Influence of MWCNT in polytetrafluoroethylene on the parameters of electronic structure and absorption of UHF radiation

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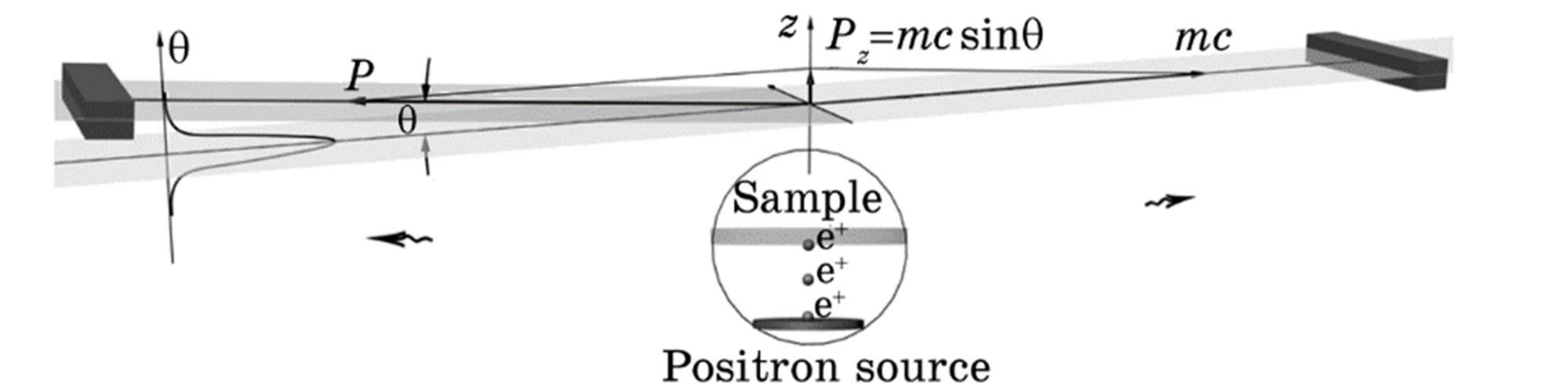


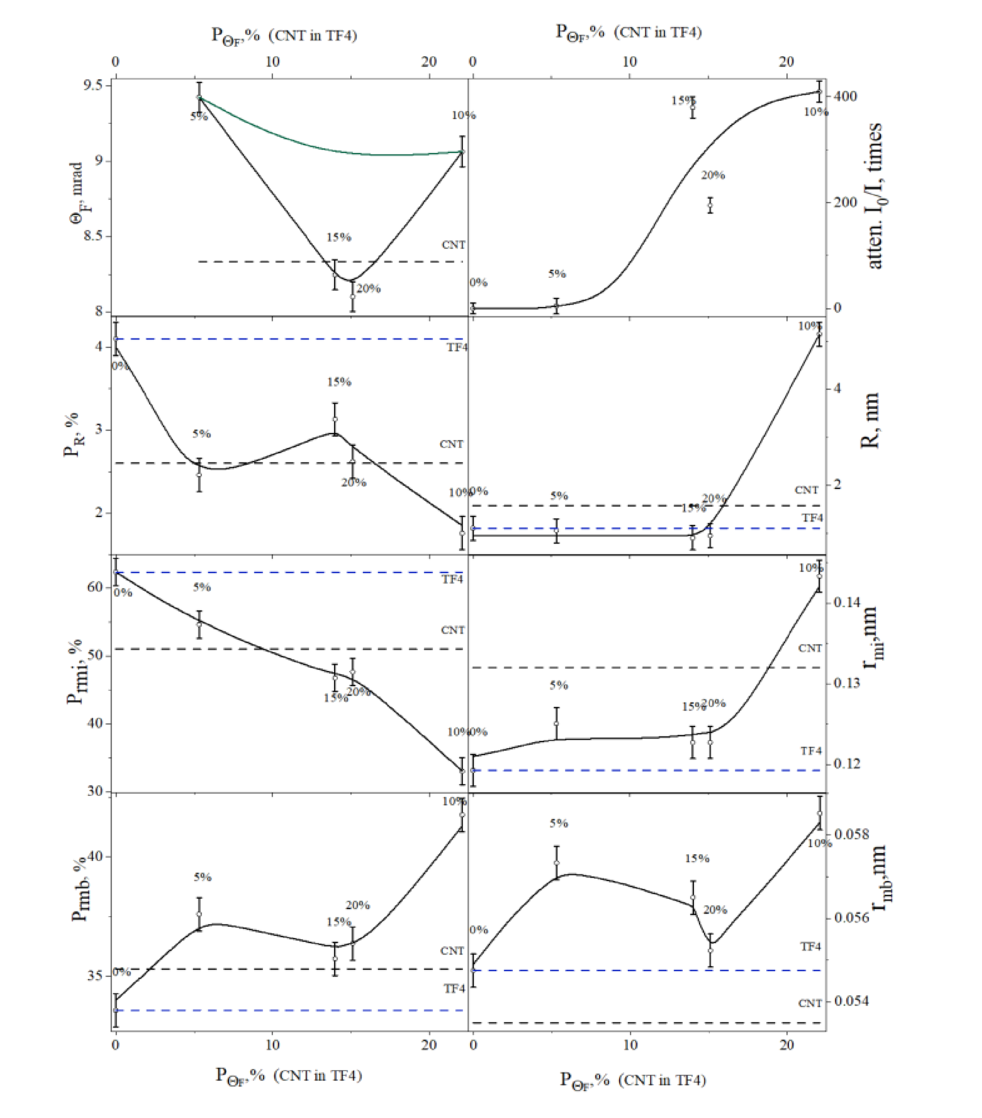
Schematic diagram of the angular correlation spectrometer of annihilation radiation

