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Study of Permeability and Electrical Resistivity in Spin Sprayed CoZn Ferrite Films

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NiZn ferrite films prepared from an aqueous solution by spin spray ferrite plating exhibit high permeability, exceeding the Snoek's limit for bulk NiZn ferrites by one order of magnitude. Using the plated NiZn ferrite films, we have developed conducted noise suppressors operated in GHz range[1]. By varying concentration of Zn in the films, operating frequencies of the suppressors were changed in hundreds MHz range[2]. In this study we investigated permeability and resistivity of spin sprayed CoZn ferrite films. The CoZn ferrite films are expected to have higher f_r (natural resonance frequency) than the NiZn ferrite films due to strong magnetic anisotropy field induced by the anisotropic Co^{2+} ions. Thus by using the CoZn ferrite films we may be able to fabricate noise suppressors operated at higher frequencies.

We prepared films with compositions $Co_xFe_{3-x}O_4$ (x = 0-0.31) and $Co_{0.11}Zn_yFe_{2.89-y}O_4$ (y = 0-0.67) onto polyimide substrates kept at 90 °C. We plated for 100 min to obtain the films to the thickness of 3-4 μm.

All the obtained films were of single phase with the spinel structure. Films falling in the composition ranges of $Co_xFe_{3-x}O_4$ (x = 0-0.07) had (100) texture, which turned to (111) texture outside the composition ranges. Because only the $Co_{0.11}Zn_yFe_{2.89-y}O_4$ ($y \geq 0.31$) films had resistivity higher than 50 Ω cm (a rough measure of lower limit required for high frequency device applications), we show in Fig. 1 permeability data only for the films with $\rho > 50\ \Omega$ cm.

The films with y = 0.31 and 0.67 had narrow peaks of imaginary permeability μ'' at 2 and 1 GHz, respectively. Therefore, using the CoZn ferrite films we will be able to fablicate noise suppressors exhibiting noise suppression effect at higher frequencies than those using the NiZn ferrite films that have μ'' peaks at several hundreds MHz[2].

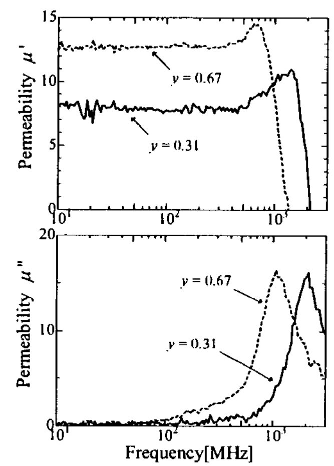

Fig. 1. Permeability for $Co_{0.11}Zn_yFe_{2.89-y}O_4$ films.

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GC05

Recent Progress in Ferromagnetic Semiconductor Heterostructures

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We review the recent progress in the study of ferromagnetic semiconductor heterostructures, mainly with focus on GaMnAs based thin films and heterostructures.

III-V-based ferromagnetic-semiconductor (FMS) $Ga_{1-x}Mn_xAs$ is a good model system for future semiconductor-spintronics devices. It is important to increase the Curie temperature (T_C) of GaMnAs (the current record is 173 K in alloy films). The mean field theory predicts that T_C of GaMnAs increases in proportion to its Mn concentration x. However, it is difficult to grow GaMnAs with x > 10%, because MnAs clusters and Mn interstitial defects are easily formed in such a high x region. Here, we have successfully grown GaMnAs films with x of 12-21% by decreasing the growth temperature to 150-200°C and by reducing the film thickness to 10 nm. The magnetic circular dichroism and the anomalous Hall effect measurements indicated that these GaMnAs films have the intrinsic FMS features. A high TC value of over 170 K was obtained when x = 12-15% [1].

Ferromagnetic-semiconductor quantum heterostructures are expected to realize novel functions by combining the resonant tunneling effect and the tunneling magnetoresistance (TMR). However, there are no reports on the clear observation of the resonant tunneling effect and TMR associated with it. We fabricated the GaMnAs quantum-well (QW) double-barrier heterostructures composed of GaMnAs(20 nm)/AlGaAs(4 nm)/GaMnAs(d nm)/AlAs(4 nm)/GaAs:Be with the quantum well thicknesses d from 3.8 nm to 20 nm on p-GaAs (001) substrates using molecular-beam epitaxy (MBE). The dI/dV-V characteristics and bias dependence of TMR measured at 2.6 K clearly show oscillatory behaviors in the negative bias region where holes are injected from the GaAs:Be layer to the GaMnAs QW. With increasing d, the peaks of these oscillations shift to smaller voltages and the period becomes short, which indicates that they are induced by the resonant tunneling effect [2].

Thus far, only two-terminal devices have mainly been studied. Meanwhile, GaMnAs-based 'three-terminal' devices have potential to add novel functions to integrated circuits. We have investigated the spin-dependent transport properties of GaMnAs-based three-terminal semiconductor spin hot-carrier transistor (SSHCT) structures. The emitter-base bias voltage VEB dependence of the collector current I_C, emitter current I_E, and base current I_B shows that the current transfer ratio α (= I_C / I_E) and the current gain β (= I_C / I_B) are 0.8-0.95 and 1-10, respectively, which means that GaMnAs-based SSHCTs have current amplification capability. In addition, we observed an oscillatory behavior of the tunneling magnetoresistance ratio with the increasing bias, which can be explained by the resonant tunneling effect in the GaMnAs quantum well [3].

If time permits, the developments and possible applications of group-IV FMSs will be presented in the conference [4-6].

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