PLASMA-MECHANICAL OSCILLATIONS IN CARBON NANOTUBES ARRAY

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Abstract – The results of the simulation of plasma-mechanical oscillations in carbon multiwalled nanotubes array under electromagnetic radiation are presented considering thermal fluctuations, internal stress, static load and the ponderomotive forces between the nanotubes.

I. INTRODUCTION

Recently a great interest in the study of the interaction between the electromagnetic radiation (EMR) with the frequency range from 1 GHz to 1 THz and the carbon nanotubes (CNTs) arrays has grown up. Despite the large number of existing works on measurements and modeling of these processes, many things still remain unclear. The cases of interaction of the EMR with individual single-walled CNTs are mainly considered in the theoretical works, while the known phenomenological models developed for composites containing nanoparticles are used in the experimental works for the interpretation of the data obtained.

The aim of the work is to simulate the plasma-mechanical oscillations in a multi-walled carbon nanotubes array under the influence of electromagnetic radiation taking into the account the ponderomotive forces between the nanotubes, thermal fluctuations, stress and static load.

II. PLASMA-MECHANICAL OSCILLATIONS

The real arrays of aligned CNTs are far from perfect, they are characterized by heterogeneity, the presence of branches, intersections, curves, bridges, contacts between the tubes and the inclusion of magnetic nanoparticles. The characteristic dimensions of the free fragments of CNTs between the points of attachment, contact, or bending are tens or hundreds of nanometers.

Free fragments of CNTs in the array, having high elasticity, undergo mechanical vibrations. Such fluctuations are caused both by external (mechanical stress, heat, electric and magnetic fields, currents) and inner (thermal fluctuations, magnetoelastic effects, residual strains and stresses) factors. The free CNT fragments are characterized by natural frequencies of mechanical oscillations, the values of which are determined, additionally to the CNTs radii, the elastic moduli and the lengths of these areas, by the presence of fixtures and strains.

The charge fluctuations are determined by the characteristic frequencies of plasma oscillations, which are excited by passing a current through a nanotube, and external radiation. EMR generates eddy currents in the conductive CNTs with characteristic frequencies depending on the CNTs size, their conductivity, and the Fermi velocity, which values lie in the range of 50 GHz and above.

Multi-walled CNTs with a diameter of 30-50 nm and a length of 300-500 nm oscillate with a natural frequency of the mechanical vibrations of 1-2 GHz and have a quality factor of 1000 at room temperature [1].

III. RESULTS AND DISCUSSION

The calculations performed have shown that the mechanical vibrations of CNTs may be excited both by the presence of the original CNT bending under the static load, and due to the charge oscillations of neighboring CNTs. In the first case, in the absence of repulsive forces between the CNTs the vibrations are damped with a time determined by the damping constant γ. In the second case, the oscillations are forced.

The results obtained for the case of a relatively small external force are shown in Fig. 1 for center of CNT corresponding to the center of the free CNT fragment.

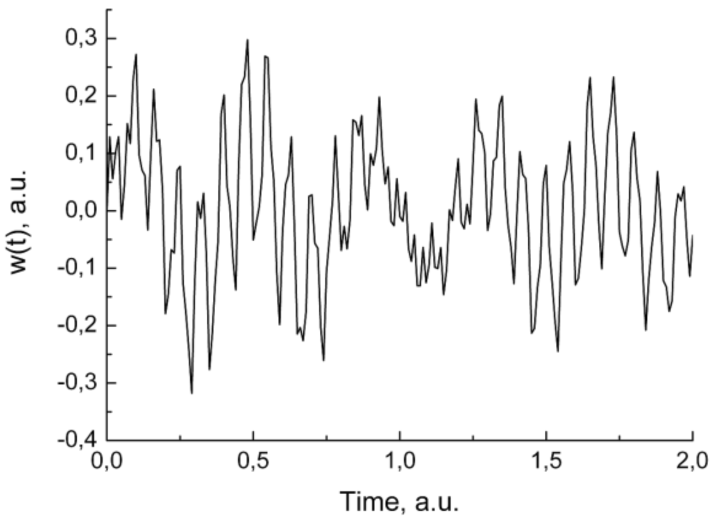

Figure 1 - The CNT fluctuations in the case of relatively small repulsion force between the CNTs.

IV. Conclusion

With the growth of the repulsive force at a frequency of about 80 times greater than CNTs natural frequency, the amplitude-modulated periodic oscillations appeared with two characteristic frequencies.

The preliminary results of the calculations have shown that the presence of the noise component of force leads to stochastic fluctuations.

References

[1] D. Dragoman, M. Dragoman. Electromagnetic wave propagation in dense carbon nanotube arrays// J. Appl. Phys. – 2006. – Vol.99, – P.076106 (3 pages).