خواص مغناطیسی گرافن تولید شده به روش لیزری

طیبه محمدی[۱]، پرویز پروین[۱]، حسن غفوری فرد[۲]، محسن محرابی[۱]، سارا حسامی افشار[۱]

[۱]دانشکده مهندسی انرژی و فیزیک، دانشگاه صنعتی امیرکبیر

[۲]دانشکده مهندسی برق، دانشگاه صنعتی امیرکبیر

چکیده – در این مقاله مشخصات گرافن تولید شده توسط لیزر به طور ویژه مشخصات مغناطیسی آن بررسی شده‌است و با نمونه‌های گرافنی دیگر مقایسه گردیده‌است. نتایج نشان می‌دهد که گرافن لیزری دارای یک شبکه کم نقص می‌باشد. در این گزارش هم‌چنین روش‌هایی برای بهبود خاصیت مغناطیسی گرافن مطرح گردیده و بررسی شده‌است بدین صورت که با اعمال ناخالصی در شبکه گرافن ما شاهد بروز خاصیت مغناطیسی در آن بوده‌ایم.

کلید واژه- گرافن، سنتز لیزری، خاصیت مغناطیسی.

magnetic properties of graphene generated by laser ablation

T.mohammadi[a], *P.parvin[a], H.ghafoori fard[b], M.mehrabi[a], S.hesami afshar[a]

[a]Department of Energy Engineering and Physics, Amirkabir University of Technology

[b]Electrical engineering department, Amirkabir University of Technology

P.O. Box 15875-4413, Tehran, Iran

*parvin@aut.ac.ir

Abstract- In this paper, properties of new carbon-based material, graphene was investigated. Specially magnetic properties of graphene generated by laser ablation in Cryogenic Media was studied and compared with that of chemical methods. Graphene fabricated by laser method exhibits diamagnetic property that is consistent with other pristine graphene lattices and therefore its structure is close to low defect graphene. In order to improve the magnetic properties of graphene, functionalization with silver atoms was carried out to appear better magnetism.

Keywords: graphene, laser ablation, magnetic properties.

Magnetic Properties of Graphene Generated by Laser Ablation

T.mohammadi, P.parvin, H.ghafoori fard, M.mehrabi, S.hesami afshar

1 Introduction

One of the important elements in nanotechnology is carbon. The existence of multiple flavors of hybridization in carbon is what leads to the different allotropes. Graphene is a planar allotrope of carbon where all the carbon atoms form covalent bonds in a single planeelectronic band structure of graphene is the starting point for the understanding and derivation of the band structure of CNTs. Graphene was named and studied by Hanns-Peter Boehem in 1961 and later isolated and researched by Russian born scientists Andre Geim and Konstantine Novoselov in 2004. [1]

Graphene has magnetic properties as a result of its unique band structure. Recently, magnetism of carbon-based materials is of particular technological interest. First of all, it could reduce the demand for magnetic materials with d and f –orbital shell (iron, mangan, rare earth metals). intrinsic magnetism related to p electrons is advantageous over the conventional d –or f electron based magnetic systems due to weak spin-orbit interaction and long electron spin coherence time. Secondly, carbon-based magnetic materials would greatly extend the limits of technologies relying on magnetism in metals or diluted magnetic semiconductors (DMS), like flexibility, processibility or production costs. Graphene also has potential in spintronic.[2] Intrinsic graphene is diamagnetic but inserting defects in the graphene lattice makes it show paramagnetic or ferromagnetic property. a diamagnetic material, there are no unpaired electrons and repelled by a magnetic field thus its magnetic curve shows a negative slope. In a paramagnetic material there are unpaired electrons which are free to align their magnetic moment in any direction so in external magnetic field their magnetic moments will tend to align themselves in the same direction as the applied field and the curve is a line with positive slope. The curve of ferromagnetic materials is like to paramagnetism and also shows a hysteresis loop. Many groups have been theoretically and experimentally studied the magnetism of graphene. and experimental observations of magnetic ordering are often explained by the presence of impurities, boundaries or defects.[3] R.nair et.al. in their work on magnetic properties of graphene, investigated the pristine graphene was prepared by ultrasonic cleavage of high-purity HOPG in an organic solvent, N -methylpyrrolidone and point defected graphene by fluorine atomes. In their reports, pristine graphene laminates exhibited strong diamagnetic susceptibility visible at 300Kand 100K and in the defective sample paramagnetism was corroborated.[4] In this work the magnetic properties of graphene synthesized by laser ablation, and improvement of the magnetism was investigated. In part 2 method of experiment and in part 3 the results of this work are discussed

2 expriment

Here graphene was prepared based on the pulsed laser ablation of graphite target inside the cryogenic liquid using the pulsed nanosecond Q-switched Nd:Y3Al5O12 (Nd:YAG) laser at 1064 nm and 100 mJ pulsed energy and 10 nSec duration. The mechanism of the graphene formation is proposed based on the penetration of liquid nitrogen into the interlayer spacing of graphite and the subsequent expansion to gas phase during laser heating. Most of techniques for graphene fabrication suffer from several drawbacks such as high synthesis tempera-tures, high vacuum conditions, low yield, and difficulty to control the size and long growth duration which exhibit challenges for the material integration, cost and through-put but A simple and fast technique for the graphite exfoliation by laser in cryogenic liquid is applied to generate graphene. Single-stage fabrication process is taken into account as a remarkable advantage without need to high vacuum devices and additional chemical components.[5]

Magnetic measurement of graphene in this report was carried out by AGFM(Alternating gradient force magnetometer).

