Ultra high sensitivity induced by the injection locking in spin-transfer torque diode.

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Microwave detectors based on the spin-torque diode effect are among the key emerging spintronic devices. It has been already demonstrated that they have the potential to overcome the theoretical performance limits of their semiconductor (Schottky) counterparts at room temperature [1] and zero bias field [2]. These two proprieties are necessary for practical implementations of spin-diode microwave detectors. Here, we will discuss are recent results on nanoscale magnetic tunnel junction microwave detectors, exhibiting high-detection sensitivity at room temperature without any external bias fields, and for low-input power (micro-Watts or lower). There are several non-linear mechanisms that can drive an increase of sensitivity in biased spin-transfer torque diode. In details, two previous experiments demonstrated that the detection voltage can be enhanced due to non-adiabatic stochastic resonance [3] or nonlinear FMR [1]. The use of the former mechanism needs a control of both temperature and external field together to the bias current, while the latter achieved at room temperature needs a bias field (>100mT) along a tilted out- of-plane direction. On the other hand, we have observed a third mechanism, i.e. the injection locking able to drive giant sensitivity. This result has been achieved by a proper design of the magnetic tunnel junctions with the following properties: (i) a perpendicularly magnetized free layer with an in-plane polarizer, which allows for the excitation of a microwave signal in absence of the external magnetic fields [4], (ii) an MgO-based MTJ material stack exhibiting high -tunnel magnetoresistance (TMR) (around 90% in our case), and (iii) the injection-locking mechanism due to the simultaneous application of bias and microwave currents.

Our results show the possibility to achieve a sensitivity significantly larger than both state-of-the-art Schottky diode detectors and existing spintronic diodes reaching more than 150.000V/W (in optimized devices) for input power of the order of tens of nanowatts with an output resistance <5kOhm. In addition, the same device can be designed to have a broadband signal detection answer, which is essential for energy harvesting from ambient RF and microwave energy sources.

These mechanisms that will be discussed in detail in the presentation may provide a pathway to enable further performance improvement of spin-torque diode microwave detectors.

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