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Prototype of noise suppressor without insulating layer using high-resistivity nanogranular CoFeAlO magnetic film on coplanar waveguide (CPW) transmission line

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I. Introduction

The general trend to increase the operation speeds of electronic equipment for improving device performance leads to the growing need to suppress the electromagnetic noise in high- frequency range. Developing countermeasures for suppressing electromagnetic noise in the frequency range of several hundred MHz to several GHz has therefore become an important technical issue. Magnetic materials have become a very important role in suppressing electromagnetic noise; the loss generation of ferromagnetic resonance is used to suppress radiating electromagnetic noise. Recently, CoZrNb and CoPdAlO sputtered magnetic films have come to be used for the integrated countermeasure of electromagnetic noise emission on an RF integrated transmission line [1-3]. And spin sprayed Ni-Zn(-Co) soft ferrite films with high resistivity are also reported to show a good attenuation characteristic against the RF electromagnetic noise on CPW transmission line [4]. Nanogranular CoFeAlO thin films are reported to have a high saturation magnetization ($4\pi M_S$), a high anisotropy field (H_K), and a large resistivity, resulting in excellent high-frequency magnetic properties, such as a high ferromagnetic resonance frequency combined with a large real part of permeability [5-7]. It is therefore expected that this excellent high-frequency soft magnetic properties are well applicable to the RF electromagnetic noise attenuation on CPW transmission line devices. In this study, a non-integrated noise suppressor using a high-resistivity CoFeAlO film on a CPW transmission line is fabricated to evaluate the noise suppression of CoFeAlO films, and the possibility of the films for noise suppressors is discussed.

II. Experiments

CoFeAlO nanogranular thin films with a thickness of 0.1 μm are prepared by radio frequency magnetron sputtering. The films are deposited on Si substrates in a static field of 1 kOe to induce uniaxial magnetic anisotropy. The films show a very large electrical resistivity of 374 μΩcm together with a large H_K of 50 Oe, a hard axis coercivity of 1.25 Oe, and $4\pi M_S$ of 12.9 kG. The real part of the relative permeability is 260 at low frequencies and this value is maintained up to 1.3 GHz. The ferromagnetic resonance frequency is 2.24 GHz combined with a large real part of permeability of 260. The film is loaded on a CPW transmission line: the surface of the film is placed to touch directly on the CPW transmission line without pressure on the film. The dimensions of the film are 4 mm (l) × 4 mm (w) × 0.1 μm (t). The CPW transmission line (5 mm × 50 μm × 3 μm for the signal line and 5 mm × 165 μm × 3 μm for the ground lines) with characteristic impedance of 50 Ω at the both ends to the network analyzer (HP 8720D) is used to extract scattering parameters (S_{11} and S_{21}) and evaluate noise suppression effects.

III. Results and discussion

Fig. 1 shows transmitted scattering parameter and power loss of non-integrated CPW transmission line loaded with CoFeAlO film. In Fig. 1(a), the insertion loss is very low (less than 0.3 dB) and this value is maintained over 2 GHz. And the large attenuation peak is observed at about 3.4 GHz which is probably due to ferromagnetic resonance loss of the CoFeAlO magnetic film on CPW transmission line. The degree of noise suppression is about 3dB up to 20 GHz. In Fig. 1(b), the large loss peak is observed at about 3.4 GHz which is identical with that of the peak appearing in Fig. 1(a). It is therefore concluded that the major loss generation results from the ferromagnetic resonance of the covering CoFeAlO film. This ferromagnetic resonance frequency is much higher than 2.24 GHz which is measured by a permeameter. This disagreement results from the exchange force. The r.f. field from the CPW transmission line accesses only to small area of the magnetic film (~ 100 μm wide) in spite of the total width of the magnetic film (4 mm), causing the exchange force between the signal line area and the both sides of the signal line area of the film. So, the exchange force is added to the intrinsic anisotropy induced during the film deposition, making the effective anisotropy field very high and then shifting the pass band of CPW transmission line to a very high frequency range. The attenuation obtained in Fig. 1(a) is not enough for application to noise suppressors. However, as considering the very large volume of other magnetic films [1~4] used for non-integrated noise suppressors on CPW transmission line, the value of 3 dB is absolutely not so low. And no pressure is applied onto the covering film when measuring scattering parameters. It implies that the nanogranular CoFeAlO films with high resistivity is well applicable to a RF noise suppressor using a direct contact method between the magnetic film and CPW transmission line. The degrees of noise suppression and power loss can be much improved by integrating the large volume of CoFeAlO film on the CPW transmission line.

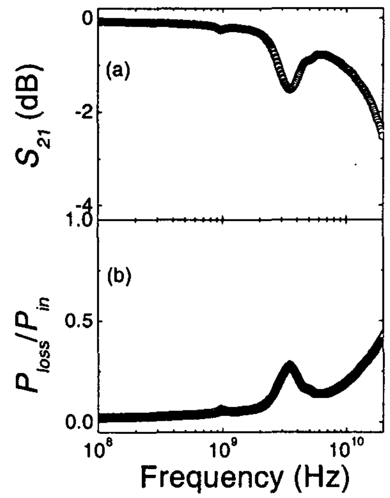

Fig. 1 (a) S_{21} and (b) power loss of CPW transmission line loaded with CoFeAlO film

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