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CONTEMPORARY NANOMATERIALS FOR LOW VISIBLE AIRPLANE CONSTRUCTION

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Abstract**—***Reflective properties of different objects such as airplane, space apparatus, solar cells depend from the dielectric properties of its surface materials. The dielectric properties of different composites from carbon nanotubes were investigated. These composites are an effective surface materials for low visible airplane construction. It is found that at decreasing of thickness of sample the rapid drop of passing monochromatic irradiation intensity is observed. The sample thickness range varies from 0.1 mm till 0.6 mm. This phenomenon is explained due to changing in orientation of the carbon nanotubes. It leads to increasing of efficiency of monochromatic irradiation absorption by the objects.*

Index Terms—Dielectric properties; nanomaterials; carbon nanotubes composites; low visible objects.

I. INTRODUCTION

Among the requirements for a modern airplane is a requirement of their low visibility, i. e. low reflectivity with respect to electromagnetic radiation. The reflectivity of the airplane is determined primarily by their construction and dielectric properties of their surface materials. The urgency of such studies caused nontrivial physical properties of sets of small particles and disperse systems, as well as the possibility of their use in the new set of effective absorbing and scattering surface materials with new optical properties for the purposes of such promising areas as nanophysics, optoelectronics airplane construction materials. The interaction of light with nanostructured substance is the essence of nanooptics. Unusual is the fact that the size of nanoparticles (~ 10 nm) is much smaller than the wavelength of light (400–700 nm), that is 1–2 orders smaller than the diffraction limit.

Nonlinear optical properties of nanoclusters in transparent medium is a diverse field of research. The absorption maximums are have been found in the spectra of nanoparticles Li, In, K, Na, Ca. The peculiarity of the metal nanoparticles optical properties is plasmon resonance absorption and scattering associated with the interaction of electromagnetic radiation from the plasma of free electrons in the metal. The spectral position of these features (400–700 nm) depends on the material, its size, shape and energy of free electrons in the nanoparticles.

Generally, carbon nanotubes (CNT) have good electro- and thermal conductivities, and mechanical stability and are considered as one of the most perspective objects of nanoelectronics. They are elements of such electronic systems, as cold field emitters, super condensers, solar elements, nanosystems, detectors, etc.

On the basis of carbon nanotubes the devices reacting to the total spectrum of an optical range of electromagnetic waves is developed. Application of such detectors is extremely wide: cells of solar batteries with high efficiency, digital cameras working at very low light exposure, an artificial retina, and etc. Detectors on the basis of carbon nanotubes can be formed on the flexible polymeric support, that does them cheaper in manufacturing and absolute harmless for a human body.

II. METHOD OF MEASUREMENT

We used two sources of generation of infrared irradiation: light source non-monochromatic - filament bulb and laser unit, which generated monochromatic beam of wavelength $\lambda = 1.06$ μm, the generation time $\tau = 1 - 2$ ms, energy source of the beam $E = 100$ mJ.

Installation for measurement infrared non-monochromatic irradiation of composites poly-tetrafluorethylene (F4)-CNT with different percentage of CNT, consisted of a metal sample – standard Al and metal sample – Al sensor on which a thin layer or as a flattened tablets of investigated samples F4-CNT with different concentration of CNT were layered. Both metal samples Al-standard and sensor connected to a multimeter using differential thermocouple. The flow of electromagnetic irradiation that was generated and emitted by filament bulb interacts with Al-standard and composite F4-CNT. As a result of this interaction in substances generated by the flow of free charge carriers, which leads to thermoelectric force which values are recorded using a multimeter. Received values of voltage of standard and investigated composite F4-CNT are transferred in values of temperature, using graduated table for thermocouple chromel-alumel.

Experimental equipment for the measurement scheme of monochromatic infrared irradiation of composite F4 – 5 % CNT with different thickness consisted of a metal structure, reception element, recording unit and laser sources. By means of me-

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chanical compression model F4 – 5 % CNT the different thickness was received. The electronic microscopy photography of oriented CNT massive on Ni-substrate is shown in Fig. 1.

