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ELECTRON MICROSCOPY CONTRAST IN IMAGES OF AMORPHOUS OBJECTS

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The theory and the methods of interpreting contrast in the EM images of crystalline or partially crystalline substances are given in detail in many articles and monographs. The number of works devoted to the detailed analysis of contrast formation in the EM images of amorphous materials is much less. It is generally accepted that formation of the EM images of the amorphous objects could be described rather strictly within the framework of the amplitude contrast theory. In the bright field imaging mode the contrast formation, when considered classically, is formed by occlusion and absorption of electrons in the sample.

The amplitude contrast theory is particularly developed for organic objects and materials comprising light atoms (C, SiO_2 etc.). As a rule, it is assumed here that the microstructure of the material is highly homogeneous, while contrast heterogeneities in the EM images are primarily determined by the difference in thicknesses or masses of different local areas of the sample under study. Many amorphous objects reveal more complex structure on the microstructural level. Therefore, existing theoretical approaches to analyzing the amplitude contrast of such objects are very limited and do not take into account a number of important factors that influence essentially the process of formation of their EM images. Accordingly, theoretical clarification of the character of the influence of different structural details of the complex amorphous samples on the quantitative parameters of their image contrast is an important and topical task.

To determine quantitatively the amplitude contrast of the electron-microscopic images it seems expedient to apply a strict approach similar to that used in optics. In accordance with such approach, it has been suggested to calculate the amplitude (absorption) contrast in the electron-microscopy images of the amorphous objects with different types of heterogeneities of the atomic and continual structure as $K = (\Phi_1 - \Phi_2)/\Phi_1$, where Φ_1 and Φ_2 are the total fluxes of electrons scattered beyond the aperture diaphragm by the two analyzed local areas of the object under study. Such determination of the contrast ensures the following important conditions: i) linear dependence of the contrast value between the elements of the image for two local areas of the object on the difference of the total fluxes Φ of electron beams formed by these elements; ii) contrast variations are registered in the interval from 0 до 1 relative unit; iii) the contrast value can be determined both through the variation of the fluxes Φ_1, Φ_2 and via their ratio Φ_2/Φ_1.

In preposed relation, the flux value Φ_i for a certain local area of the sample is determined by the total contribution of all its structural parameters, i.e. the chemical composition, the atomic structure, the geometrical thickness, the presence of nanopores etc. Therefore, the determined contrast value K will reflect by all the structural parameters the integral difference of the two areas under analysis. It is not a simple experimental task to find the contribution to the contrast of one of the above parameters. In our opinion, it must include the X-ray microanalysis of the differences in the chemical composition of these areas with nanometer locality; the micro- and nano-diffractional investigations of their atomic structure with the registration of the relevant diffractograms; the measurements of the geometrical thicknesses of these areas, e.g. by the force microscopy methods. Today such studies are being carried out by us for the amorphous films of some arsenic and germanium chalcogenides.