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# Magnetic Field Dependence of Opening and Closing Dirac Cone in Ni/Graphene/Ni nano-spin-valve-like structure

We present magnetic properties and electronic structure studies of a graphene-based nano-spin-valve-like structure theoretically. Magnetic nickel layers on both sides of graphene are considered. A spin-polarized generalized-gradient-approximation determines electronic states. In the most energetically stable stacking arrangement of graphene and two nickel layers, the anti-parallel spin configuration of the underlayer and overlayer magnetic moments has the lowest energy[1], which is in agreement with previous experimental studies.[2] The spin density mapping and obtained band-structure results show that when upper and lower Ni(111) slabs have anti-parallel (parallel) magnetic-moment configuration, the carbon atoms of sublattice A and B will have antiferromagnetic (ferromagnetic) spin configuration. A band gap at the Dirac cone is open when the alignment is anti-parallel configuration, and it is closed when the alignment is parallel configuration[1]. Therefore, the in-plane conductance of the graphene layer depends on the magnetic alignment of two nickel slabs when the Fermi level is adjusted at the Dirac point. This result will give arise the reconsideration of the Klein paradox on graphene[3] as we consider the conductance of graphene nano-ribbon with the partially sandwiched by magnetic nickel layers from upper and lower side as shown in figure 1.

## References

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[2] S. Mandal, S. K. Saha, Nanoscale, 4 (2012) 986-990
[3] M. I. Katsnelson, K. S. Novoselov, and A. K. Geim, Nature Phys., 2 (2006) 620

## Figures

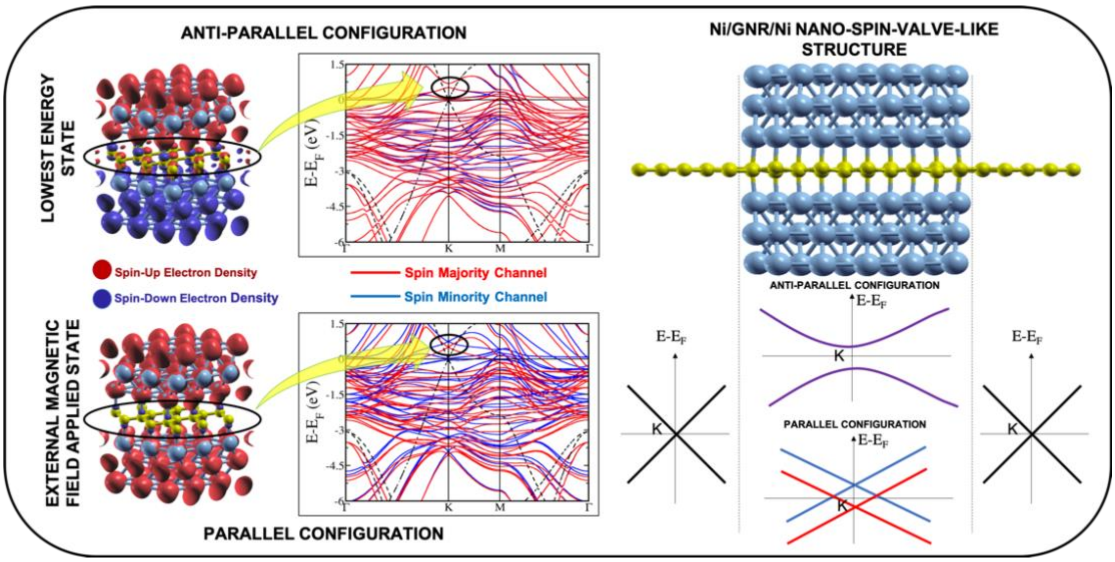


**Figure 1:** Spin-dependent charge density mapping (left) and bandstructure of Ni/Graphene/Ni nanostructure (middle). When the magnetic moment between upper and lower nickel slabs is antiparallel (parallel), the Dirac cone of graphene is open (close). The Klein paradox on graphene need to be reconsidered by proposed partially sandwiched structure of graphene nano-ribbon with nickel layers from upper and lower side (right).