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Smart Electroconductive Textile by Catalytic Deposition of Carbon Nanotubes onto Glass Cloth[1]

G. T. Smagulova[a, b], S. Kim[a, b], N. G. Prikhod'ko[a, c], B. T. Lesbayev[a, b], A. V. Mironenko[a], A. A. Zakhidov[d], and Z. A. Mansurov[a, b]

[a] *Institute of Combustion Problems, 172 Bogenbay batyr st., Almaty, Kazakhstan*

[b] *Al-Farabi National University, 71 Al-Farabi av., Almaty, Kazakhstan*

[c] *Almaty University of Energetics and Communications, 126 Baitursynova st., Almaty, Kazakhstan*

[d] *University of Texas at Dallas, NanoTech Institute, 800 West Campbell Road, Richardson, TX, USA*

e-mail: smagulova.gauhar@inbox.ru

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Abstract—Cobalt oxide nanoparticles were deposited on the surface of glass cloth by solution-combustion synthesis and used as a catalyst for the growth of carbon nanotubes via the CVD process. The structure and morphology of thus prepared smart glass cloth were characterized by XRD, TEM, and SEM. Thus prepared carbon nanotubes 23–26 nm in diameter exhibited good current–voltage characteristics. The heating efficiency of the flexible heating element at low temperature was tested on a soldier model. The smart glass cloth showed good electroconductive and effective Joule heating from external current source. The conductive glass cloth can be recommended for use in various functional applications.

Keywords: solution-combustion synthesis, glass cloth, carbon nanotubes, smart electroconductive textile

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INTRODUCTION

Current trend in modern R & D is the production of smart textiles such as color changing fabrics, lighting textiles, conductive textiles, etc. [1]. Electroconductive clothes found their wide application and in every-day life and technology. There is a need to adjust their conductivity properties to specific conditions of a given application. To date, several methods have been suggested for fabrication of electroconductive clothes, such as electrospinning (polymers, metals) and electrochemical deposition of electroconductive materials. The fabrication of flexible heating elements was reported in [2]. Highly conductive textiles were obtained upon impregnation of the textile with thiophene monomer followed by oxidative polymerization. The most common methods for producing electrically conductive textiles are based on intercalation of thin metal fibers in the textile structure [3]. It is important that such textiles be strong, flexible, ecologically sound, and chemically stable.

The production of textile electrodes for flexible electrochemical supercapacitors was reported in [4]. Textile electrodes are manufactured from glass pipeline with Fe_3O_4-containing graphene oxide and carbon nanotubes. Synthesis of carbon nanotubes (CNTs) was carried out in a CVD chamber over Fe_3O_4-containing graphene fiber at 750°C in a C_2H_2/H_2/argon flow (5 : 150 : 800) for 15 min.

Carbon nanotubes exhibit unique physicochemical properties making them promising for various applications [5, 6]. Carbon nanotubes are used in energy storage, bio nanotechnology, microelectronics, etc. [7]. The structure and properties of CNTs depend on composition and morphology of catalysts, synthesis conditions, etc. One-dimensional carbon nanomaterials were synthesized over a fiberglass-based Pd catalyst [8]. Glass cloth is known for its high chemical stability, good mechanical properties, heat resistance, flexibility, and the ability to adopt various spatial configurations. Recently, the catalysts immobilized on glass cloth were used in carbon dioxide reforming of methane [9].

In this work, we investigated the possibility of using cobalt oxide nanoparticles prepared by solution-combustion technique as a catalyst for synthesis of carbon nanotubes by CVD method. Solution-combustion is a relatively new, rapidly developing cost-effective method for synthesis of nanomaterials, including oxide ones [10]. Catalysts immobilized on glass cloth have already been applied to combustion synthesis of nanomaterials [11]. This work aimed at catalytic synthesis of 1D carbon nanomaterials for use in electroconductive textile.

[1] The article is published in the original.

