Electrochemical Functionalization of Graphene in an Extensive Range of Electrical Power

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1- Introduction

Graphite is essentially made up of hundreds of thousands of layers of graphene. The separation of these graphene flakes is called exfoliation. Because of being inexpensive and efficient, electrochemical exfoliation is more attractive to study.

Despite the important role of electrical power in electrochemical exfoliation, it hasn't been investigated extensively. In this research, the effect of electrical power in an extensive range on the amount of exfoliated graphene and oxygen functional groups was studied. Transmission electron microscopy, weighing, UV-vis spectroscopy and electrical conductivity were used for characterization of the products.

2- Experimental

In these experiments, graphite rods were used as both anode and cathode. The electrolyte contained deionized water and sulfuric acid. Exfoliation of graphite anode began after DC voltage of 1.9, 5, 9, 12, 13.6 V were applied (Fig. 1).

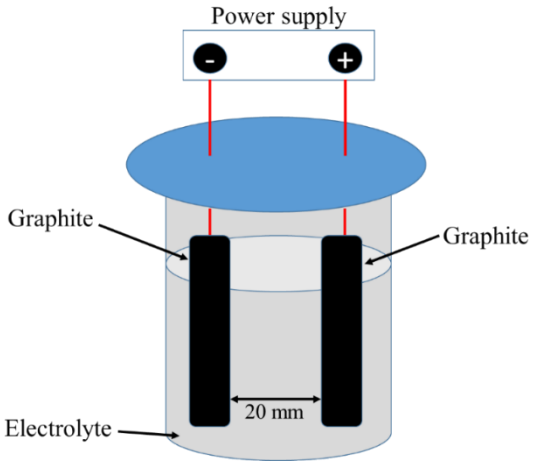

Fig. 1 Schematic of the electrochemical cell used in this research

In order to compare the quantity of synthesized graphene in each electrical power, two parameters were defined as eroded-weight and exfoliated-weight. In that, the former is the weight of all separated particles from graphite rod and the latter is the weight of just few-layer graphene flakes.

3- Results and Discussion

One of the significant factors in electrochemical exfoliation is the electrical power of the cell. Moreover, the electric current and applied voltage are not constant during the exfoliation. Thus, a combination of these two parameters defined as electrical power, is studied with the aim that the fluctuation of either of them be considered.

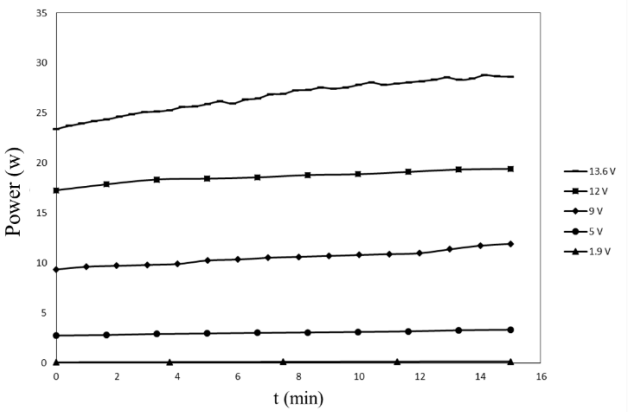

Fig. 2 Fluctuation of power during the electrochemical exfoliation

According to Fig. 2, with increasing the applied voltage, the electric power increases. Because in higher voltages, the electric current is also high, as a result, power increases. However, in applied voltages of 9, 12, 13.6 V, the energy entering the cell, destroys the structure of the graphite rod.

The other important factor in this research is the total amount of eroded particles. Fig. 3 shows the change of eroded weight with the applied power to the cell.

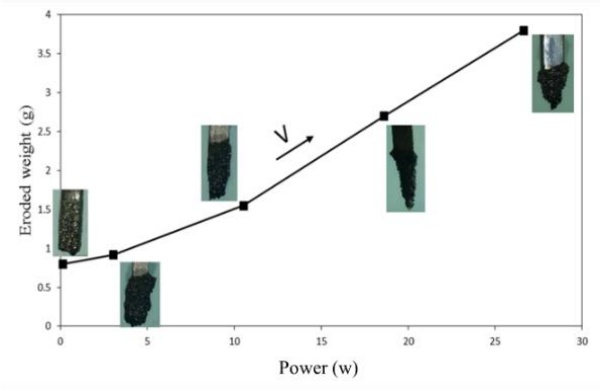

Fig. 3 Eroded weight versus electric power

As for Fig. 3, with increase of applied power, eroded weight increases. Moreover, the structure of graphite rods reveals that the maximum swelling takes place in power of 3 W.

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It can be discussed that by increasing the applied power to the cell, anions move toward anode more quickly. With the same token, anions intercalate between the layers of graphite rod in group of ions. As a result, the inflation of graphite increases until the power of 3 W. After that, intercalation of anions lead to anode erosion. So, the increase of eroded weight is originated from swift and cluster intercalation of anions. On the other hand, at low power, ions intercalate between the layers of graphite individually. Therefore, the eroded weight is not considerable. Also, similar structure of graphite rods was reported in Taheri's research.

Transmission Electron Microscopy (TEM) is a common way to investigate the structure of the mono-layer and multi-layer graphene flakes. In this research, the effect of electric power on the structure of graphene flakes was evaluated by TEM (Fig. 4).

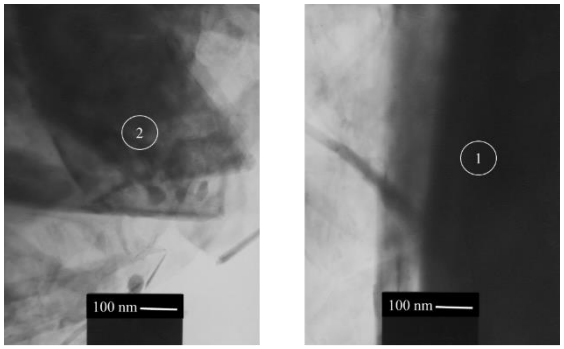

Fig. 4 Graphene synthesized in 1) 26.6 W, 2) 0.11 W

Fig. 4, section 1, the TEM image of graphene flake is almost dark. It shows that in high applied powers, the number and thickness of graphene flakes are considerable and the majority of the product are multi-layer graphene, owing to graphite demolition in 26.6 W. On the other hand, a translucent TEM image of graphene is obvious in section 2. It reveals that in 0.11 W, most of the products are mono-layer graphene flakes and the dominant mechanism is exfoliation.

4- Conclusions

According to the evidence mentioned above, the conclusion can be drawn that in the electric power range of this research, 0.11 to 12.6 W, with increase of power the eroded weight increases. However, in low powers, exfoliated weight considerable, because the superficial exfoliation of mono-layer graphene flakes is the dominant mechanism.

There is an indirect relationship between eroded weight and exfoliated weight. The more anode devastation in high powers, the less exfoliation takes place.