Graphene spintronics: The current state of the art

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Abstract

I will give an overview of the current state of the physics and technology of graphene spintronics. I will explain the basic concepts of spin accumulation, spin transport, spin precession, spin manipulation and spin relaxation. It will be shown how various types of measurements (two, three and four terminal geometries) can be used to extract the spin transport parameters in graphene, such as spin relaxation length and spin relaxation time. The various mechanisms responsible for spin relaxation in graphene (Elliott Yafet vs. Dyakonov Perel) will be discussed, and how they depend on the graphene quality and mobility. I will present results obtained on various graphene substrates (with SiO_2 as reference [1]), such as boron nitride [2], and graphene grown on the C and Si face of silicon carbide [7,8]. Also suspended graphene has been used to optimize the spintronics properties of graphene [3].

I will discuss that the ultimate potential of graphene for spintronics has not yet been established, and that the current record of 7 micrometer for the room temperature spin relaxation length is expected to be broken soon. A connection with (para [5] and (possibly) ferro) magnetism in graphene will be made, discussing recent measurements [4,6] which have shown that magnetic moments can be induced in graphene, which can be studied in detail by their effect on spin transport. The potential of spin transport for detecting (localized) spins which are present above or below the graphene will be addressed [7]

Finally I will present a roadmap for future planned developments in science and technology of graphene spintronics, based on the for the graphene workpackage in the EU Graphene Flagship. It will be shown how the spintronics workpackage, by a concerted effort of experiment and theory, will address the science and technology of graphene spintronics in various systems, working towards future applications.

References

1. Nikolaos Tombros, Csaba Józsa, Mihaita Popinciuc, Harry T. Jonkman & Bart J. van Wees, "Electronic spin transport and spin precession in single graphene layers at room temperature", Nature 448, 571-574 (2007)
2. P. J. Zomer, M. H. D. Guimarães, N. Tombros, B. J. van Wees, "Long Distance Spin Transport in High Mobility Graphene on Hexagonal Boron Nitride", Phys. Rev. B 86, 161416(R) (2012).
3. M. H. D. Guimarães, A. Veligura, P. J. Zomer, T. Maassen, I. J. Vera-Marun, N. Tombros, and B. J. van Wees, "Spin Transport in High-Quality Suspended Graphene Devices", Nano Letters 12 (7), 3512-3517 (2012).
4. M. Wojtaszek, I. J. Vera-Marun, T. Maassen, B. J. van Wees, "Enhancement of spin relaxation time in hydrogenated graphene spin valve devices", Phys. Rev. B: Rap. Comm. 87, 081402(R) (2013).
5. R. R. Nair et al., “Spin-half paramagnetism in graphene induced by point defects” Nature Physics 8, 199–202 (2012)
6. K.M. McCreary et al., “Magnetic moment formation in graphene detected by scattering of pure spin currents,”Phys. Rev. Lett. 109 , 186604 (2012)
7. B. Dlubak et al., “Highly efficient spin tranposrt in epitaxial graphene on SiC”, Nat. Phys. 557 (2012)
8. T. Maassen, J. J. van den Berg, E. H. Huisman, H. Dijkstra, F. Fromm, T. Seyller, B. J. van Wees, "Localized States Influence Spin Transport in Epitaxial Graphene", Phys. Rev. Lett. 110, 067209 (2013)