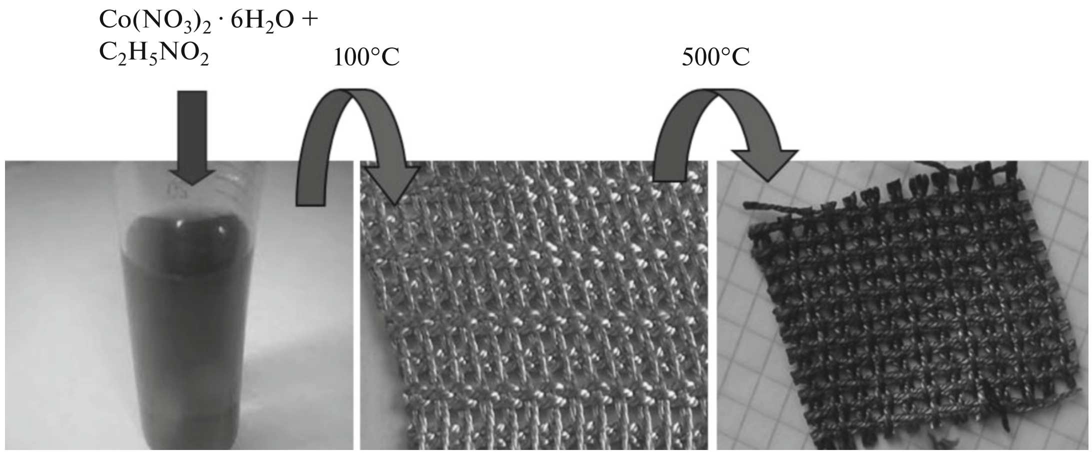

Fig. 1. Schematic of the catalyst preparation procedure.

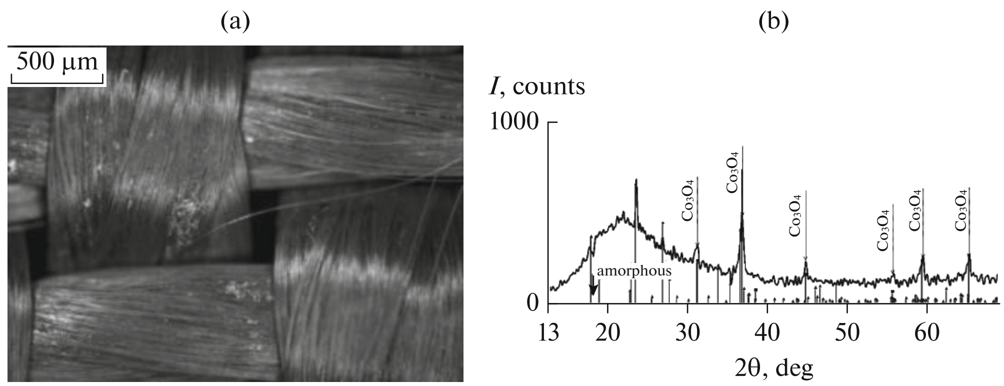

Fig. 2. (a) Micrograph and (b) XRD pattern of the glass cloth with deposited Co_3O_4 nanoparticles.

EXPERIMENTAL

Cobalt oxide nanoparticles were deposited onto the surface of glass cloth as described below. In experiments, we used the solution of cobalt nitrate $(Co(NO_3)_2 \cdot 6H_2O$ (5 wt %) as a source of cobalt and glycine $C_2H_5NO_2$ as a fuel. Glass cloth samples were impregnated with an aqueous solution containing stoichiometric amounts of cobalt nitrate and glycine. After drying, the samples were placed in a furnace and kept there at 500°C for 1 h. The catalyst preparation procedure is schematically illustrated in Fig. 1. The moment of ignition could be visually observed as the onset of weak bluish glow above the sample. The combustion reaction yielded the Co_3O_4 particles 30–100 nm in size immobilized on the surface of glass cloth [12].