$$I^{theor}(\theta) = I_P\left[\frac{\theta_F^2-\theta^2}{2} + A_B T ln\left(1+exp\left\{-\frac{\theta_F^2-\theta^2}{2A_BT}\right\}\right)\right] + \sum_{j=1}^{3}\frac{I_G^j}{\sigma_j\sqrt{2\pi}}exp\left\{-\frac{\theta^2}{2\sigma_j^2}\right\}$$

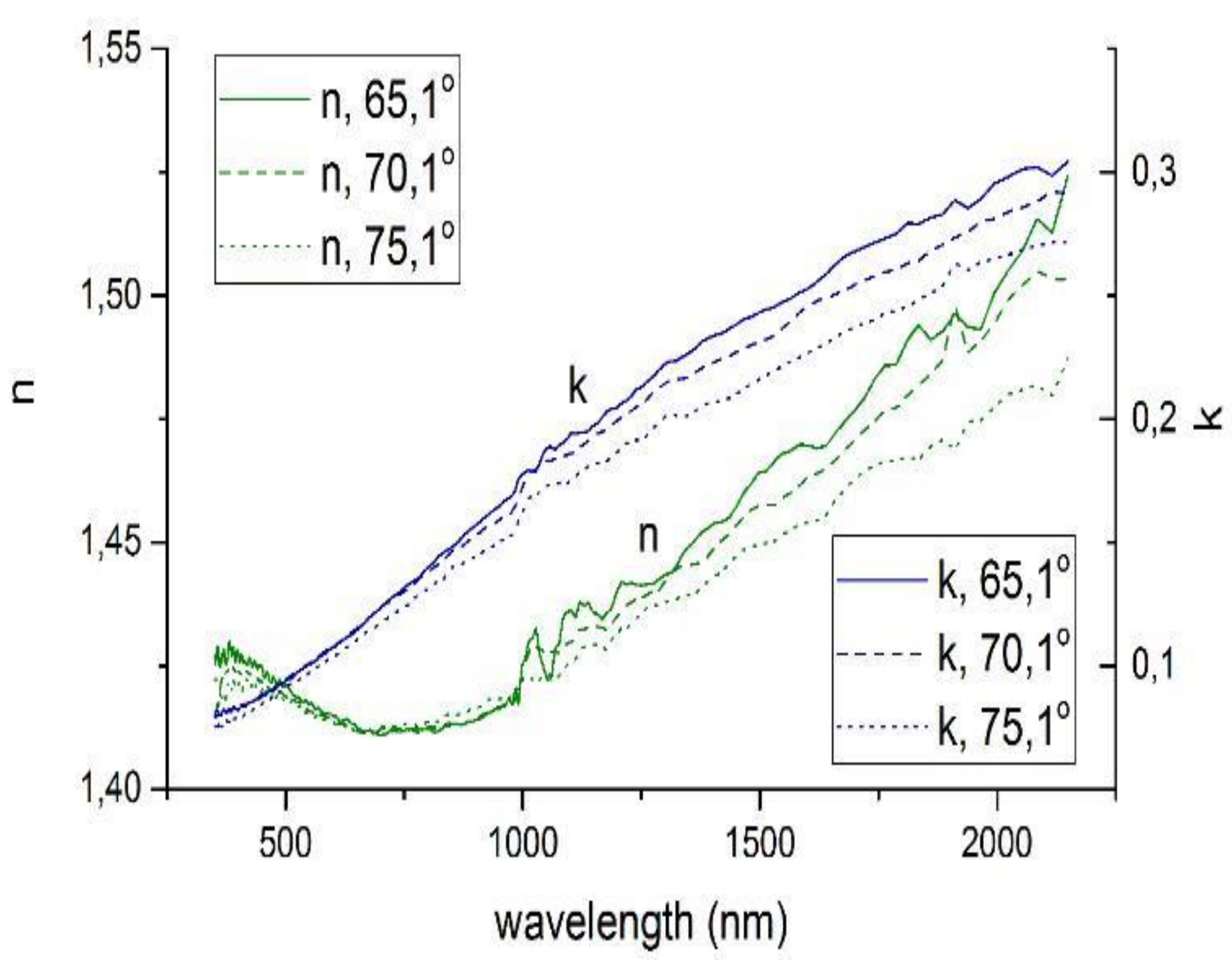
Using the methods of angular correlation of annihilation radiation (ACAR), attenuation of electromagnetic radiation (ER) of UHF diapasone, and optical ellipsometry, it was shown that a 2% decrease in the probability of annihilation of positrons in pores of free volume is accompanied by 15–25% changes in other parameters of electronic structure of composites contained the polytetrafluoroethylene and multiwalled carbon nanotubes (PTFE+MWCNTs). PTFE is transparent to electromagnetic radiation, but after the addition of 10 wt% MWCNTs, it demonstrates a more than 400-fold decrease in the ER intensity when the radiation passes through a specimen with a thickness of ≈2 mm.

