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Semiconductor nonlinear effect assisted magnetoresistance & magnetic logic

Discovery of giant Magnetoresistance (MR) won Nobel Prize in Physics in 2007, and it initiated Spintronics. However, most MR devices are based magnetic materials which are not compatable with Si based devices. Coupling semiconductor nonlinear transport effect and Hall Effect in semiconductor, we developed a Si-based geometrical enhanced MR device whose room-temperature MR ratio reaching 30 % at 0.065 T. We also realized the geometrical enhanced MR in GaAs and Ge. We further coupled semiconductor nonlinear transport effect and anomalous Hall Effect in a Perpendicular Magnetic Anisotropic (PMA) material, and realized a giant MR of 22000 % at 1 mT in PMA material at room temperature. Based on our Si based MR device, we developed a current-controlled reconfigurable MR logic device, which could perform all four basic Boolean logic including AND, OR, NAND and NOR in one device. We proposed an alternative way to realize magnetoelectric logic by coupling spin-dependent transport effect in magnetic material and nonlinear transport effect in semiconductor material. All four basic Boolean logic operations could be performed with high output ratio. We further proposed a magnetic logic-memory device by coupling anomalous Hall Effect in magnetic material and negative differential resistance phenomena in semiconductor [Figure 1]. All four basic Boolean logic operations could be programmed by magnetic bit at room temperature with high output ratio (>1000 %) and low magnetic field (~5 mT). This device demonstrated that non-volatile information reading, processing and writing could be realized in one step and one device. Hence, logic and non-volatile memory could be closely integrated in one chip. The time and energy used in the processes of information transformation and transfer could be saved. This might break through the von Neumann performance bottleneck and make computer more energy efficiency and higher performance.

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Biography

Xiaozhong Zhang obtained his BSc from Fudan University (China) in 1982 and MSc from Shanghai Jiaotong University (China) in 1984. He obtained his PhD from University of Oxford in1989 and worked as a postdoc at The Royal Institution of Great Britain during 1989-1992. Then, he worked as a faculty at National University of Singapore for seven years. Since 1999 he has been working as a professor at School of Materials Science and Engineering of Tsinghua University. He was a director of electron microscopy laboratory of Tsinghua University during 1999-2006. He is now the deputy director of the Key Laboratory of Advanced Materials, Education Ministry, and is serving as the deputy chief of Chinese national nano-technology standardization committee. He has published more than 190 papers in referred journals and is a co-editor of IUCrJ. His research interests are spintronics, carbon materials, nanostructures, electron microscopy and computational materials science.

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