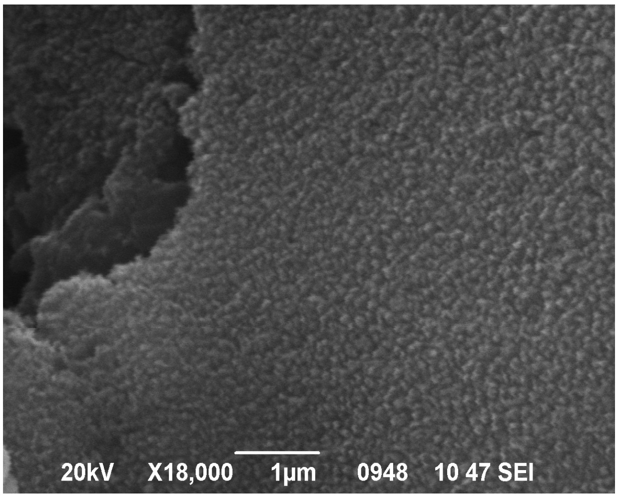

Fig. 1. Electronic microscopy photography of oriented CNT massive on Ni-substrate

Than, a sample of specific thickness was layered on the glass was settled between two metal discs, which are further connected by screws. This metal structure attached to the measuring head, which fixed the value of energy of laser irradiation passed through the sample. The principle of the device was to reception the acquisition of element (measuring heads) power (or energy) of laser irradiation and converting it into an equivalent value of thermoelectric power the value was recorded to the recording unit.

III. Results and Discussions

Received dependence of heating temperature of samples F4, F4-0.5 % CNT, F4-0.1 % CNT, F4-1 % CNT, F4-2 % CNT, F4-3 % CNT, F4-5 % CNT, F4-10 % CNT, F4-15 % CNT, F4-25 % CNT from concentration of CNT in sample and absorbed electromagnetic irradiation by F4-5 % CNT with different thickness. The max rate of composite heating of F4-CNT (Fig. 2) corresponds to the content of 15 % of CNT. More slowly heated composite with a lower percentage of CNT in the structure of F4-3 % CNT and thus even slower heating of the sample F4. Analyzing the obtained dependences, we can conclude that increasing the percentage of carbon nanotubes in the sample F4-CNT leads to an increase in heat transfer processes and processes of thermoconductivity in the composite.

To learn how composite F4 with different percentage of CNT, heat faster or slower relate to standard Al was plotted graph the difference ΔT, °C between heating temperature of standard Al and heating temperature of composites F4-CNT depending on the percentage of CNT k, % in the sample (Fig. 3). The resulting graph has non-monotonic behavior of the temperature ΔT, °C of k, %. The first stage of adding a small amount of CNT to F4 leads to an increase of values ΔT, but interesting behavior is observed for 2 % of CNT in F4. There is the sharp decline of curve for ΔT (k) values from 6.42 °C to 5.47 °C. However, at a greater addition to the F4 CNT function ΔT (k) grows, it achieves satiation and after that the curve monotonously declines ΔT (k). This non-monotonic behavior of heating temperature rate of the sample relative to the standard can be explained using the following Fig. 4.

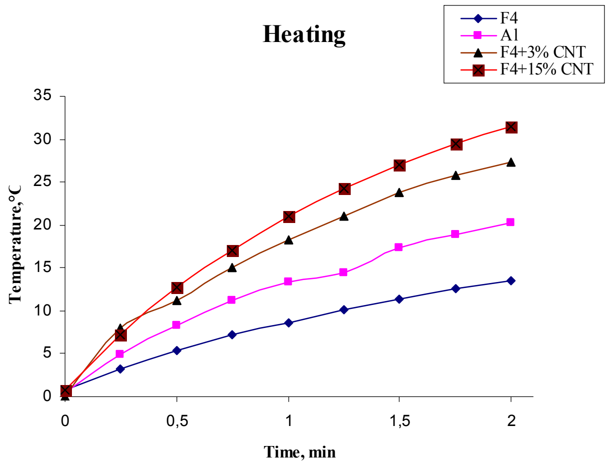

Fig. 2. Dependence of heating temperature T, °C standard Al, F4 and composites F4-3 % CNT, F4-15 % CNT from heating time t, min

By comparing the Figs 3 and 4 we can see the tendency of heating temperature change behavior of the sample and changes in inductive capacity (dielectric permeability) of medium from the concentration of filler CNT in it.

