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RF Integrated Noise Filters using Nano-granualr Co-Fe-Al-O Soft Magnetic Thin Films on Coplanar Transmission Line

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Abstract

The present work aims to elucidate the possibility of the integrated countermeasure of radio-frequency (RF) electromagnetic noise emission on an RF integrated coplanar waveguide transmission line by using loss generation of both nano-granular soft ferromagnetic thin films and dielectric thin films. In order to achieve the aim, RF integrated noise filters incorporated with magnetic and dielectric thin films were fabricated and characterized over a very high frequency range up to 20 GHz. The exact filtering mechanism was investigated by computer simulation.

Co-Fe-Al-O nano-granular thin films are fabricated by RF-magnetron sputtering under an $Ar+O_2$ atmosphere. High resolution transmission electron microscopy reveals that the Co-Fe-Al-O films are composed of bcc (Co,Fe) nano-grains finer than 5 nm and an Al-O amorphous phase. The composition of the optimized film is $Co_{41}Fe_{38}Al_{13}O_8$ and its properties are: 374 μΩcm a uniaxial anisotropy field of 50 Oe, a hard axis coercivity of 1.25 Oe, and a saturation magnetization 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. The effects of the various parameters such as saturation magnetization, anisotropy field, film thickness and resistivity of soft magnetic thin films on the permeability spectra are investigated by using the Landau-Lifshitz-Gilbert equation. Both effects of eddy current loss and ferromagnetic resonance loss on the intrinsic permeability are taken into account to obtain the expression for the effective relative permeability. The calculated permeability spectra are in good agreement with experimental results for nano-granular Co-Fe-Al-O thin films, even though only one fitting

parameter, the damping constant, is used. The present Co-Fe-Al-O nano-granular thin films with a high electrical resistivity and high resonance frequency are considered to be suitable for GHz device applications.

The RF integrated noise filters are fabricated by photolithography. Two different substrates are used: a glass substrate and a Si-substrate with 2.5-μm-thick SiO_2 layer on top of it. The stack for the noise filters consists of the magnetic film ($Co_{41}Fe_{38}Al_{13}O_8$) / SiO_2 / Cu transmission line / seed layer (Cu/Ti) / substrate. The signal attenuation on the transmission line is estimated by the S-parameters (S_{11}, S_{21}) up to 20 GHz. Good signal attenuation characteristics are observed in the present filters. In case of the 2000-μm-wide, 15-mm-long, and 1-μm-thick magnetic film together with 0.1-μm-thick SiO_2 insulator layer, the magnitude of the signal attenuation at the L-C resonant point (the dip) is greater by about -55 dB than that of the coplanar transmission without the magnetic film By decreasing the width of the magnetic film from 2000 to 200 μm, the magnitude of the signal attenuation remains nearly unchanged. For the noise filters fabricated on Si-substrate, of which the magnetic film's dimensions are 2000-μm-wide, 15-mm-long, and 1-μm-thick with 0.1-μm-thick SiO_2 insulator layer between the magnetic film and the Si-substrate, the magnitude of the signal attenuation reaches around -80 dB. This value is very large as compared with that of the noise filter fabricated on the glass substrate and implies a very positive possibility for application to the MMIC noise filter based on the Si-substrate.