Electric field and strain control of magnetism: Towards ultralow energy memory devices

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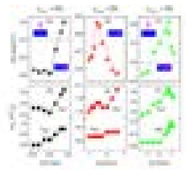
Voltage-controlled magnetic anisotropy (VCMA) plays a central role in the operation of the next-generation of ultralow energy, non-volatile, magneto-electric random access memory (MeRAM). The major challenge in the development of the next-generation MeRAM is the low (< 100 fJ/(Vm)) magnetoelectric (ME) coefficient which in turn leads to high switching bit energy and high write voltage. Employing *ab initio* electronic structure calculations we demonstrate for the first time that epitaxial strain, which is ubiquitous in many heavy metal (HM)/ferromagnet (FM)/insultor trilayers, has a dramatic effect on VCMA of the HM/FeCo/MgO heterostructures (HM=Ta, Au, Hf). Strain can give rise to a wide range of novel VCMA behavior shown below where the magnetic anisotropy can change from V- to a Λ-shape E-field dependence with giant ME coefficients which are asymmetric under voltage reversal. By tuning the epitaxial strain the ME coefficient can reach values as large as ~1800 fJ/(V.m) which in turn lead to magnetic switching in the low-E-field regime. The underlying mechanism is the interplay between the modification of the MgO dielectric constant by strain and the changes of the spin-orbit coupled d-states at the interfaces due to the synergetic effect of strain and electric field. I will also present results of manipulation of the magnetization direction of ultrathin FeRh/insulator bilayers in the antiferromagtic or ferromagnetic phase by purely E-field means (rather than E-field induced strain). I will show an E-field magnetization switching with giant voltage controlled magnetic anisotropy efficiency and a spin reorientation across the metamagnetic transition. These findings open interesting prospects for exploiting strain engineering to harvest higher efficiency VCMA for the next generation MeRAM devices based on ferromagnetic and antiferromagnetic materials. This research was supported by NSF Grant No. ERC-TANMS-116050.



Biography

Nicholas G Kioussis has completed his PhD from University of Illinois at Chicago and postdoctoral studies from West Virginia University. He is the founder and director of the W. M. Keck Computational Materials Theory Center at California State University Northridge. He has published more than 150 papers in reputed journals in the areas of Electronic structure calculations, Multiscale modeling of defects, strongly correlated electron systems, spin transport in magnetic tunnel junctions, and topological insulators and Weyl semimetals. He served as the Director of several International Workshops on Correlations Effects and Materials Properties. Awards include DOE Faculty Fellowship, Lawrence Livermore National Laboratory, Marie Curie Fellowship, Outstanding faculty award, US Air Force Fellowship, Wang Family Excellence Faculty Award.

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