Gap state charge induced spin-dependent negative differential resistance in junctions

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Abstract:

Negative differential resistance (NDR) is an important nonlinear electronic property necessary for electronic power amplification, oscillators, and circuit switches. We propose and demonstrate through first-principles calculation a new spin-dependent NDR mechanism in magnetic tunnel junctions (MTJ) with cubic cation disordered crystals (CCDC) AlO_x or $Mg_{1-x}Al_xO$ as barrier materials. The CCDC is a class of insulators whose band gap can be changed by cation doping. The gap becomes arched in an ultrathin layer due to the space charge formed from metal-induced gap states. A generalized Simmons formula for tunneling current through junction with an arched gap is derived, which shows NDR. This mechanism is applicable to 2D and 3D ultrathin junctions with a sufficiently small band gap that forms a large space charge. It also provides a new way of controlling the spin-dependent transportation in spintronic devices by an electric field.