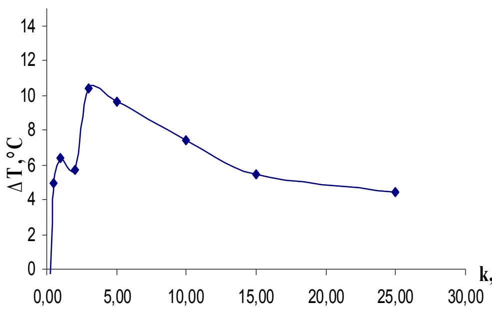

Fig. 3. Dependence of the difference ΔT, °C between heating temperatures of standard Al and composites F4, F4-0.5% CNT, F4-0.1% CNT, F4-1% CNT, F4-2% CNT, F4-3% CNT, F4-5% CNT, F4-10% CNT, F4-15% CNT, F4-25% CNT from percentage of CNT k, %

Causes of the detected anomalies have not yet been determined. However, we can make the following assumptions. In the investigated system insulator – conductor inductive capacity (dielectric permeability) behavior determined by the Maxwell - Wagner polarization, surface energy as a conductor [2] and insulator, and conductivity of the whole system and its proximity to the percolation threshold [3]. At low concentrations of filler CNT in the composite are formed structure and ε value increases due to the Maxwell – Wagner polarization. However, with increasing concentration and with the presence of a large difference in surface energy of F4 and carbon nanotubes, the composite structure becomes unstable and the nanotubes begin to form conglomerates, which surface is less than the total surface of their constituent nanotubes.

As a result, Maxwell–Wagner polarization decreases. In addition, changes in the nanostructure, which is a result of mechanical mixing and compression in the polymer, changes its shape from elongated to globular, leads to the displacement threshold percolation in the direction of large concentrations and reduces the dielectric permeability of composite.

The result of all these mechanisms reduced the value of ε. Further ε value increasing with filler concentration increasing in the composite leads to increase of the number of agglomerates and bundles of nanotubes, which reduces the dielectric layer between the major structures and leads to increases of electrical capacity. Due to the random variation of sizes and forms of nanotubes agglomerates decreases the value of dielectric permeability ε.

Below the changes in the intensity of absorbed irradiation after passing a laser (monochromatic) radiation through the sample F4-5 % CNT of different thickness are presented.

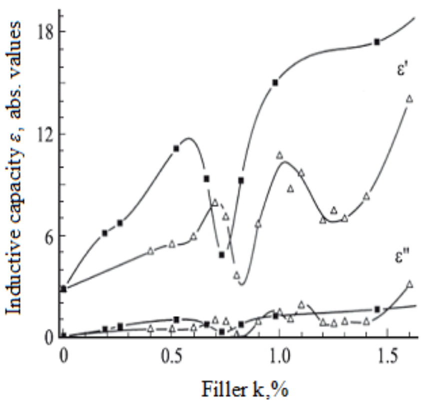

Fig. 4. Dependence of inductive capacity (dielectric permeability) of composite ε, abs. values, from the filler concentration *k*, % [4]

During a mechanical compression of the sample F4-5 % CNT with different thickness, orientation of carbon nanotubes changed from vertical to, mostly, horizontal, CNT oriented along the sample surface. As a result of F4-CNT sample anisotropy the intensity of irradiation which absorbed and passed through sample started to change and began to depend on the size and orientation of particles in composite F4-5 % CNT. So, the dielectric and reflected properties of composites change also.

