Static and dynamic spin-torque-diode sensitivity induced by the thermoelectric charge and spin currents in magnetic tunnel junctions

G.D. Demin[1,2], A.F. Popkov[1,2]

1. Moscow Institute of Physics and Technology (State University), Dolgoprudny, Russia, demin.gd@phystech.edu

2. National Research University of Electronic Technology (MIET), Moscow, Russia, gddemin@edu.miet.ru

The search for new applications of spin caloritronics, which determines the relationship between charge, spin and heat currents in the presence of temperature gradient across the tunnel barrier in magnetic tunnel junctions (MTJ), is still of particular interest to researchers [1, 2]. An intersection of this field and the rectification effect of an alternating current, which generates the rectified direct-current (DC) voltage in MTJ-based spin-torque diode [3], can open an original method for the thermal control of the spin-torque-diode sensitivity, caused by the inhomogeneous heating of MTJ during its microwave irradiation (Fig. 1). In the static regime, this contribution to the spin-torque sensitivity can be related to the tunnel magneto-Seebeck effect in MTJ, while in the dynamic regime the sensitivity additive shift is determined by the magnetodynamic response of the free layer of MTJ to the thermal spin-transfer torques due to the non-zero temperature gradient across the tunnel barrier [4].

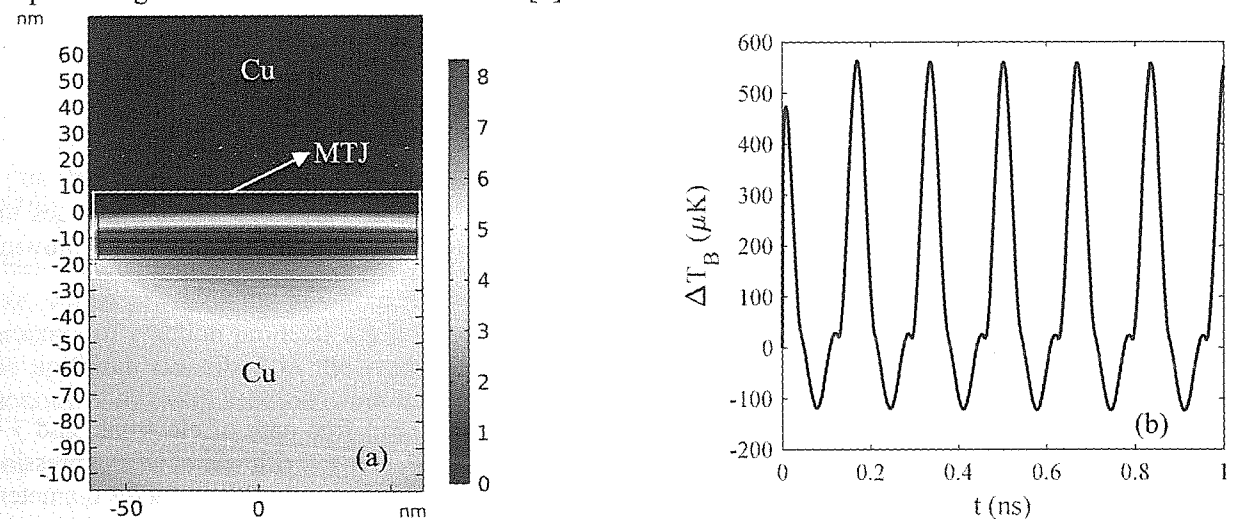

Fig. 1. (a) The temperature increment $T-T_0$ (in mK) of MTJ generated by the input microwave power of 1 μW, where $T_0 = 20$ K is the room temperature. (b) Time dependence of the temperature drop on both sides of the tunnel barrier of MTJ, induced by the input microwave power of 1 μW at the current frequency of 6 GHz.

Based on the quantum-mechanical transport calculations of the charge and spin fluxes associated with the inhomogeneous thermal heating of three-dimensional structure of MTJ by the input RF microwave power, finite-element analysis of the thermal contribution to the spin-torque sensitivity of MTJ was carried out in the case of nonzero bias current. Within the magnon-induced spin-transfer torque model suggested by J. Slonczewski in [5], the amplification of DC rectifying voltage in the spin-torque diode initiated by the spin pumping to the tunnel barrier from magnons was also estimated. The results obtained can be used for the development of new types of microwave detectors based on spin thermoelectric effects in MTJ. The work was supported by the Russian Science Foundation (project № 16-19-00181).

1. G.E.W. Bauer, E. Saitoh, and B.J. van Wees. "Spin caloritronics". Nat. Mater., **11**, pp. 391-399, 2012.

2. H. Yu, S.D. Brechet, and J.-P. Ansermet. "Spin caloritronics, origin and outlook". Phys. Lett. A, **381**(9), pp. 825-837, 2017.

3. A.A. Khudorozhkov, P.N. Skirdkov, K.A. Zvezdin, P.M. Vetoshko, and A.F. Popkov. "Spin-torque diode frequency tuning via soft exchange pinning of both magnetic layers". Phys. Rev. B, **96**, p. 214410, 2017.

4. M. Wilczyński. "Thermopower, figure of merit and spin-transfer torque induced by the temperature gradient in planar tunnel junctions". J. Phys.: Condens. Matter, **23**, p. 456001, 2011.

5. J.C. Slonczewski. "Initiation of spin-transfer torque by thermal transport from magnons". Phys. Rev. B **82**, p. 054403, 2010.