3 Results and discussion

Figure 1 shows TEM image of graphene sample synthesized by laser ablation. The layers of graphene is visible.

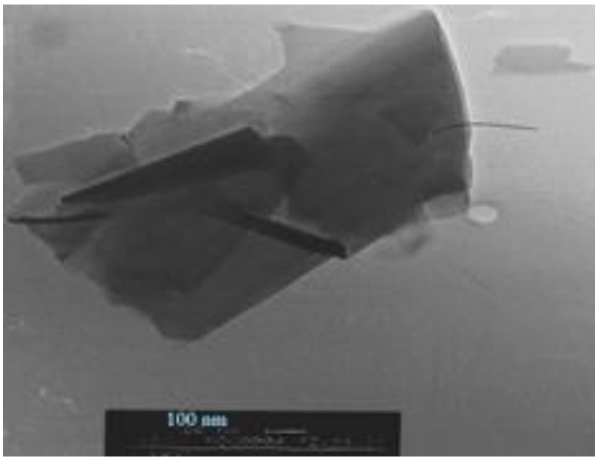

Figure 1: TEM image of graphene synthesized by laser

Figure 2 shows magnetic curve of this sample. It is visible that curve is related to a diamagnetic material and consistent with other reports on magnetic properties of pristine graphene such as [4]. The susceptibility of this curve is acceptable in comparing to other graphenes. Beside the negative ΔM in this curve, there is a hysteresis loop that may be related to superconductivity that agrees with report on superconductivity of HOPG sample in [6].

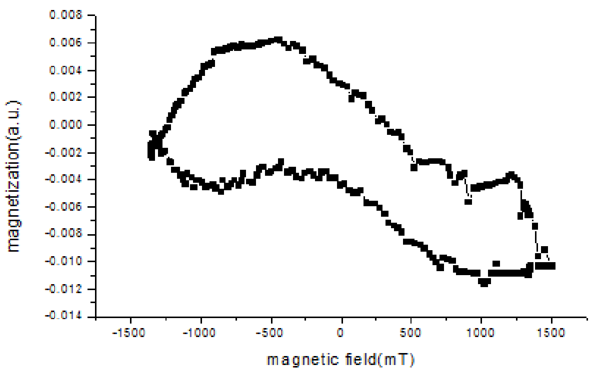

Figure 2: magnetic curve of graphene generated by laser ablation.

For improvement of magnetism in graphene, we should insert defects in graphene lattice. The reason of inducing magnetism by defects describes as a relation that is Lieb's theorem of bipartite system such as graphene, derived from the tight binding Hubbard model. According to this theorem $s = 1/2|N_A - N_B|$ is total spin of lattice where N_A and N_B are the numbers of sites in sublattices A and B, respectively. For the perfect graphene($N_A = N_B$), total magnetic moment is zero and for each point defect S=1/2 expected in system.[7] For this work, silver atoms were used to induce magnetism in graphene. Silver atom has one free electron in it's valance band, therefor bonds to free $2p_z$ orbitals and changes hybridization of graphene from sp^2 to sp^3 and breaks the sublattice symmetry of the graphene lattice and thus total spin becomes non zero with a net magnetic moment. Figure 3 illustrates the schematic of bonding of silver atome to graphene lattice.

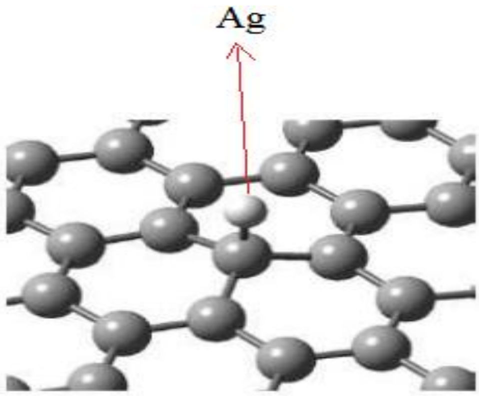

Figure 3: schematic of bonding of silver atom to graphene.

In figure 4 displays magnetic curve of defective graphene. The susceptibility in this sample is approximately in the range of 10^{-7} that shows stronger paramagnetism in comparing with Ref [4]. In the magnetic curve of hybrided graphene, around of zero field, a positive slope is observed. It arises from the intrinsic magnetic moment caused by defects that is like as Ref [8].

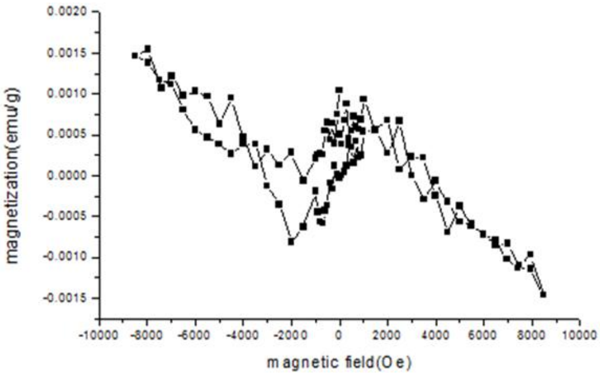

Figure 4: magnetic curve of hybrided graphene.

Conclusion

Here, magnetic properties of graphene synthesized by laser ablation and its improvement was investigated. The results showed that graphene generated by this method is diamagnetism and its structure is close to low defect graphene lattice. In order to improve the magnetic state, hybridization of graphene with silver atoms was carried out. The net magnetic moment around zero field and the susceptibility increment were identified the evidences of this effect.

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