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ABSTRACTS

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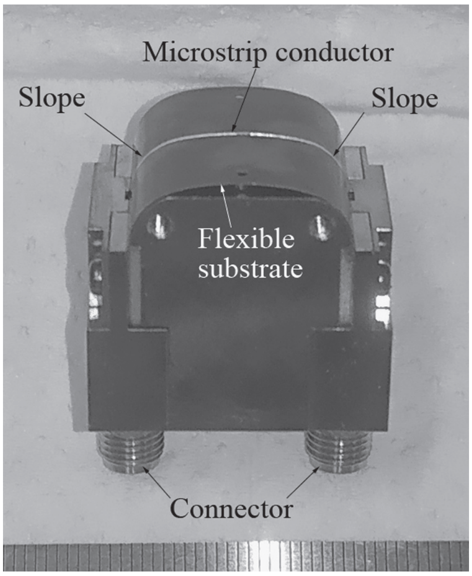

Fig. 1 Photograph of the probe.

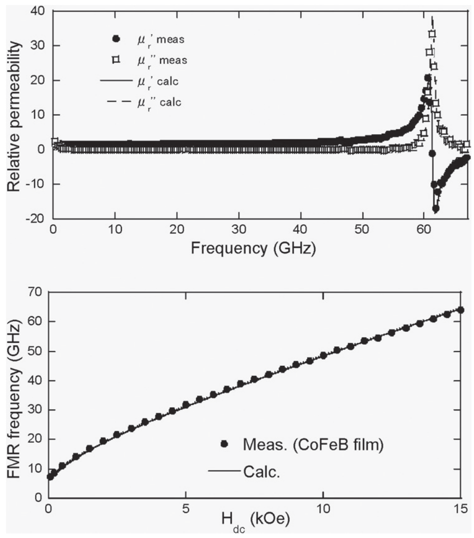

Fig. 2 (a) Relative permeability of CoFeB film (45 mm × 25 mm, 0.5 µm thick), (b) ferromagnetic resonance frequency as a function of dc field.

EV-17. Development of a spintronic vision system based on spin-torque diodes and its optimization for autonomous driving tasks. *G.D. Demin*[1,2], A. Buzdakov[2], N.A. Djuzhev[1], V.A. Bespalov[1] and K.A. Zvezdin[2] *1. R&D Center "MEMSEC", National Research University of Electronic Technology (MIET), Moscow, Russian Federation; 2. Laboratory of Physics of Magnetic Heterostructures and Spintronics for Energy-Efficient Information Technologies, Moscow Institute of Physics and Technology (MIPT), Dolgoprudny, Russian Federation*

Nowadays, development and searching for new solutions to the implementation of machine vision systems in vehicle control draw the attention of the scientific world. One of the crucial tasks is to ensure high accuracy in detecting road obstacles in the near vehicle zone in adverse conditions, such as bad weather, traffic overload, and poor lighting. One of the promising technologies capable of satisfying these requirements is the machine vision technology based on spin-torque diodes [1, 2]. A spin-torque diode is a magnetic tunnel junction, which demonstrates the effect of voltage rectification when microwave current flows through it. Spin-torque diodes have a sensitivity that substantially exceeds the sensitivity of semiconductor Schottky diodes [3]. Recently, it was shown that it is also possible to detect hidden objects located outside the line of sight by a microwave holography technique using spin-torque diode system [4]. Here we present a proposed spintronic machine vision system with a method of recording the amplitude of a reflected signal in the time domain by the array of spin-diode based microwave detectors. An experimental demonstration of this system was carried out using the setup consisting of the double-ridge horn antenna for transmission, several antipodal Vivaldi antenna elements for reception and a spin-diode based signal processing circuit (Fig. 1). Based on the experimental setup, we developed a finite-element model of microwave object detection system using an array of spin-torque diodes (CoFeB/MgO/CoFeB), the SPICE model of which was built by us earlier [5]. During the simulation, a frequency shift of the reflected signal on a spin-torque diode was detected when the object changed its position. The results show the effectiveness of using spintronic technologies to perform the tasks of near-field and far-field sensing of objects and can be used to improve the characteristics of the developed spintronic vision system for autonomous driving platforms. The work was performed using the equipment of R&D Center "MEMSEC" (MIET) and supported by the RF President Grant (No. 075-15-2019-1139).

