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Flexible film broadband absorber based on diamond-graphite mixture and polyethylene

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ABSTRACT

Flexible film broadband absorber based on diamond-graphite mixture and polyethylene was fabricated by hot pressing. The film thickness of the absorber was 90 μm. We have measured angular reflectivity, diffusional reflectivity and transmittance in the range 85–8000 cm^{-1} (117–1.25 μm) in order to determine the absorption. It was shown that room temperature pressing of mesh print with 250 μm step significantly reduces reflectivity of the absorber. The absorption was over 0.85 in the range 85–320 cm^{-1} (117–31.25 μm) and >0.98 in the range 320–8000 cm^{-1} (31.25–1.25 μm). We believe that the designed and manufactured absorber might become a promising material for optical devices where high broadband absorption and flexibility are required.

1. Introduction

At the present time, the interactions of photon radiation with materials have been actively studied [1–3]. This is due, on the one hand, to the fact that optical properties of materials are studied by using photon radiation [4–8]. On the other hand, characteristics of photon radiation are determined by using optical materials [9]. In many cases, the photon radiation is used to determine reflectivity, transmittance and absorption of new materials [10–14]. Reflectivity, transmittance and absorption of designed materials may be different for each wavelength range [13].

There are many optical high-quality materials, that have been used in different applications. These materials may be optical filters [15], optical waveguides [16], mirrors [17,18], selective mirrors [19], photodetectors [20,21], transparent conductive electrodes [6,13,22], absorbers [23,24] and so on. Among these materials, absorbers are unique materials. This is because the high-quality absorbers possess the smallest reflectivity and transmittance coefficients. Simultaneously, absorption is the largest. Ideally, a high-quality absorber supposed to be a black body where no light is transmitted or reflected. It should be noticed that the black body is a theoretical object that absorbs all photon radiation and the most efficient thermal absorber and emitter [23]. In real life a black body does not exist.

Since the black body efficiently converts light to heat, it makes the black body valuable for many applications. As an example, absorbers like black body have been used in solar thermoelectric converters [25], solar steam generation [26], solar thermophotovoltaic device [27], infrared thermal detectors [28] and so on. There is also specific task of using the absorber like black body. That is a measurement of the absorption temperature dependence and highly reflective coatings emission [29].

There are many methods of manufacturing the absorbers and creating a black surface [30]. For example, it was shown that black surfaces can be obtained by chemical etching of Ni–P alloy [31,32]. The method for creating of absorption coating for solar water heating applications is known [33]. Recently developed metamaterial absorbers for the terahertz range are interesting and promising for to use [34–39]. Also, nanostructured materials can be used as high-quality absorbers [40]. However, most of the absorbers have a narrow absorption range that limits their application.

To expand the absorption range, it is necessary to use carbon materials due to their absorbing properties. However, absorption and emission of carbon materials are limited in 0.8–0.85 because of reflection at interface. Nanostructured carbon materials can be used to resolve this issue. In the study [23], it was shown that the high-quality absorber from vertically aligned single-walled carbon

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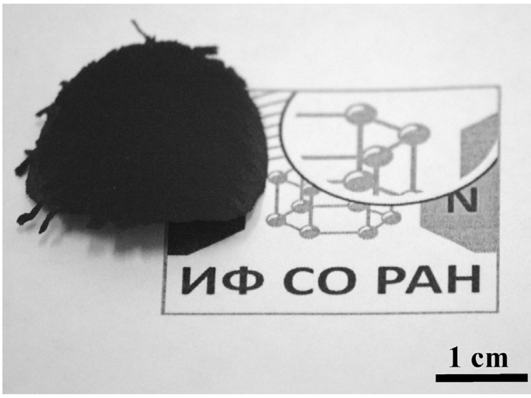

Fig. 1. A typical image of the film flexible absorber based on diamond-graphite mixture and polyethylene.

nanotubes absorbs light across a very wide spectral range 0.2–200 μm. However, most of absorbers based on nanostructured carbon materials that have been made on solid substrates with no have flexibility.

In this study, we have developed and fabricated a flexible film broadband absorber using diamond-graphite mixture and polyethylene. Angular reflectivity, diffusional reflectivity and transmittance of the absorber were investigated in the range 85–8000 cm^{-1} (117–1.25 μm).

2. Experimental

Diamond-graphite mixture and ultrahigh molecular polyethylene (UMP) were used to produce the flexible film absorber. The diamond-graphite mixture was obtained by the detonation synthesis. The method details can be found in references [41–43]. The diamond-graphite mixture contains up to 35% of nanodiamonds, 55–60% of non-diamond forms of carbon, and 5–10% of metal-containing impurities (mainly iron, its oxides and copper from explosive chamber material, detonators and wires). Here the weight percentages are implied. The ultrahigh molecular polyethylene was bought in Sigma-Aldrich. The diamond-graphite mixture was mixed with the ultrahigh molecular polyethylene in an agate mortar. The weight percentage for the diamond-graphite mixture and UMP was 25% and 75%, respectively. During manufacturing process of a film absorber, we tried to maximize the weight content of diamond-graphite mixture. However, over 25% of diamond-graphite mixture content, the absorber was brittle and collapsed. Thus, 25% of diamond-graphite mixture was in optimal weight ratio.

