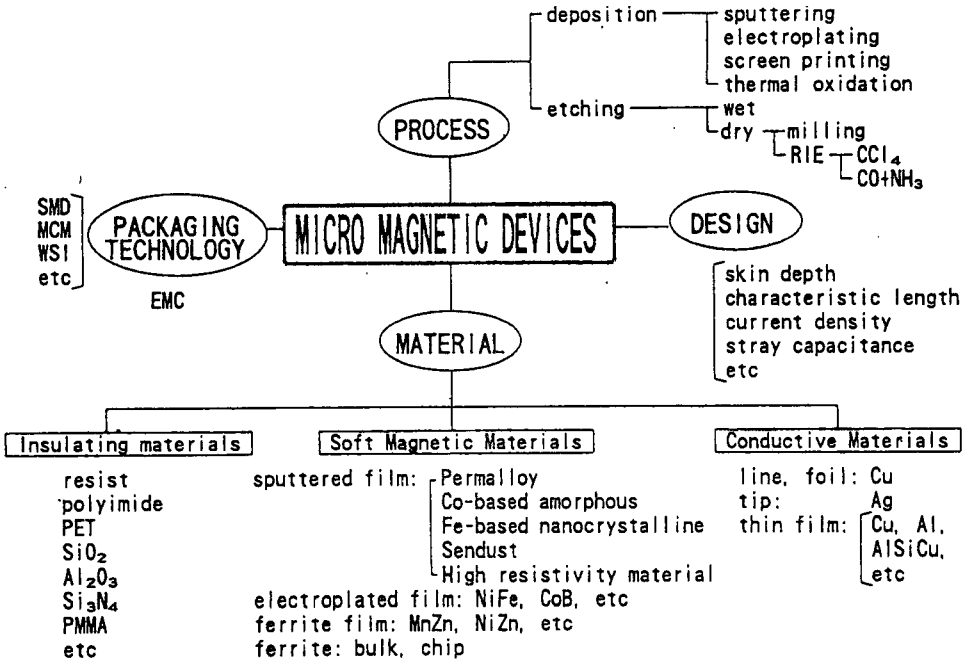

Fig. 1 Technology are of Micro-Magnetic Devices.

	Design parameter	Material parameter
Inductance		
Magnetic-core inductance (Reluctance of magnetic path)	*Structure of the core *Characteristic length *Length of magnetic-path *Cross sectional area of magnetic film *Thickness of insulator	Permeability, μ_r'
Air-core inductance Self inductance Mutual inductance Magnetic shielding factor	*Coil pattern *Structure and dimension of magnetic thin-film core	
Resistance		
Copper losses dc resistance	*Coil length *Cross sectional area	*Resistivity
ac resistance Skin effect	*Frequency *Skin depth	*Resistivity
Proximity effect	*Geometrical mean distance between the neighboring legs of the coil *Leakage flux from magnetic thin-film	
Iron losses	*Frequency *Thickness of magnetic thin-film	Permeability, μ_r'' Hysteresis loss Eddy current loss Ferromagnetic resonance
Stray capacitance		
between magnetic film and conductor magnetic film and ground plane conductors	*facing area *distance of electrodes	permittivity

Fig. 2 Material parameters and structural parameters for Micro-Magnetic Devices