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Effect of uniaxial strain on the tunnel magnetoresistance of T-shaped graphene nanoribbon based spin-valve

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ABSTRACT

We theoretically investigated the spin-dependent transport through a T-shaped graphene nanoribbon (TsGNR) based spin-valve consisting of armchair graphene sandwiched between two semi-infinite ferromagnetic armchair graphene nanoribbon leads in the presence of an applied uniaxial strain. Based on a tight-binding model and standard nonequilibrium Green's function technique, it is demonstrated that the tunnel magnetoresistance (TMR) for the system can be increased about 98% by tuning the uniaxial strain. Our results show that the absolute values of TMR around the zero bias voltage for compressive strain are larger than tensile strain. In addition, the TMR of the system can be nicely controlled by GNR width.

1. Introduction

Graphene, an atomically thin layer of graphite, has attracted a great deal of attentions in recent years for both unique physical properties and potential applications. Due to its excellent properties, such as high electronic mobility, low intrinsic spin-orbit and hyperfine couplings and long spin diffusion length, graphene is expected to be a promising candidate for spintronics applications. The application of physical phenomena such as giant magnetoresistance (GMR) and tunnel magnetoresistance (TMR) has led to the building of spintronic devices such as spin valve, magnetic memories, transistors, switches and diodes, etc [1–4]. Graphene-based spin valves have been successfully fabricated and the spin injection from ferromagnetic (FM) metal electrodes into graphene has been experimentally achieved. Hill et al. fabricated graphene-based spin valve device, where a 200 *nm* wide graphene wire is contacted by two soft magnetic NiFe electrodes, and observed a 10% change in the resistance as the electrodes switch from a parallel to an antiparallel configuration [5]. Wang et al. reported the magnetoresistance properties of the graphite-based spin valve devices consisting of graphite flakes contacted by FM electrodes [6]. They found that the magnetoresistance values can reach up to 12% at 7*K* when an ultrathin MgO tunnel barrier was inserted at the FM/graphite interface. Also, spin-dependent transport through the graphene-based spin valves has been widely studied theoretically in the recent years [7–16]. Using first-principles calculations, Kim and Kim found that graphene nanoribbons (GNRs) contacted to FM electrodes exhibit very large values of magnetoresistance [10]. Based on the tight-binding model, Brey and Fertig investigated the magnetoresistance of a graphene-based spin valves in the limit of infinite width [11]. They found that the magnetoresistance is rather small, largely due to the insensitivity of the conductivity with respect to the relative magnetization orientations of the FM leads. Using Keldysh's nonequilibrium Green's function method, Ding et al. studied the spin-dependent transport through the graphene spin-valve device and found that the

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magnetoresistance versus the bias exhibits a cusp around zero bias in the absence of an external magnetic field, and oscillating behavior at a high magnetic field [12]. Recently, studies have shown that spin-polarized carriers can be realized by depositing a FM insulator on graphene [17–19].

To construct a graphene-based nanoelectronic device, the ability to adjust the electronic properties of graphene is absolutely required. For this reason, the effects of the external conditions such as disorder [13], gate voltage [14], the magnetic impurities [15] and kind of electrodes [16] on the spin-dependent transport properties of graphene-based spin valves have been addressed. Recently, strain has been suggested as another effective approach to control the band gap and electronic properties of the GNRs [20–25]. The effect of strain on the electronic properties of GNR is strongly dependent on the ribbon edge shape, i.e., armchair versus zigzag [26]. Recently several GNR junctions based on the two types of GNRs have been proposed, such as T-shaped [27], L-shaped [28], V-shaped [29], Z-shaped [30], S- and U-shaped [31] junctions.

In this paper, using the well-known Green's function method in the tight-binding model, the spin-dependent transport properties of T-shaped graphene nanoribbons (TsGNRs) based spin-valve are numerically investigated in the presence of uniaxial strain. Quite interestingly we see that, the TMR of the system can be enhanced very nicely by tuning the uniaxial strain strength and geometry of the TsGNRs. This phenomenon can be utilized in designing the future graphene based spintronic devices.

2. Model and method

Here we describe our method based on a TsGNR based spin-valve consisting of an armchair GNR (central region) connected to two semi-infinite FM armchair GNR electrodes, as depicted in Fig. 1. The central region is placed on x-y plane subjected to uniaxial strain along the x-direction. Here, n_{L1} and n_{L2} are the width of the FM electrodes and central region, respectively. In addition, n_W describes the length of the central region. The Hamiltonian for the entire system reads

$$H = H_G + H_R + H_L + H_C, \tag{1}$$

where H_G represents the Hamiltonian of the central region, H_R and H_L describe the right and left FM electrodes, respectively, H_C is the Hamiltonian for the coupling between central region and FM electrodes. Using the tight-binding model with nearest-neighbor hopping approximation, these partial Hamiltonian can be, respectively, written as follows:

$$H_G = \sum_i \left\{ \varepsilon c_i^\dagger c_i \; - t\left(c_i^\dagger c_{i+1} + c_{i+1}^\dagger c_i\right)\right\}. \tag{2}$$

$$H_{\beta(=LorR)} = \sum_{i_\beta,\sigma} \left\{ \left(\varepsilon_0 - \sigma.\mathbf{J}_\beta\right) c_{i_\beta,\sigma}^\dagger c_{i_\beta,\sigma} - t_0\left(c_{i_\beta,\sigma}^\dagger c_{i_\beta+1,\sigma} + c_{i_\beta+1,\sigma}^\dagger c_{i_\beta,\sigma}\right)\right\}. \tag{3}$$

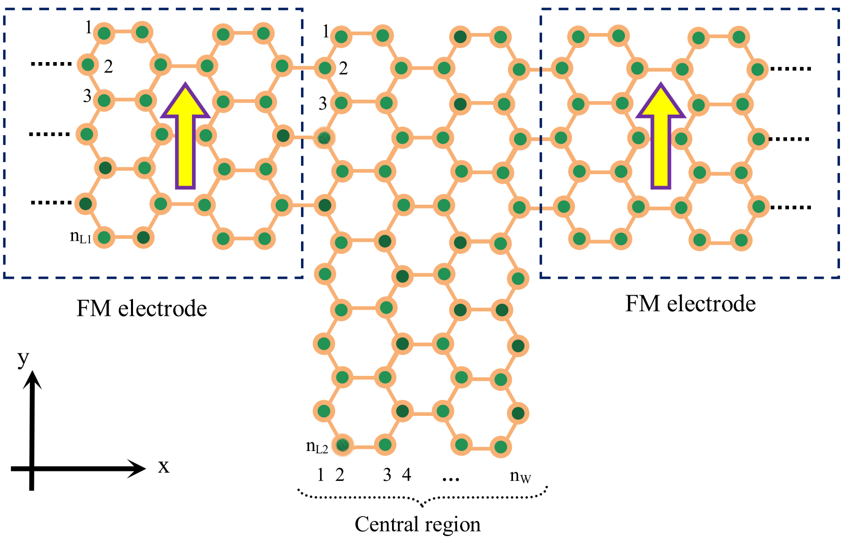

Fig. 1. A Schematic illustration of a TsGNR based spin-valve which divided into a central region and two left and right FM electrodes for parallel configuration. For anti-parallel configuration the magnetization in the right electrode is fixed at the $-y$ direction.