Synthesis of carbon nanotubes was carried on by using a conventional CVD facility and conditions; gas flow: He 650 cm^3/min, H_2 150 cm^3/min, C_2H_2 19.5 cm^3/min; $T = 710$°C; and $t = 20$ min.

Synthesized materials were characterized by XRD, SEM (Zeiss-LEO Model 1530), and TEM (JEOL JEM-1011).

RESULTS AND DISCUSSION

Figure 2a shows the micrograph of a glass cloth with deposited Co_3O_4 particles while Fig. 2b, the XRD pattern. Figure 3 shows SEM and TEM images of carbon nanotubes grown on the surface of glass cloth.

Pure glass cloth is dielectric. After deposition of CNTs, it showed the resistance $R = 0.36$ Ω/cm^2. Figure 4 shows the current–voltage characteristic and the temperature of electrically heated glass cloth as a function of applied power. At $I = 1.25$ A, the textile temperature (T) is 100°C; at $I = 3.25$ A, T is seen to attain a value of 380°C (Fig. 4b).

The glass cloth/CNT composite has a number of advantages. The material showed a semiconductor-type behavior. Therefore, this electroconductive smart textile may be used for manufacturing flexible and strong heating elements. Figure 5 presents the images of soldier model with a heating jacket fabricated from flexible glass cloth with immobilized CNTs. The performance of the heating jacket was tested at low temperature (0°C). After connecting to a current source, the temperature of the jacket increased from 0 to 45°C

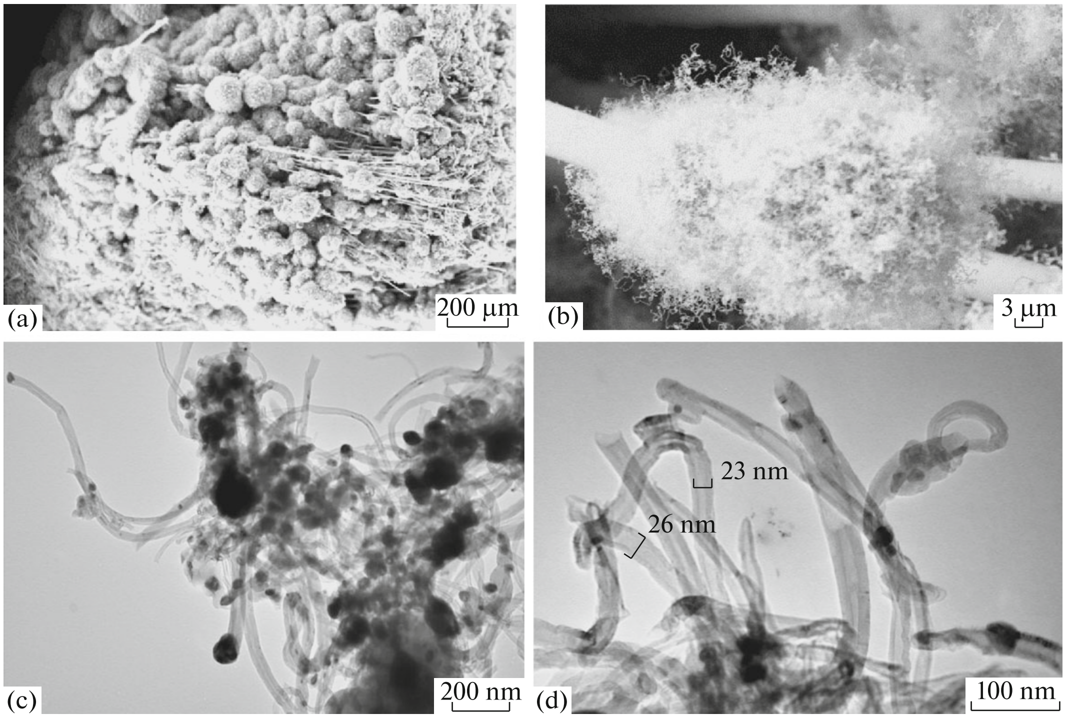

Fig. 3. (a), (b) SEM and (c), (d) TEM images of carbon nanotubes grown on the surface of glass cloth.