The measurements of the attenuation of electromagnetic radiation in the composite samples were carried out on an automatic attenuation meter P2-52/3 in the frequency range of 1.5–2.0 GHz according to the standard scheme for attenuation measuring in four-pole networks using a copper standard. The optical properties of the samples — the spectral dependences of the refractive indices *n* and absorption *k* — were obtained using angular ellipsometry. The ACAR spectra for the studied samples were obtained using a long-slit annihilation spectrometer with an angular resolution of 1.07 mrad.

It was found that the average radius of the free volume pores *R* and the probability P_R of annihilation of positrons in this area are determined by the electronic structure parameters of the polymer matrix only. The Fermi angle Θ_F and corresponding probability of positrons annihilation with free electrons are determined by the electronic structure parameters of MWCNTs only. Since the electronic structure of the cores and defects of the polymer matrix (at least outside the interphase) does not change, changes in these characteristics are mainly due to changes in the MWCNTs electronic structure. It was found that in a specimen with 10 wt% MWCNTs, the highest density of free electrons is observed, and the highest electron density is observed on defects. The average of free volume pore radius reaches its maximum value at 10 wt% MWCNTs in the composite.



Dependences of the parameters of the electronic structure and absorption of electromagnetic radiation at a frequency of 2 GHz in the PTFE + MWCNT composites on the probability of annihilation of positrons with free electrons P_{θ_F}



Spectral dependences of refractive indices *n* and absorption *k* at three different angles of incidence for a composite with 10 wt% MWCNTs.

The absorption of ER increases with an increase in the free electrons density in MWCNTs. The maximum absorption of ER is observed at a concentration of MWCNTs equal to about 10 wt%. When the composition of the composite approaches pure MWCNTs, the absorption again significantly decreases (by more than an order of magnitude). The colossal ER absorption effect (>400 times) is due to the fine structure of the π-electrons density of states in MWCNTs near the Fermi level. In MWCNTs there is a rather high concentration of itinerant π-electrons and, at the same time, almost zero density of their states at the Fermi level. There are almost no free states above the Fermi level, and π-electrons hardly participate in the processes of small excitations. Due to the transfer of charges from the matrix to MWCNTs (or vice versa), the position of the Fermi level in composite changes and allowed states appear in the density of states immediately above it. As evidenced by the spectral dependences of the refractive indices and absorption coefficient, this leads to an almost linear increase in absorption in the entire investigated wavelength range. Moreover, the same almost 100% absorption should presumably be observed in the infrared range of radiation.