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Expanded noise absorbing bandwidth of noise suppressor by using magnetic multilayer films with different thickness

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An electromagnetic noise is a serious concern at high frequencies and this is particularly true in the GHz frequency range where most of current wireless communications devices are operated. Developing countermeasures for suppressing electromagnetic noise in the frequency range of several hundreds MHz to several GHz have therefore become important technical issues. Magnetic materials have played important roles in effectively suppressing electromagnetic noise and the basic mechanism in this case is the loss generation of ferromagnetic resonance (FMR). Several sputtered magnetic films were previously used for an integrated countermeasure of electromagnetic noise emission on an RF integrated transmission line [1-3]. A typical device structure consists of a magnetic thin film on top of a transmission line. In the past, a single-layered magnetic film was invariably used and the observed bandwidth of noise suppression was usually narrow due to a single FMR peak. In an effort to extend the noise suppression bandwidth, a double-layered structure is used consisting of two magnetic thin films separated by a non-magnetic spacer. The main idea is to vary the thickness of the double magnetic thin films (100 nm versus 500 nm, in the present work), resulting in a different shape anisotropy and hence FMR frequency. A nanogranular Co-Fe-Al-O alloy is used as the magnetic thin film in both layers and SiO_2 as the spacer layer (20 nm thick).

Nanogranular Co-Fe-Al-O thin films were first developed by Ohnuma et al. [4] and, later, by Sohn et al. [5,6]. These films exhibit a high saturation magnetization and a high anisotropy field, combined with large electrical resistivity resulting in excellent high-frequency magnetic properties such as a high FMR frequency and a large real part of permeability (μ_r') [4-6]. It is therefore expected that the present Co-Fe-Al-O thin film is suited for the RF electromagnetic noise attenuation device on a coplanar waveguide (CPW) transmission line.

The CPW transmission line with the characteristic impedance of 50 Ω was designed for a signal line width of 50 μm and a thickness of 3 μm on a 7059 corning glass substrate (15 mm × 4 mm × 1 mm). The S-parameters (S_{11} and S_{21}) were measured with a HP 8720D network analyzer in the frequency range of 0.1 to 20 GHz. Two ground-signal-ground (GSG) pin type wafer probes were in mechanical contact with both ends of the CPW transmission line. The film surface, not the glass substrate, was placed on top of a coplanar waveguide (CPW) transmission line. To increase proximity between the magnetic thin film and the CPW line, proper pressure was intentionally applied.

The frequency dependence of permeability and loss term obtained in a double-layered Co-Fe-Al-O film with a SiO_2 spacer in the as-deposited state is shown in Fig. 1. Both real (μ') and imaginary (μ'') parts up to 600 MHz are almost consistent with the calculations based on the experimental values for saturation magnetization, anisotropy field, electrical resistivity, and film thickness. The calculation was performed on the basis of Landau-Lifshitz-Gilbert equation [7] for spin dynamics and the eddy current inversely proportional to electrical resistivity. And the measured FMR frequencies, 896 MHz and 1.953 GHz, of a double-layered Co-Fe-Al-O film are in good agreement with calculated results. However, the measured results of the real and imaginary parts are in poor agreement with the calculated ones in a high frequency region, over 600 MHz. One reason may be that the calculation neglects the effect of capacitance between Co-Fe-Al-O films separated by an insulating SiO_2 spacer. Fig. 2 shows the frequency dependence of the power losses for a non-integrated coplanar waveguide (CPW) transmission line loaded with the present double layer structure, together with the results for single magnetic layers (an amorphous Co-Zr-Nb film and a nanogranular Co-Pd-Al-O film, 2 μm thick for both films) [1] for comparison. The lateral dimensions (15 mm × 2 mm) are equal to each other. The results show that there is a significant increase of the bandwidth, also of the level of the power losses as compared with that of a Co-Zr-Nb film, when the present double-layered structure is loaded on the CPW transmission line. Considering that the noise absorption is proportional to the power losses, the present device shows much better noise absorption properties including a wider bandwidth.

Fig. 1

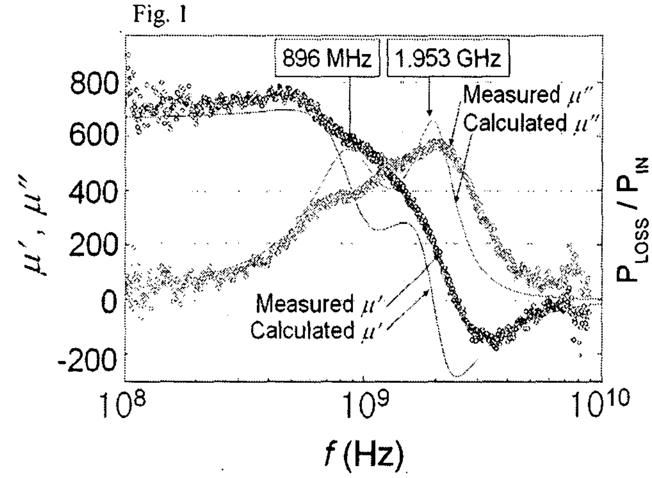

Fig. 2

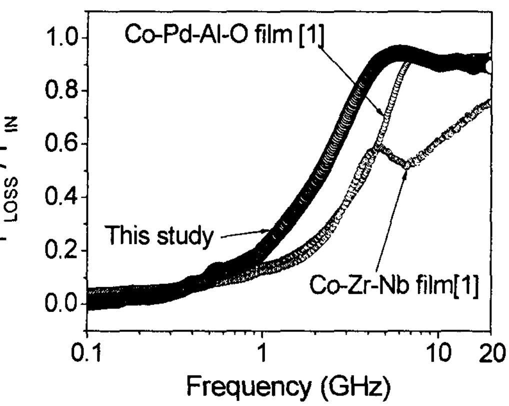

Fig. 1 Measured and calculated frequency characteristics of permeability for a double-layered Co-Fe-Al-O film with a SiO_2 spacer in the as-deposited state. Fig.2 Frequency dependence of the power losses for Co-Fe-Al-O film-loaded CPW line and other magnetic films-loaded CPW lines for comparision.

References

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