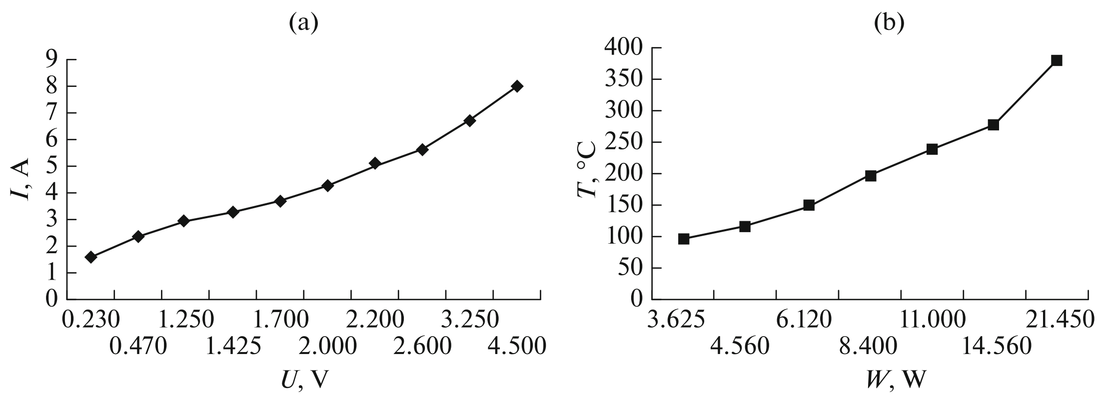

Fig. 4. (a) I–U characteristic and (b) temperature T of glass cloth vs. applied electric power W.

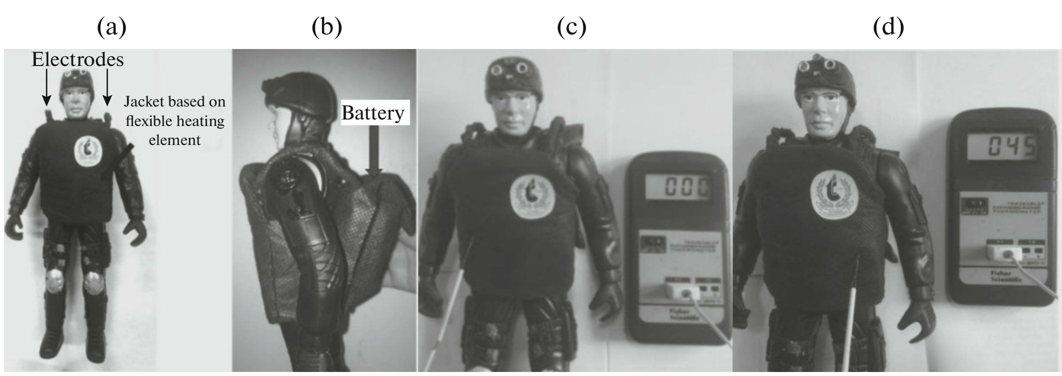

Fig. 5. Images of soldier model with a heating jacket made of the glass cloth with immobilized CNTs (a), (b); and the temperature of jacket before (c) and after (d) connecting to a current source.

(see Figs. 5c, 5d). In principle, it can be raised even to 700–800°C, if some outer protective coating against oxidation of carbon nanotubes with atmospheric oxygen will be additionally installed.

CONCLUSIONS

Cobalt oxide nanoparticles were deposited onto the surface of glass cloth by solution-combustion synthesis and used as a catalyst for the growth of carbon nanotubes via the CVD process. Thus prepared carbon nanotubes 23–26 nm in diameter exhibited good current–voltage characteristics. The heating efficiency of the flexible heating element at low temperature was tested on a soldier model. The smart glass cloth showed good electroconductive and effective Joule heating by an external current source. The conductive glass cloth can be recommended for use in various functional applications.

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