DECORATION OF RADIOACTIVE AND IRRADIATED POTASSIUM SULFATE CRYSTALS WITH METAL SOLS

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It is known that particles of charged sols, when deposited on a crystalline surface, are adsorbed predominantly on charged regions. Thus, with the aid of a lead selenide sol it was possible to reveal the electrical microrelief of the surface of silicon crystals ([1]). As follows from a number of experiments, radioactive preparations under certain conditions must possess a rather considerable charge ([2–4]). For example, in impurity-free water, particles of a $BaSO_4$ precipitate (100 mC S^{35} per 1 g of salt) can carry a positive charge of the order of $3 \cdot 10^{-14}$ coul/cm^2, which arises as a result of the constant emission of electrons (the electrons are formed in the β-decay of S^{35}) from the surface of the radioactive crystals. In a poorly conducting medium the charge may be considerably higher.

Under external irradiation, the sign and magnitude of the charge are determined by the irradiation conditions. For example, thin layers of dielectrics acquire a positive charge under the action of γ-quanta, whereas β-particles charge the dielectric negatively. The resulting potential difference may even lead to breakdown of the dielectric ([5]).

The preservation of charges in irradiated preparations depends on many factors. Thus, the initial distribution of charges in a solid, caused by non-Ohmic forces (irradiation, etc.), relaxes to zero exponentially with a time constant $\tau = \varepsilon/\sigma$, where ε is the dielectric constant of the given specimen and σ is its specific conductivity ([6]). For metals $\tau \sim 10^{-18}$ sec, for semiconductors τ ranges from 10^{-10} to 1 sec, and in the case of dielectrics (K_2SO_4), $\tau \sim 10^5$ sec. Although the estimate given is rather rough, it clearly shows that only in dielectrics can a charge be preserved for a long time.

There are several methods for measuring charge accumulated in dielectrics ([5]). However, their application to radioactive specimens is very difficult, since ionization processes, always occurring in the surrounding medium, will introduce errors that are difficult to control. Therefore, in the present work the method of decoration with charged sols was applied to radioactive (with respect to S^{35})

and γ-, β-irradiated potassium sulfate crystals in order to reveal charges on their surface.

The crystals investigated are typical dielectrics: $\varepsilon \simeq 6$, $\sigma \simeq 10^{-14}$ ohm • cm. Potassium sulfate crystals were grown from aqueous solutions (isothermal evaporation) ([7]). Two sols were chosen as decorating agents: silver in acetone (the sol particles carry a negative charge) and nickel in methyl alcohol (positively charged). The preparation of the sols, their stability, and determination of the sign of the ζ-potential are described in works ([8,9]).

For decoration, cleavages of crystals made perpendicular to the growth axis were immersed for 1-3 min in the solution of the corresponding sol, after which the crystal was washed with the corresponding solvent and dried in air. Then a carbon film 100-200 Å thick was deposited onto the surface of the crystal; by dissolving the crystal in water, this film was separated together with the sol particles. In individual cases, from the surface under study there were obtained carbon replicas preliminarily shadowed with platinum–

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Fig. 1. Weakly radioactive potassium sulfate crystal (0.08 mC of S^{35} per 1 g of salt), decorated with silver sol

Fig. 2. The same crystal, annealed at 300°C for 3 h. Decorated with silver sol

Fig. 3. Radioactive sulfate crystal (150 mC of S^{35} per 1 g of salt), decorated with silver sol

Fig. 4. Nonradioactive K_2SO_4 crystal irradiated with γ- and β-particles at an absorbed dose of ~ 1 Mrad. Decorated with nickel sol

native replicas. The study was carried out on an EM-5 electron microscope at an accelerating voltage of 60 kV.

Electron-microscopic examination of the replicas showed that the cleavage surface of potassium sulfate crystals is nonuniform, and relief elements are observed on it both of the tubercular type and in the form of steps and entire bands of steps.* Deposition of the sol on such a surface occurs mainly on the relief elements. A more uniform distribution of the silver sol is observed on weakly radioactive potassium sulfate crystals (Fig. 1). In this case the crystals may have a positive charge, but one insufficient to retain a large number of sol particles (Figs. 1-4, see insert facing p. 1297).

In the course of annealing, the charge localized in dielectrics is rapidly released (5). Consequently, after annealing of radioactive charged crystals, the decorating particles should be adsorbed predominantly on inhomogeneities of the surface relief. This is confirmed by Fig. 2, where the sol particles are fixed mainly on the relief elements, similarly to what occurs on nonradioactive crystals.

Unannealed K_2SO_4 crystals with high specific radioactivity are uniformly covered with a very dense layer of particles of colloidal silver (Fig. 3), which is direct proof of the existence of a stationary positive charge. Upon annealing of highly radioactive crystals, a picture similar to Fig. 2 was also observed. Similar results were obtained at specific activities of 10 and 50 mC S^{35}/g, but on K_2SO_4 crystals containing 5 mC S^{35}/g, dense filling of the surface with sol no longer occurred. Thus, under the given experimental conditions, the charge of the K_2SO_4 surface reaches a sufficiently large value only at a specific activity of $\sim$ 10 mC S^{35}/g. Unfortunately, it is impossible to estimate the magnitude of this charge, but the qualitative observations are unambiguous.

Figure 4 shows an electron-microscopic photograph of the surface of K_2SO_4 irradiated with a gamma source (Co^{60}). The irradiation conditions were such that the crystal could acquire only a negative charge (5). As can be seen in this photograph, particles of the positively charged nickel sol cover the entire surface of the crystal rather uniformly, whereas the silver sol is deposited in much smaller amounts and mainly on the relief elements.

In addition, an attempt was made to determine the influence of an external electric field on the distribution of the sol over the K_2SO_4 surface. For this purpose, during decoration a potential difference of $\sim$ 100 V/cm was created between the crystal and the solution. It turned out that the action of a constant electric field leads to aggregation of the sol on the K_2SO_4 surface, irrespective of the sign of the sol charge or the direction of the field. The reason for this phenomenon apparently lies in the disturbance of the aggregate stability of the sol when an electric current passes through it.

Thus, with the aid of decoration by charged metal sols, it has been shown that radioactive potassium sulfate crystals possess an excess positive charge.

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* Potassium sulfate crystals do not possess cleavage.

Note: Figure translations are in progress. See original paper for figures.