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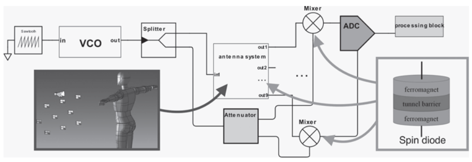

Figure 1. Circuit schematics of the spintronic machine vision system based on spin-torque diodes.

EV-18. Magnetoelectric control of the microwave sensitivity of a spin-torque diode based on the magnetic tunnel junction with a ferromagnetic/ferroelectric bilayer by short THz electromagnetic pulse. *G.D. Demin*[1,2], A.V. Popov[1] and N.A. Djuzhev[1] *1. R&D Center "MEMSEC", National Research University of Electronic Technology (MIET), Moscow, Russian Federation; 2. Laboratory of Physics of Magnetic Heterostructures and spintronics for energy-efficient information technologies, Moscow Institute of Physics and Technology (State University), Dolgoprudny, Russian Federation*

Over the past decade, significant progress has been made in the development of spintronic microwave detectors based on spin-torque diode effect in magnetic tunnel junctions (MTJs), which demonstrate a microwave sensitivity of the resonant type up to 200 kV/W and higher [1]. This effect is due to the voltage rectification in MTJ as a result of microwave modulation of its resistance by input microwave current. However, to obtain such high sensitivity of spin-torque diodes, the presence of additional dc bias current (about 0.1-0.3 mA) is still necessary, which reduces the energy efficiency of such devices. In this regard, today an important task is to find alternative ways to control the sensitivity of spin-torque diodes in the absence of a bias current, which is associated with the consideration of new mechanisms providing low-energy manipulation of magnetization [2-4]. The ultrafast polarization switching of a ferroelectric layer by a short THz electromagnetic pulse seems very promising to solve this issue [5]. This phenomenon makes it possible to effectively control the magnetization state of the ferromagnet/ferroelectric bilayer as a part of MTJ via magnetoelectric coupling (Fig. 1). Moreover, the Joule heating of the MTJ with a microwave current may provide an additional increase in the microwave sensitivity [6]. We consider this concept as applied to tune the sensitivity in spintronic microwave detectors in the absence of a bias current. The dynamics of ferroelectric domains in the MTJ ferroelectric layer under the action of THz electromagnetic pulse was studied, and a numerical analysis of the diode sensitivity as a function of the ferroelectric polarization state was carried out. The results obtained can be used in the development of low-power spin-torque diodes operating on a new magnetoelectric detection principle. The work was performed using the equipment of MIET Core Facilities Center "MEMSEC" and supported by the RF President Grant (No. 075-15-2019-1139).

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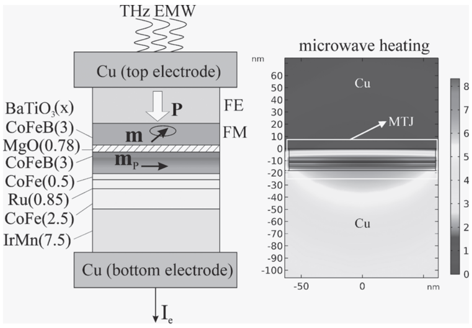

Figure 1. Sketch of the magnetoelectric control of the spin-torque diode based on MTJ with a ferromagnetic/ferroelectric bilayer by THz electromagnetic wave (EMW) irradiation and the temperature increment of MTJ due to its microwave heating (in mK).

