Spin-dependent diode performance in fully epitaxial magnetic tunnel junctions with bilayer tunnel barrier

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Metal/insulator/metal (MIM) and metal/insulator/insulator/metal (MIIM) tunnel diodes have great potential for high-frequency rectifier systems, such as for THz/infrared detectors and radio-frequency energy harvesting applications [1,2]. Amorphous or polycrystalline tunnel barriers have often been used in both MIM and MIIM diodes, and a single-crystalline tunnel barrier has never been used despite its high potential for tunnel-device applications. Here, we report on the spin-dependent diode properties of fully epitaxial Fe/ZnO/MgO/Fe(001) magnetic tunnel junctions (MTJs) Note that, for these MTJs, the operation principle of the rectifying process does not come from a spin-torque diode effect [3] but from intrinsic nonlinear and/or asymmetric current-voltage (*I*-*V*) characteristics.

MTJ films were prepared by molecular beam epitaxy. The structure of the MTJ was Au (5 nm) / Co (10 nm) / Fe (5 nm) / ZnO (1.2 nm) / MgO (1 nm) / Fe (30 nm)/MgO(001) substrates. Crystallographic studies, such as RHEED and TEM observations, revealed that the ZnO tunnel barriers are single-crystalline with a rock-salt crystal structure. Magnetoresistance ratios up to 96% (127%) were observed at RT (20 K).

We found that the MTJs exhibited notable asymmetric *I-V* characteristics due to the bilayer tunnel barrier, and those diode properties strongly depended on the magnetization alignment of the Fe electrodes. The current responsibilities of the MTJs were largely enhanced at the anti-parallel alignment (2 ~ 3 A/W at RT) and almost comparable to those of high-performance MIIM diodes with dissimilar electrodes [4] as well as to a state-of-the-art spin-torque diode [2,5]. We demonstrated that a zero-bias anomaly in the tunnel conductance, which originates from the magnon excitations at the Fe/barrier interfaces, plays a crucial role in observed spin-dependent diode performance.

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Reference

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