I. A. Abroyan, V. V. Korablev, N. N. Petrov, and A. I. Titov, *Secondary-Emission Methods of Investigating the Structure and Composition of the Surface Layers of Solids*. Comprehensive systematic analysis of the surfaces of solids and of their surface layers (element composition, structure, electron properties, and so on) have recently attracted enormous attention.[1] This paper reports a review of work carried out in the Department of Physical Electronics of the M. I. Kalinin Polytechnic Institute in Leningrad. In addition to the traditional approach to the problem (Auger electron spectroscopy, diffraction of slow electrons, and so on), these problems are being tackled by techniques based on new methods and on physical processes that have not as yet been used as a matter of routine in other laboratories.

1. Method of studying the structure of the surface layer, based on the variation of the coefficient of inelastic reflection of electrons (η) with the orientation of the primary beam relative to the single crystal.

Experimental studies are being carried out of the dependence of η on the angle of incidence ϑ or the azimuthal angle φ, and of the so-called electron channeling or pseudo-Kikuchi imaging (with the aid of a scanning electron microscope).

The functions $\eta(\vartheta, \varphi)$ are not monotonic for single crystals. The topology of the $\eta(\vartheta, \varphi)$ surface is related to the ordered disposition of atoms in the crystal lattice, and can be explained in terms of the dynamic theory of diffraction. Changes in the structure of irradiated specimens should, of course, lead to a smoothing of this topology, and can be used as a control on the structure of surface layers.[2] By varying the primary-electron energy, it is possible to vary the sensitivity of the method and the thickness of the surface layer under exploration. The following practical applications of this method have been developed:

a) Measurement of the thickness of unordered films of known composition (between a fraction of one and several hundred monoatomic layers) on the surface of single crystals, independently of the composition and the physical properties of the deposited material.[3]

b) Measurement of the parameters of disordered regions produced under ion bombardment (mean area of transverse cross section and depth, and the degree of damage to the crystal structure). A series of experiments has been carried out on the defect implantation efficiency in the case of germanium bombarded by inert-gas ions for different energies, type of ion, ion-current density, and target temperature (see, for example, Abroyan *et al.*[4]).

c) Studies of the distribution in depth of structural damage produced during ion implantation, in which the above method is combined with the successive removal of layers of known thickness from the surface of the semiconductor. This technique is being used to investigate profiles of radiation-defect distributions in silicon under ion implantation (see, for example, Abroyan *et al.*[5]).

2. The scanning electron-beam method of investigating the work function $e\varphi$,[6] which produces information about the distribution of local $e\varphi$ over the surface of specimens on the screen of a kinescope and records the relative distribution $e\varphi dS/d(e\varphi) = f(e\varphi)$ on a strip-chart recorder. [The ordinate of the resulting, $f(e\varphi)$ curve is proportional at each point to the area S of a region with a particular value of the work function.] A narrow focused beam of electrons is used to scan the target surface with electron energies approaching zero. Other things being equal, the current between the cathode and the chosen point on the target surface is determined by the contact potential difference, i.e., the local work function at the particular point.

The method can be recommended for studying the following processes:

a) adsorption and desorption of foreign atoms on metal and semiconductor surfaces;

b) diffusion and migration of individual components in metal compounds and alloys;

c) recrystallization in metal specimens during thermal treatment and various types of deformation.

3. Auger ion spectroscopy.[7] The ejection of inner-shell electrons under ion bombardment occurs not as a result of Coulomb excitation, as in the case of electron bombardment, but through an exchange mechanism (a peculiar charge transfer process) which depends on the individual properties of the partners participating in the encounter. Auger ion spectroscopy can be used to detect the presence of certain elements on the surface with greater efficiency than under electron bombardment. For example, helium-ion bombardment can be used to detect oxygen atoms and argon-ion bombardment to detect sulfur. The combined utilization of the above secondary-emission techniques opens up great possibilities for obtaining detailed information about the properties of the material at any given point on the specimen surface. The element composition of the surface at a given point can be examined by analyzing the energy spectrum of Auger electrons,[8] whereas the state of the crystal structure can be deduced from electron channeling patterns.[9]

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