The reduction of critical switching current density for tungsten-based spin-orbit torque devices

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Spin-orbit torque (SOT)-magnetic random access memory (MRAM) attracts broad interest because of its notable features, including high endurance and fast switching speed. These advantages arise from the separation of read/write current paths and the reduction of incubation time. However, the widespread adoption of SOT-MRAM is hampered by the high-power dissipation issue due to high SOT critical switching current density (JSW). In this abstract, we then focused on the experimental methods to reduce the JSW. There are several reasons may affect the JSW. One of the reasons is due to the lower charge-to-spin conversion efficiency (?DL) which is related to the spin Hall effect (SHE) of the heavy metal (HM) layer and/or the Rashba effect at the interface of HM/Ferromagnetic material (FM) heterostructure. We propose two methods to enhance the ?DL to the tungsten-based SOT material. First of all, we demonstrated relatively high ?DL up to -0.44 in the 5nm-thick [W/WN]n multilayer system (n represents the number of multiple layers), which is almost 60% larger than that of the ? phase tungsten (?DL = -0.28) we prepared. This enhancement of ?DL is attributed to the increased portion of the amorphous structure in the [W/WN]n, leading to the enhanced scattering effect in the multilayer system. Secondly, we modified the interface in between the W (3.5 nm)/CoFeB heterostructure by inserting an ultrathin MgO layer. Experimental results show high |?DL| up to 0.58 by introducing a 0.22-nm-thick MgO interlayer. The enhancement can be explained by the increased Rashba effect because of the band structure splitting with MgO exited on top of the tungsten. As a result, the JSW in the corresponding MTJs was also reduced by nearly 48% under 1-ns-width pulse tests. Another contributing factor to the larger JSW is linked to the saturation magnetization (MS) of the free layer. We purposely re-engineered the free layer to adjust the MS of the free layer with the doping method, the Ic can be lowered down to 30% of that of POR without sacrificing the tunneling magnetoresistance (TMR) ratios. The promising results offer potential solutions to address the high-power dissipation issue for the tungsten-based SOT-MTJs.

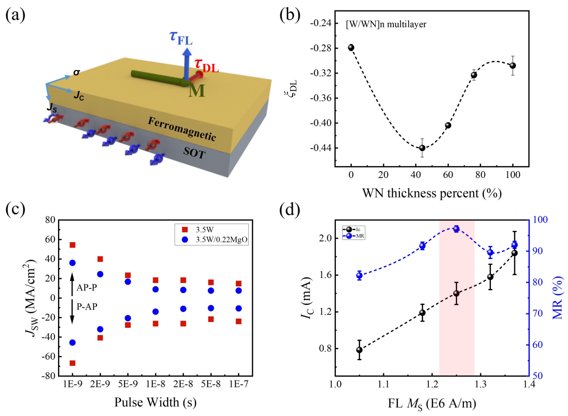

Figure 1. (a) Schematic diagram of current-induced magnetization switching by SOT. (b) The charge-to-spin conversion efficiency as a function of WN thickness percentage in [W/WN]n multilayer. (c) The extracted Jsw as a function of the pulse widths for both P-to-AP and AP-to-P switching directions. (d) The Ic and MR as a function of Ms of the free layer with the doping method.

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