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Spin torque, tunnel-current spin polarization and magnetoresistance in MgO magnetic tunnel junctions

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The ability of electron currents to transfer spin angular momentum, as well as charge, from one ferromagnetic electrode to another, and hence to exert a significant spin-torque on the electrodes, provides a powerful new tool for the study of spin transport in electronic structures, in addition to establishing new opportunities for future applications. The closely related issue of spin-dependent electron transport in magnetic tunnel junctions (MTJs) is of wide-spread interest, both fundamentally and because the importance this phenomena has for information storage. A critical aspect of MTJs is the bias dependence of the tunnel magnetoresistance (TMR), which in general, decreases as the voltage bias (V) increases. Currently, there is no consensus as to a microscopic model that accounts for this behavior. In this study, we employ the spin torque response of MTJs with ultra-thin MgO tunnel barrier layers to investigate the relationship between spin transfer and TMR under finite bias, and find that the spin torque per unit current exerted on the free layer decreases by $< 10\%$ over a bias range where the TMR decreases by $> 40\%$. This behavior is inconsistent with a decrease in the tunnel polarization factors calculated with the Julliere formula extended to finite bias, and as predicted by free-electron tunneling models, or by surface-magnon emission models that substantially decrease the surface magnetization with increasing bias. We find, however, that magnetic-state-dependent tunneling decay lengths (effective masses) as theoretically predicted for MgO tunnel barriers, are consistent with our results. Since these results also have significant implications for spin-torque driven magnetic random access memory, we will consider these effects in addition to our work with MTJs having two polarizing magnetic layers in order to boost spin-torque as well as allow us to determine the extent of the considerable self-heating for MTJs under bias.