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.

This work was supported by the Grant-in-Aid for Scientific Research on Innovative Area, “Nano
Spin Conversion Science” (Grant No. 26103003).

Reference