

Enhancement of spin-transfer torque in superlattice-barrier magnetic tunnel junctions



P. Tseng and W. J. Hsueh

Nanomagnetism group, Department of Engineering Science and Ocean Engineering, National Taiwan University, 1 Sec. 4, Roosevelt Road, Taipei, 10660, Taiwan

ABSTRACT

Huge current-induced spin-transfer torque (STT) effect in a magnetic tunnel junction (MTJ) with a superlattice tunneling barrier constituted by periodic layers of a nonmagnetic metal and an MgO insulator is discussed. The forbidden and allowed bands in the superlattice barrier are appropriately designed through modulating the thickness of the nonmagnetic metal layer in the superlattice barrier. The results demonstrate that the improvement of STT by band structure in superlattice MTJ can achieve four (three) orders greater than that of traditional single (double)-barrier structure for our previous work. In addition, the number of cells in the superlattice barrier are proportional to the STT and the charge current density that directly affects the energy consumption of device.

INTRODUCTION

Magnetic tunnel junctions have attracted a lot of attentions owing to the potential applications in magnetic random access memories (MRAMs), magnetic field sensors, nonvolatile and other spintronic devices. Switching of magnetization state is one of the most important operating principle in MTJs. The mechanism of spin transfer from conduction electrons to localized magnetic moments is caused by a torque applied to the layer's magnetization. This phenomenon is called current-induced magnetization switching, which is obtained by using a current-induced spin transfer torque (STT). The reduction of the critical current density is a very important issue to realized the applications of STT magnetic random access memories (STT-MRAMs). The concept of our results can provide a novel physics mechanism and advantageous application in spintronics and nanoelectronic memory.

MODEL AND FORMULATION

The behavior of electrons in a MTJ structure can be described by Schrödinger Hamiltonian:

$$H = \frac{\hbar^2}{2m^*} \nabla^2 + U - \Delta \cdot \sigma$$

A structure of superlattice MTJ is shown in figure 1. The yellow electrodes indicate the pinned and free layer. The purple and green layers indicate the nonmagnetic metal and insulator. The pinned layer and free layer have a magnetization angle θ . We consider two coordinate systems in this work, axial (x, y, z) for the pinned layer and layers in the superlattice barrier, and axial (x', y', z') for the free layer. The direction of magnetization for the pinned or free layer are followed the z or z' axes, respectively. The y and y' axes are perpendicular to boundary layers.

