Direct synthesis of hydrogenated graphene using decomposition of hydrocarbons in plasma jet

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The synthesis of hydrogenated graphene using a high current DC plasma torch has been investigated. In the experiment the hydrocarbons with the working gas (helium, argon, nitrogen) have been introduced into the plasma jet, wherein heating and decompositions of components occurred in the plasma jet followed by condensation of the synthesis product. Products have been characterized by X-ray photoelectron spectroscopy, field emission scanning electron microscopy and Raman spectroscopy. Thermal stability and phase composition of products were evaluated by thermogravimetry and differential scanning calorimetry. It was found that by varying the parameters it was possible to achieve hydrogen to carbon ratio in final product up to 1:4.

1. Introduction

As a derivative of graphene, graphane is a nonmagnetic semiconductor with an energy gap formed by 100% hydrogenation of graphene with stoichiometry CH. Graphane opens new possibilities for the use of carbon based materials in applications involving manipulation of electronic properties, thermal conductivity, hydrogen storage, and magnetization. Graphane usually prepared in two steps by hydrogenation of graphene that was synthesized before.

2. Methods

For the synthesis of hydrogenated graphene in one step a high current DC plasma torch was used. In the experiment the carbon precursors (propane-butane, methane, acetylene) with the working gas (helium, argon, nitrogen) have been introduced into the plasma jet, wherein heating and decompositions of components occurred in the plasma jet followed by condensation of the synthesis product. The plasma torch electric power reached 40 kW. The main parameters were: varying pressure in the range from 150 to 730 Torr and gas flow rate. Products have been characterized by X-ray photoelectron spectroscopy, field emission scanning electron microscopy and Raman spectroscopy. Thermal stability and phase composition of products were evaluated by thermogravimetry and differential scanning calorimetry. Express - gravimetry (vario MICRO cube) method have been used to determine the elemental composition of synthesized product.

3. Results

Experimental results confirmed the possibility of hydrogenation of graphene in its synthesis. Figure 1 shows a typical SEM image of hydrogenated graphene structures that are morphologically identical to the structure obtained by the use of plasma afterglow [1]. Figure 2 presents Raman spectrum of the sample synthesized at 710 Torr using helium and propane-butane plasma. There are two characteristic peaks for graphane G (1581 cm^{-1}) and 2D (2692 cm^{-1}) [2]. D peak located at 1347 cm^{-1} appearing in graphene due to violation of the translational symmetry of the sp2 C-C bonds due to the formation of sp3 C-H bonds. Analysis of 2D peak form shows that the synthesized graphene structures are double-layer.

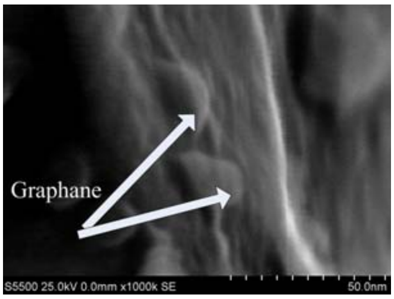

Figure 1. SEM image of graphane

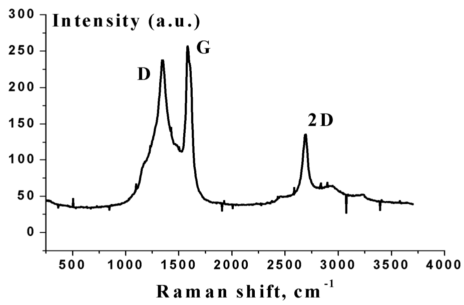

Figure 2. Raman spectrum of hydrogenated graphene

Direct method express - gravimetry found the ratio of the content of H:C in the samples. By varying the synthesis parameters it was possible to achieve hydrogen to carbon ratio up to 1:4.

4. References

[1] B Eren, D. Hug, L. Marot and et al. J. Nanotechnol. **3** (2012) 852.

[2] D.C. Elias, R.R. Nair, T.M.G. Mohiuddin and et al, Science, **323** (2009) 610.