Issue VI, 22 November 2023
e-ISSN 2707-9481
ISBN 978-601-323-356-7
Institute of Metallurgy and Ore Beneficiation, Satbayev University, Almaty, Kazakhstan
https://doi.org/10.31643/2023.29

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Investigation of vibrational properties of carbon films obtained by magnetron sputtering method

Abstract: In the present work, thin carbon films and nanofibers of different morphologies were obtained by magnetron sputtering on a modernized VUP-2 unit. Information of vibrational properties of carbon films and nanofilaments was obtained by Raman spectroscopy. Carbon nanofilaments were obtained in the G band region 1580-1595 cm-1, which is in good agreement with the known literature data. Apparently, the most fascinating results were achieved when steel-3 was used as a substrate. This is probably due to the presence of carbon in steel-3, which serves as a condensation center for the formation of carbon structures, including carbon tubes. The study of amorphous films and their applications in diverse industries constitutes a significant area of scientific research, and this article offers an overview of synthesis methods and potential material applications.
Keywords: Carbon thin films, magnetron sputtering, vibrational properties, material applications, synthesis methods.

Cite this article as: Baitimbetova B., Kydirbai G. (2023). Investigation of vibrational properties of carbon films obtained by magnetron sputtering method. *Challenges of Science*. Issue VI, 2023, pp. 237-239. https://doi.org/10.31643/2023.29

Introduction

Nowadays, the production of thin films from metals and semiconductors is becoming increasingly important. Modern microelectronics is largely based on the use of thin film technologies (Chen, 2001; Karboz & Dossayeva, 2019). The main methods of deposition of such films and layers with thicknesses measured in hundreds and thousands of nanometers are vacuum deposition methods. These methods allow to obtain films with a given composition and desired geometric profile, while possessing a high degree of repeatability. One of the most promising and dynamically developing classes of materials are carbon nanostructures. The creation and study of thin carbon materials with various structures intended for use as sensors in micro-, nano-, and optoelectronics (Nafradi et al., 2006; Garcia, 2002; Johnson, 2000) remain urgent tasks in the field of molecular electronics (Kenzhaliyev, 2019; Smith, 1998; Wan, 1999).

It is important to note that film formation processes play a key role in many methods of creating nanostructures. In a general sense, technology embodies a set of methods and means used to achieve specific goals and transform an initial state into a desired state. Thus, thin film technology in this context is a set of methods used to create and modify thin films, as well as the corresponding equipment. It is important to note that the properties of films are closely related to the conditions under which they are produced, so thin film technology also addresses sample characterization and methods for studying them. Magnetron sputtering is based on the formation of a ring-shaped plasma above the surface of the cathode. This plasma results from the collision of electrons with gas molecules, most often argon. During the discharge process, the positive ions formed are accelerated towards the cathode and bombard its surface, resulting in the knocking out of material particles from this surface. The purpose of this work is to create thin carbon films and nanofilaments of various shapes using the method of magnetron sputtering on the modernized unit VUP-2.

Experimental Setup and Methods

A technique for synthesizing carbon nanofilaments using magnetron nanotechnology has been developed and successfully applied. This process is carried out by magnetron sputtering of graphite target at constant current and different pressures of working gas at room temperature. The coating rate under fixed conditions is: voltage U=500 V, discharge current I=30 mA, temperature T=250°C, pressure P=3.2 * 10^{-2} Pa, and application time t=10 minutes. Raman spectra were measured using MT-MDT Ntegra Spectra at room The spectra were excited by a semiconductor laser (λ=473 nm).

Results and Discussion

Information on the nanostructure of hydrocarbon clusters in the structure of carbon films can be obtained by Raman spectroscopy. The results of Raman spectroscopy of the samples obtained by us are summarized in Table 1 and fig 1. Raman spectroscopy, which investigates the vibrational modes of a carbon matrix, is a valuable source of information.

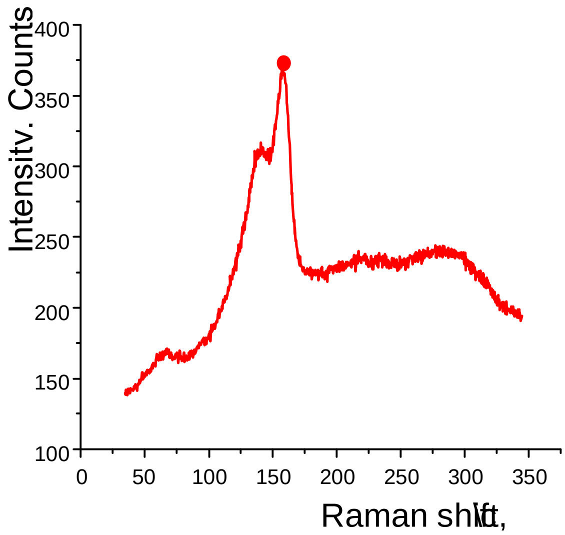

Figure 1. Raman spectrum obtained by synthesis on a substrate (steel-3) using the magnetron sputtering technique.

Table 1. Parameters of Raman spectra of carbon films obtained by magnetron sputtering method

Substrate	D-line		G-line
ω, cm^{-1}	**Width of lines at half height, cm^{-1}**	**ω, cm^{-1}**	**, Width of lines at half height, cm^{-1}**
~1348	62	~1584	72
~1359	38	~1588	52
~1348	61	~1584	21

From the presented graphical data, it can be seen that two characteristic bands are observed in all the spectra: the D-line in the region of 1350 $cm^{-1}$and the G-line in the region of 1593 cm^{-1}.

In the spectra of glass, organic glass and steel-3 films, a relatively intense graphite G-band spectrum in the region of 1580-1590 cm^{-1} /From the presented graphical data, it can be seen that two characteristic bands are observed in all the spectra: the D-line in the region of 1350 $cm^{-1}$and the G-line in the region of 1593 cm^{-1}.

In the spectra of glass, organic glass and steel-3 films, a relatively intense graphite G-band spectrum in the region of 1580-1590 cm^{-1} is observed, indicating the presence of well-ordered carbon nanotubes.

The crystalline X-ray spectra of carbon films, as well as the spectra of various modifications of amorphous carbon in glass, organic glass, and steel-3 substrates, are characterized by the presence of a broad band, which can be conditionally divided into two components of Gaussian type, with a small compound component in this region. A distinctive feature of these films is the presence of a substantial amount of nanostructured graphite. These results are confirmed by X-ray diffraction studies, which also reveal peaks of crystalline graphite at 1360 cm^{-1} and 1590 cm^{-1}.

Of the three substrates considered, the sample formed on steel substrate (steel-3) appears to be the most efficient. This can be explained by the presence of carbon in the steel-3 material, which serves as a center for the crystallization of carbon nanotubes, which promotes more intense formation of graphite structure.is observed, indicating the presence of well-ordered carbon nanotubes.

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Conclusions

The study of thin carbon films on glass, organic glass, and steel-3 substrates using Raman light scattering revealed the presence of a rather intense graphite G-band spectrum in the region of 1580 cm^{-1}-1595 cm^{-1}. This characteristic indicates the presence of well-ordered carbon nanotubes in these films.

The most interesting results were obtained when steel-3 was used as a substrate. This is probably due to the presence of carbon in steel-3, which serves as a center for condensation of carbon structures including carbon tubes. This contributes to a more efficient formation of ordered carbon nanostructures and, consequently, a more intense G-band spectrum in the Raman spectrum.

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