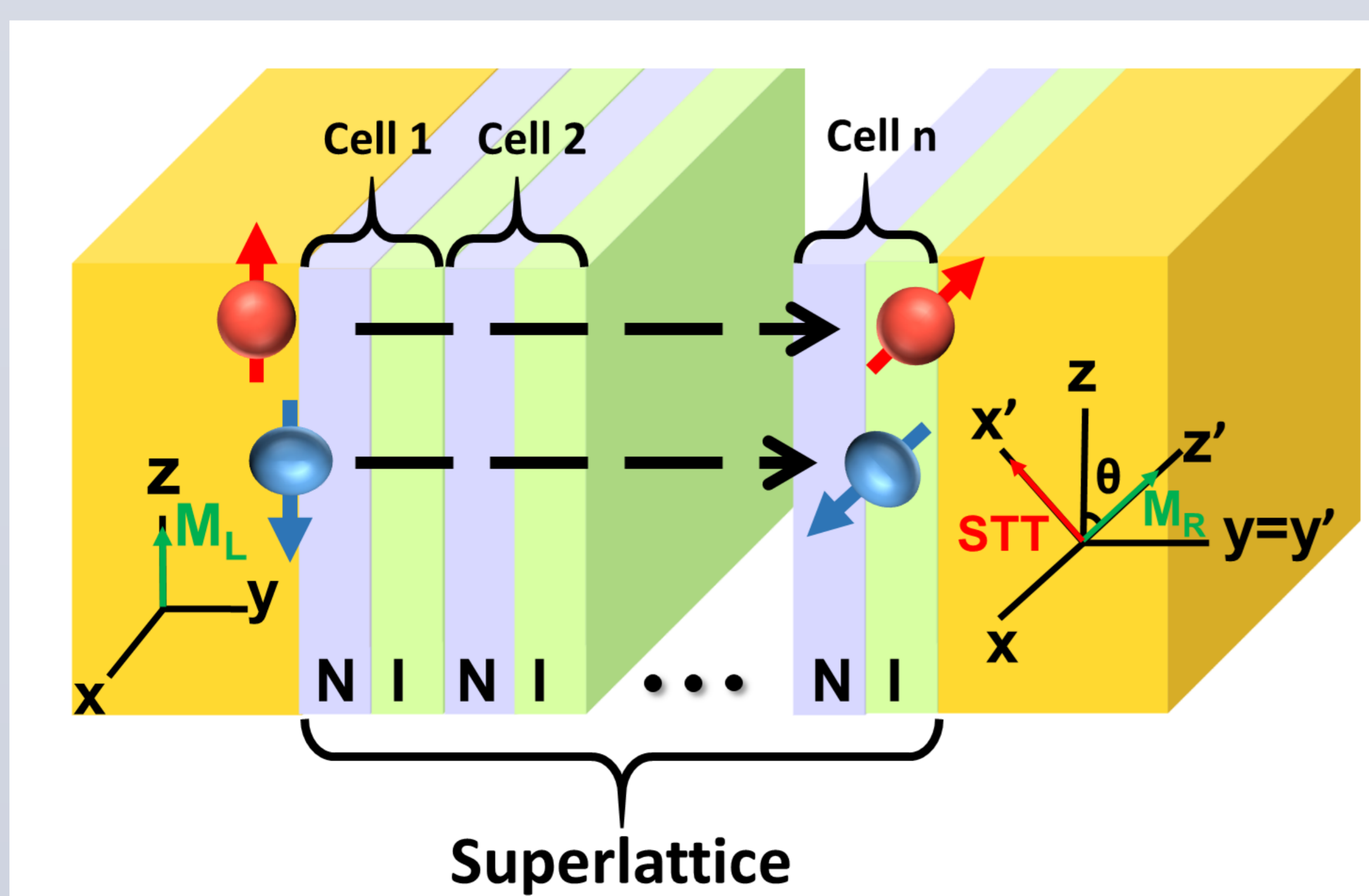


Figure 1. A schematic illustration of the superlattice-barrier MTJ.

