

Scientific session of the Division of General Physics and Astronomy, USSR Academy of Sciences (January 26-27, 1977)

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The scientific session of the Division of General Physics and Astronomy of the Academy of Sciences of the USSR was held on January 26-27, 1977 in the conference hall of the P. N. Lebedev Physics Institute of the USSR Academy of Sciences. The following papers were read:

1. *É. Ya. Zandberg and N. I. Ionov*, Surface ionization and its applications.
2. *P. G. Borzyak, G. A. Katrich, Yu. A. Kulyupin, and P. M. Tomchuk*, Electronic processes in metal island films.
3. *Yu. G. Ptushinskii, A. G. Naumovets, and O. A. Panchenko*, Electronic-adsorption phenomena on the surface of metal single crystals.

É. Ya. Zandberg and N. I. Ionov, *Surface Ionization and Its Applications*. Surface ionization is the thermal equilibrium emission of ions from the surfaces of solids. Research in this area began with the discovery in 1923 of the ionization of cesium vapor on the surface of tungsten, and with the subsequent derivation of the expression for the degree of surface ionization (α) of particles in a closed cavity at temperature T . Nonsystematic studies of surface ionization were performed up to 1950 and were restricted to a small number of elements, mainly the atoms of alkali metals and halogens. The phenomenon was used in ion sources and in molecular-beam detectors of these elements.

Because of its connection with the poorly investigated field of interaction of particles with solids, surface ionization attracted the attention of the staff of the A. F. Ioffe Physicotechnical Institute of the USSR Academy of Sciences, both as a scientific subject in its own right and as a phenomenon that could lead to new applications. This paper gave a brief review of the investigations carried out at the Institute since 1955. From the practical point of view, the interesting situation is not the ionization of particles in a cavity but on open surfaces from which positive or negative ions can be collected. There is also practical interest in possible ways of increasing α . Measurements of the distribution of ions over the initial velocities have shown that thermal equilibrium is set up between the particles and the solid during the ionization of atoms on open surfaces, and this has led to the development of a complete phenomenological theory based on statistical thermodynamics. It has also been

4. *I. A. Abroyan, V. V. Korablev, N. N. Petrov, and A. I. Titov*, Secondary-emission methods of investigating the structure and composition of surface layers on solids.

5. *V. A. Krat*, New ideas on the solar photosphere, based on stratospheric investigations.

6. *V. A. Soglasnov et al.*, Search for radiofrequency pulses from astronomical objects.

Brief summaries of five of these papers are given below.

found possible to determine the effect of external electric fields E , accelerating the ions, on the ionization process.^[1,2] For $E \leq 10^7$ V/cm, the degree of ionization of positive or negative ions is given by

$$\alpha_{\pm}(E) = \alpha_{\pm} \exp\left(\frac{e\sqrt{eE}}{kT}\right) = \begin{cases} A_+ \exp\left[\frac{e}{kT}(\varphi - V + \sqrt{eE})\right], \\ A_- \exp\left[\frac{e}{kT}(S - \varphi + \sqrt{eE})\right], \end{cases}$$

where A_+ and A_- are the ratios of the partition functions for the ionized and neutral states of the particles, respectively, φ is the work function of the solid producing uniform emission, V is the ionization potential of the atoms, S is their electron affinity, and e , k , and T have the usual meaning.

The external field has a different effect on ion emission for $\alpha \ll 1$ [when $e(\varphi + \sqrt{eE} - V) \ll kT$] and $\alpha \gg 1$ [when $e(\varphi + \sqrt{eE} - V) \gg kT$]. In the former case, the current density j is given by $j(E) = j \exp(e\sqrt{eE}/kT)$ (for $E \sim 10^7$ V/cm, $T = 1000$ °K, the current density from elements with high V is increased by a factor of $10^5 - 10^6$). For $\alpha \gg 1$, the field has practically no effect on j but produces a substantial reduction in the threshold ionization temperature (whilst for $E = 0$ we have $T_0 \sim 1000$ °K, for $E \sim 10^7$ V/cm, the temperature T_0 may fall to about 300 °K). This property lies at the basis of cold ion sources producing high current densities, the desorption and evaporation of ions by high fields, and the development of prebreakdown conductivity of high-voltage vacuum discharge gaps.

Studies of the surface ionization of *molecules* (as op-

posed to atoms), which results in the appearance of charged fragments, have revealed the laws governing the emission of the ions whose formation is preceded by the dissociation of molecules on solid surfaces.

It was found that many classes of organic compounds (containing heteroatoms belonging to group five in the Periodic Table) formed fairly stable radicals and complexes with low ionization potentials on hot metal oxides, and were readily ionized through surface ionization. The mass spectra of the positive ions of these compounds had relatively few lines, and could be characterized and predicted by established rules.^[3,4] This gave rise to a considerable simplification in the solution of many analytic problems.^[4-6]

Surface ionization has become one of the most effective techniques as a result of investigations of elements with different ionization potentials (up to about 10 eV) and electron affinities (from about 1 eV), using specially developed mass-spectrometric procedures (see, for example, Zandberg and Paleev^[7]), studies of the ionization of simple and complex molecules on the surfaces of solids with different properties (metals, semiconductors, and film systems with homogeneous and inhomogeneous emission), and the utilization of electric fields. This has not only substantially extended the range of the traditional applications of surface ionization (in ion sources and neutral-particle detectors), but has also led to applications of the phenomenon in many physicochemical studies of the properties of particles, the surfaces of solids, and particle-solid interactions.^[1,2,8] The total number of surface-ionization methods currently used in physicochemical studies is approaching 30. It includes: various methods for the determination of ionization potentials of atoms and radicals of organic compounds,^[1-3] measurements of electron affinities,^[1,2,8] measurements of bond energies in ions of organic compounds,^[3,9] a method for studying the emission inhomogeneity, i. e., the contrast of solids,^[1,2] and the phase transitions in submonolayer films of adsorbed materials,^[10] a method of studying the growth kinetics of island structures in adsorbed films,^[11,12] methods of determining true temperatures of solids and the monochromatic emissivity,^[1,10] methods of investigating the

diffusion of impurity atoms within solids^[11] and through phase boundaries,^[10] methods for studying chemical reactions in adsorbed layers and their temperature dependence,^[1,4] a method for studying the activity of catalysts in dissociation reactions,^[10] and various methods of determining the kinetic properties of particle desorption on the surfaces of solids.^[1,8,13] Physicochemical principles have now been developed for the surface-ionization mass-spectrometric analysis of amines, hydrazines, and their derivatives, with sensitivity much higher than that of other methods.^[6]

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