THERMOELECTRIC VOLTAGE RECTIFICATION IN A SPIN-TORQUE DIODE AND ITS PROSPECTS FOR MICROWAVE APPLICATIONS

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The tunnel magneto-Seebeck effect and an initiation of heat-driven spin-transfer torque in magnetic tunnel junctions (MTJs) have recently attracted great attention of researchers in the field of spin caloritronics [1,2]. In addition, these phenomena are important for the study of alternative mechanisms of spin transfer in magnetic heterostructures, which can also serve to improve the technical capabilities of the developed magnetoresistive memory elements and temperature-sensitive microwave devices [3]. The spin-torque diode effect in MTJ is the effect of rectifying voltage due to microwave modulation of its resistance induced by input microwave current, when a non-stationary spin torque is transferred from one magnetic layer (spin polarizer) to another (free layer). Such a spin-torque diode can exhibit a very high microwave sensitivity of the resonant type [4]. On the other hand, inhomogeneous heating of the spin-torque diode occurs under its microwave irradiation, which is associated with a temperature drop across the tunnel barrier of MTJ. Due to the presence of tunnel magneto-Seebeck effect and heat-driven spin-transfer torques, the thermoelectric voltage rectification in MTJ occurs at a given microwave power, which can make an additional contribution to the microwave sensitivity of a spin-torque diode (Fig. 1).

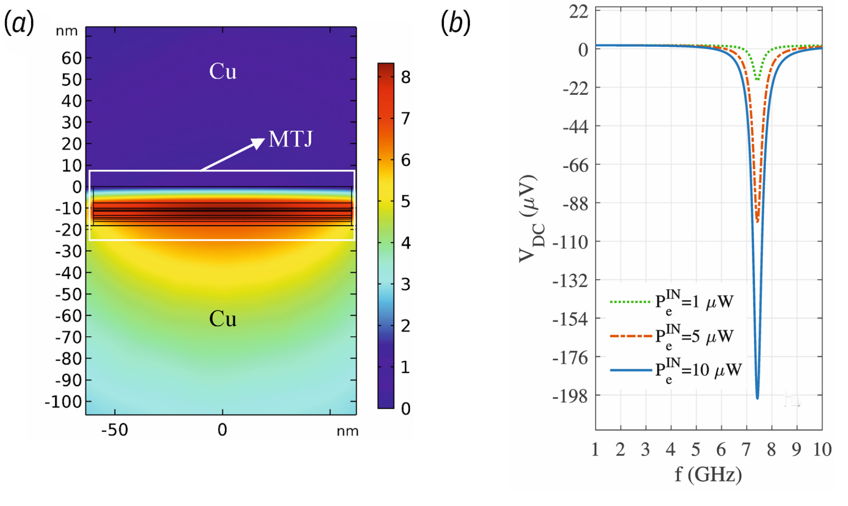

Figure 1. (*a*) — The temperature increment $T - T_0$ (in mK) of MTJ generated by its microwave irradiation with the input microwave power of 1 μW, where $T_0 = 20$ K. (*b*) — Frequency dependence of the amplitude of rectified signal generated across the simple tri-layer MTJ caused by microwave heating of the spin-torque diode, calculated for the considered MTJ structure, when the input power is varied from 1 to 10 μW and the magnetic field is about 50 mT

It is worth noting that the magnon transfer of spin flux in MTJ with the insulating ferrite caused by its microwave heating can lead to a significant increase in microwave sensitivity of spin-torque diode, which is associated with a predictable amplification of thermomagnonic spin-transfer torque in such structures compared to conventional MTJs [5] and has not been analyzed before. Another way to enhance the thermoelectric effect in a spin-torque diode is to use thermal barriers (BiTe, GeSbTe) on both sides of a thin dielectric layer of MTJ, which can increase the heat-induced spin current for a given microwave power [6].

Earlier, we carried out our first theoretical estimates of the thermoelectric contribution to the sensitivity of a spin-torque diode based on tri-layer MTJ related to the thermal transfer of spin angular momentum in the MTJ under its non-uniform heating by microwave current [7]. In this work, we obtained temperature profiles of different types of MTJ (tri-layer MTJ, MTJ with the insulating ferrite, MTJ with the thermal barriers) under its microwave irradiation (Fig. 1a), on the basis of which microscopic calculations of the spin-dependent Seebeck coefficients, heat-driven spin-transfer torques in combination with calculations of the microwave sensitivity were performed. As a result, issues of increasing sensitivity of a spin-torque diode by heat-driven spin-transfer torque in a magnetic heterostructure and the possibility of using such structures as a bolometer for microwave visualization of objects are also discussed.

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