FIGURE

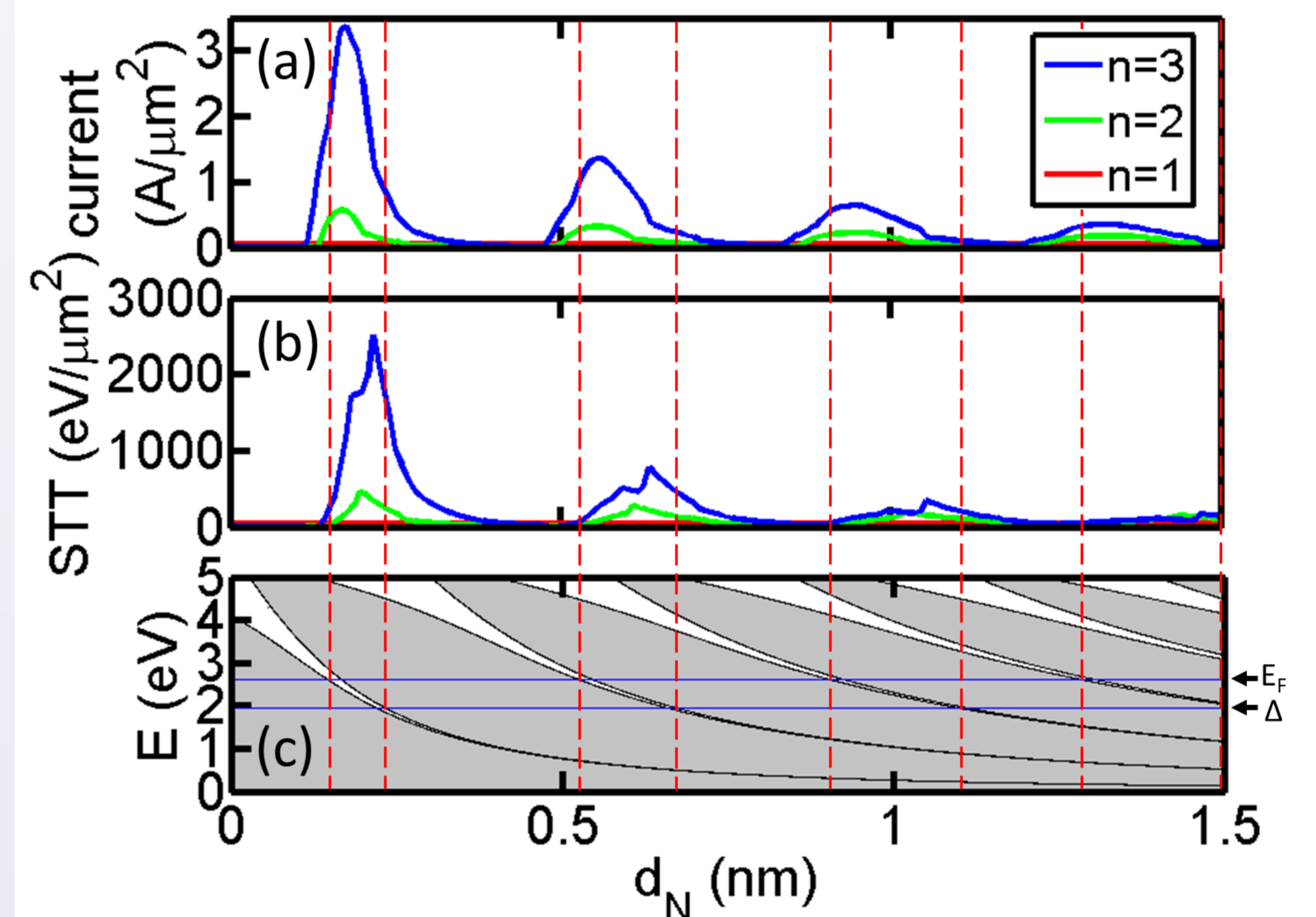


Figure 2. The (a)charge current density, (b)spin-transfer torque and (c) band structure versus thickness of nonmagnetic metal layer in the $F_p/(N/I)^n/F_f$ superlattice MTJ. The region between two red dashed lines show an allowed band within the energy interval (Δ, E_F).

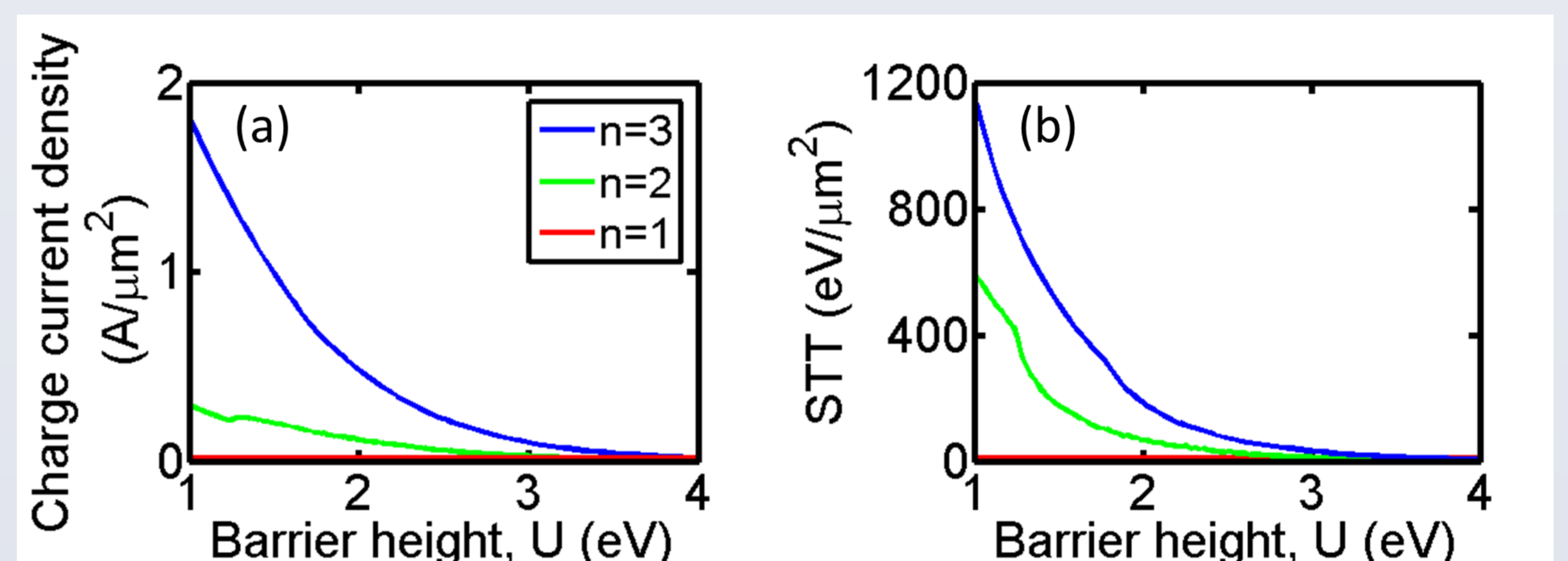


Figure 3. The (a)charge current density and (b)spin-transfer torque versus barrier height in the system.

CONCLUSIONS

In this study, the number of cells in superlattice barrier and the thickness of layer strongly influence the intensity of the STT. Our results show that the superlattice-barrier MTJ can reach values up to four orders of magnitude greater than those in traditional MTJ structure.

ACKNOWLEDGEMENT

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RELATED DOCUMENTS

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CONTACT INFORMATION

Prof. Wen-Jeng Hsueh, Ph. D
Phone: +886-2-3366-5750
Fax: +886-2-2392-9885
E-mail: hsuehwj@ntu.edu.tw

Peng Tseng, Ph. D student
Phone: +886-2-3366-5725
Fax: +886-2-2392-9885
E-mail: f03525047@ntu.edu.tw

Address: Nanomagnetism group, Department of Engineering Science and Ocean Engineering, National Taiwan University