Pressing of diamond-graphite mixture and UMP substances was produced by the Spekac Hydraulic laboratory press 15t (Germany) using a special shape and metal rings. The pressing temperature was 110°C. Obtained absorber film had thickness of ~90 μm and a good flexibility. A circle with a diameter of 9 mm was cut out from the absorber film. Mesh print with 250 μm step was made by using room temperature pressing to reduce reflectivity of the absorber. Press strengthening was 1000 kg.

To study the optical properties of obtained absorber film in near, middle and far infrared region, we used Bruker Vertex 80 Fourier-spectrometer (Germany) equipped with a variable angle reflection accessory A513 and diffuse reflectance accessory EasiDiff of PIKE Technologies (USA). Bruker optical microscope Hyperion 2000 was used to view the mesh print on the surface of the absorber film.

3. Results and discussion

Fig. 1 shows a typical film absorber obtained from diamond-graphite mixture and polyethylene.

To determine transmittance of the manufactured flexible film absorber, we have conducted measurement in range 85–8000 cm^{-1} (117–1.25 μm) as shown in Fig. 2.

As can be seen from Fig. 2a, the transmittance of the flexible film absorber strongly decreases while the wave number increases. The transmittance was 0.091 and 0.0036 at wave number of 85 and 670 cm^{-1}, respectively. In the range 400–8000 cm^{-1}, the transmittance continues decreasing up to 6000 cm^{-1} as shown in Fig. 2b However, at the beginning from 6000 cm^{-1} the transmittance slightly increases. Generally, the transmittance of the flexible film absorber did not exceed 0.004 in this region. It might be noticed from Fig. 2b that there are three regions of a significant decrease in the transmittance (717, 1458 and 2890 cm^{-1}) which are related to

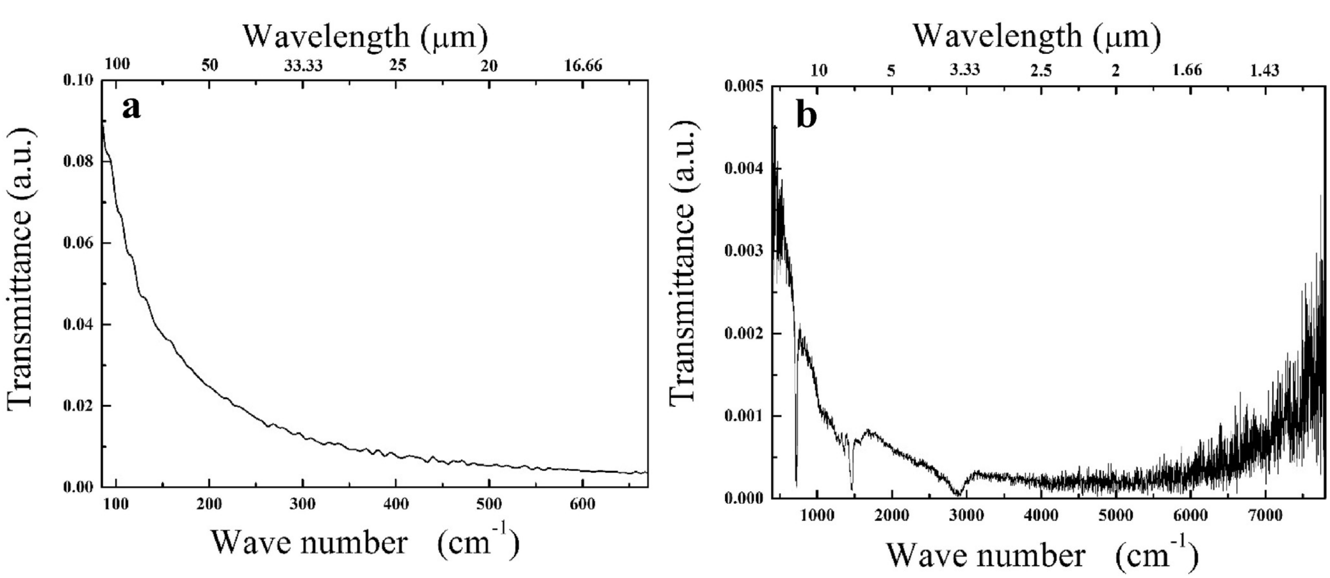

Fig. 2. The film absorber transmittance in range: (**a**) 85–670 cm^{-1} and 400 -8000 cm^{-1} (**b**).