EV-19. Theoretical Study on Lowering Loss of Skin Effect Suppressed Multi-layer Transmission Line with Positive/Negative (Cu/NiFe) Permeability Materials for High Data-Rate and Low Delay-Time I/O Interface Board. H. Nakayama[1], *Y. Aizawa*[2], K. Kubomura[2], R. Nakamura[1] and H. Tanaka[1] *1. Department of Electronics and Control Engineering, National Institute of Technology (KOSEN), Nagano College, Nagano, Japan; 2. Advanced Course of Production and Environment System, National Institute of Technology (KOSEN), Nagano College, Nagano, Japan*

INTRODUCTION - This paper proposes a new application of skin effect suppression technology [1]-[4] for long wiring on high-speed & low-delay I/O board. This proposal will overcome the difficulty of further reducing the transmission losses on the I/O board with >50 Gbps data rate. In previous research [5], it was demonstrated that suppression of the skin effect by electroplated conductor/magnetic multilayer, and estimated that the degree of transmission loss decrease at 16 GHz would be 5 %. A major challenge in this paper is to propose an electromagnetic field calculation theory for rectangular multilayer transmission line, verify it under the same conditions, clarify a lower loss structure by changing thickness of each layer. Also it is expanded to low loss design technology. *VERIFICATION* - Cu and NiFe were selected as metal conductor material and negative permeability magnetic material, respectively. The Cu and NiFe films are alternately stacked to form the multilayer, as shown in Fig. 1. The top and bottom surface layers are Cu layers. An electromagnetic field distribution, which considers of the skin effect in a rectangular multilayer transmission line, is derived based on Maxwell's equation. The current density of each layer and the total loss can be obtained by the equations (1) and (2) in Fig. 1. The loss suppression was compared under the following conditions. 1) Total number of layers is 33 and total thickness is 12.67 μm by a constant ratio, Cu t_N = 0.51 μm and NiFe t_F = 0.25 μm. 2) Optimal stacking determined by changing the thickness of each layer. *RESULTS AND DISCUSSION* - Fig. 2 shows the current density of multilayer transmission line. Compared to conventional thickness by a constant ratio, it was estimated that the loss is 90% in optimal thickness we proposed. By offsetting the phase change of current density, a lower loss structure could be determined. Compared with Cu conductor, the graph shows that the top and bottom surface current densities become low, and depth center current density becomes slightly high for the multilayer, showing the skin effect is suppressed.

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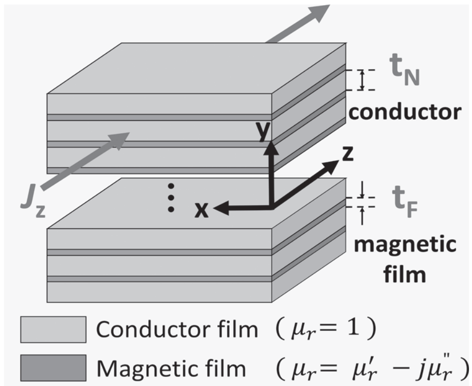

$$J_{zn}(y) = \sigma_n(A_n e^{+k_n y} + B_n e^{-k_n y}) \quad (1)$$

$$Loss_n = \int_{y_{n-1}}^{y_n} \frac{|J_{zn}(y)|}{\sigma_n} dy + \int_{y_{n-1}}^{y_n} \frac{1}{2}\omega\mu''_{rn} H_n(y) dy \quad (2)$$

Fig. 1. Structure of conductor/magnetic film multilayer.

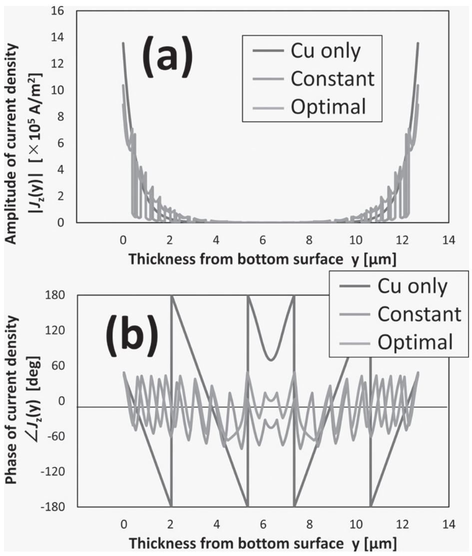

Fig. 2. Calculation result; (a) Current density (b) Current density phase.