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Effects of the arc-discharge parameters on the morphology and the electrical conductivity of the synthesized carbon materials

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Abstract

Carbon materials were synthesized by arc-discharge with various parameters of the discharge. The materials consist of soot globules of disordered carbon structure, also there are graphene fragments in the materials. Nevertheless electrical conductivity of the synthesized carbon materials basically is determined by affect of contact resistance appeared due to amorphous carbon which covers the graphene fragments. The electrical conductivity has values in the range from $2 \cdot 10^{-3}$ to 5.3 S/m in depending of the synthesis conditions. For the synthesized material containing graphene planes with sizes bigger than the most of the soot globules the electrical conductivity is determined by content ratio of the graphene planes and the soot globules. This material has electrical conductivity of 33 S/m.

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Keywords: nanocarbon; electrical conductivity; arc discharge

1. Introduction

Arc-discharge synthesis of nanomaterial has big attention after Kratchmer's work of fullerene synthesis [1] and Iijima's work, who discovered carbon nanotubes [2]. This method of nanomaterial synthesis allows to produce metal, oxide and carbide nanoparticles with sizes of several nanometers [3-5]. Nevertheless, due to high reactivity a

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contact between nanoparticles results to unite into the single nanoparticle with larger size that reduces specific area and reduces reactivity of such material. The problem of coagulation and size growth of nanoparticles is solved by synthesis of carbon matrix enclosing nanoparticles and preventing their contacts. Scott and Madzhetich are first who have synthesized nanoparticles packed in carbon matrix [6]. Now such synthesis involves the usage of composite metal-carbon electrodes, the sputtering of which results to formation of metal nanoparticles packed into carbon matrix.

Nanomaterials synthesized by method of electric arc have applications in such areas as electrocatalysis [7], including fuel cells, formation electrochromic materials [8] etc. The catalytic nanoparticles are mixed with powder of graphite to provide sufficient work characteristics of created devices [9, 10]. Authors of the present work offer other way to improve conductive properties, which is associated with synthesis of the carbon matrix with sufficient electrical conductivity. This work aims to determine effects of the external parameters of the arc-discharge synthesis influencing on the electrical conductivity of synthesized carbon material.

Electrical conductivity of the carbon material depends on content of sp^2-/sp^3- hybridized carbon, particle sizes and separation distance [11-13], amount of impurities on particle surfaces [14].The electrical conductivity is increased by compressing [14, 15] and annealing [16].

2. Experimental

Description of the experimental setup is detailed in [4]. The setup was connected to DC power source. Solid cylindrical graphite rod of 6 mm diameter was used as the sprayed anode. Movable unsprayed cathode was graphite cylindrical pellet of 20 mm diameter. Helium was used as buffer gas.

Two series of experiments were carried out. In the first serie the experiments were carried out with identical current values of 120 A and at various pressures of the buffer gas ranged from 3 to 200 Torr. The materials labeled *C3, C6, C12, C25, C50, C100* and *C200* were synthesized (the number corresponds to value of pressure in Torr). In the second serie of the experiments identical pressures of the buffer gas were set at 12 Torr and the current value of arc discharge was set in the range of 60 to 150 A. The materials labeled *C60A, C80A, C100A, C120A, C140A* and *C150A* were synthesized (The number between "*C*" and "*A*" corresponds to value of current in Amperes).

3. Results and discussions

Structure and formation processes of arc-discharge carbon materials were studied in area of fullerene synthesis [17, 18]. In the present work the synthesized carbon material consists of disordered carbon condensate with random σ-/π- bonds [19] which has forms of soot globules with average size in range from 10 to 40 nm depending on the synthesis conditions (Fig. 1(a)).

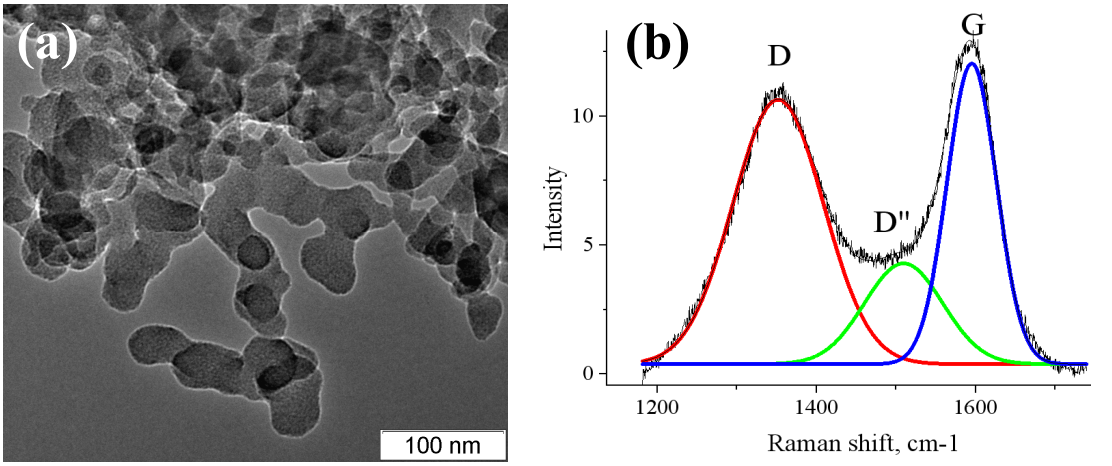

Fig. 1. Characteristic TEM-image (a) and characteristic Raman-spectrum (b) of synthesized carbon material. The results obtained for *C100.*