As a result of the investigation we can conclude that with decreasing thickness of the composite with carbon nanotubes F4-CNT the rapid drop of intensity of passing monochromatic infrared irradiation (λ = 1.06 μm) is observed in the range of sample thickness from 0.1 nm till 0.6 mm (Figs 5, 6).

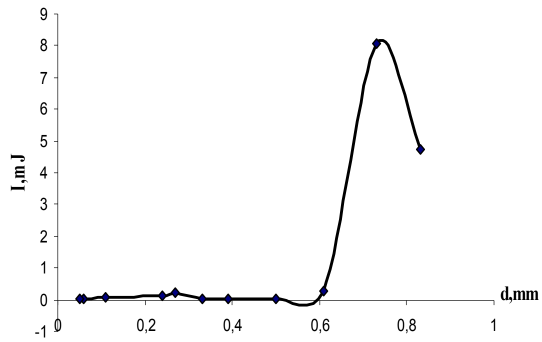

Fig. 5. Dependence of the intensity of absorbed irradiation I, mJ from thickness *d*, mm of composite F4-5 % CNT

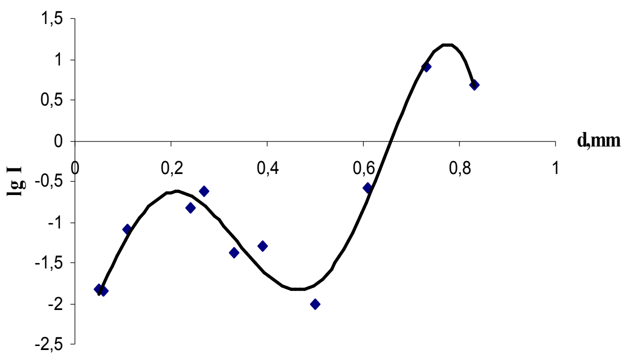

Fig. 6. Dependence of the intensity of absorbed irradiation lg I from thickness d, mm of composite F4-5 % CNT

CONCLUSIONS

As a result of the investigation we can conclude that with decreasing thickness of the composite with carbon nanotubes F4-CNT rapid drop of intensity of passing monochromatic infrared irradiation (λ = = 1.06 μm) is observed in the range of sample thickness from 0.1 nm till 0.6 mm, due to reorientation of CNT from chaotic to the direction along the sample surface F4-CNT. This leads to increasing of the efficiency of monochromatic infrared irradiation absorption by composites. The dielectric and reflective properties of composites change also.

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Д. Е. Азнакаєва, Т. В. Бородій. Сучасні наноматеріали для побудови слабко видимих літальних апаратів

Досліджено діелектричні властивості різних композитів з карбонових нанотрубок. Ці композити є ефективними поверхневими матеріалами для побудови слабко видимих літательних апаратів. Встановлено, що при зменшенні товщини зразка спостерігається швидке падіння інтенсивності монохроматичного випромінювання. Діапазон товщин зразка варьювався від 0,1 до 0,6 мм. Це явище пояснюєтся зміною орієнтації вуглецевих нанотрубок, що призводить до збільшення ефективності поглинання монохроматичного випромінювання об’єктом.

Ключові слова: діелектричні властивості; наноматеріали; композити з карбонових нанотрубок; слабковидимі об’єкти.

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Д. Э. Азнакаева, Т. В. Бородий. Современные наноматериалы для построения слабо видимых летательных аппаратов

Исследованы диэлектрические свойства различных композитов из карбоновых нанотрубок. Эти композиты являются эффективными поверхностными материалами для построения слабо видимых летательных аппаратов. Установлено, что при уменьшении толщины образца наблюдается быстрое падение интенсивности монохроматического излучения. Диапазон толщин образца варьировался от 0,1 до 0,6 мм. Это явление объясняется изменением ориентации углеродных нанотрубок, что приводит к увеличению эффективности поглощения монохроматического излучения объектом.

Ключевые слова: диэлектрические свойства; наноматериалы; композиты из карбоновых нанотрубок; слабовидимые объекты.

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