Electron emission from a diamond single crystal

V. B. Ganenko, V. A. Gushchin, Yu. V. Zhebrovskiĭ, L. Ya. Kolesnikov, A. L. Rubashkin, and P. V. Sorokin
Khar'kov Physicotechnical Institute, Academy of Sciences of the Ukraine, 310108, Khar'kov, the Ukraine

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The orientation dependence of the high-energy component of the secondary-emission current has been studied on a diamond single crystal. This is the first such study. This effect could in principle be utilized to orient a diamond platelet with respect to an electron beam.

Secondary electron emission has been studied thoroughly and is used to measure the currents of charged-particle beams.[1–3] It has also been found that the secondary electron emission has a characteristic orientation dependence when high-energy electron and positron beams interact with silicon and niobium single crystals of various thicknesses.[4–6] The primary reason for this effect is a spatial redistribution of the flux of initial particles as they pass near crystallographic axes or planes.[7]

In this letter we are reporting the first study of the orientation dependence of secondary electron emission from a diamond single crystal with a fairly high resistance.

The experiment was carried out at the linear electron accelerator of the Khar'kov Physicotechnical Institute, on the Kristall apparatus, which is used to produce linearly polarized photons by means of coherent bremsstrahlung.[8]

An electron beam with an energy $E_0 = 1.2$ GeV was incident on a diamond single crystal 1.8 mm thick at a small angle θ from the [100] axis. The single crystal (the emitter) was insulated from the crystal holder of the goniometer and positioned between collectors. These collectors were rings with an inside diameter of 12 mm and were positioned 5 mm from the emitter. The electron emission caused the potential of the diamond crystal to swing positive. The charge carried off by the secondary electrons was measured by a sensitive integrator, whose output signal was fed to a count-rate meter and then to a chart recorder. The current of the primary electron beam was measured by a secondary-emission monitor[3] calibrated beforehand with the help of a Faraday cup.

According to the results of Ref. 5, the orientation dependence of the emission current is manifested only in the high-energy component ($E \gtrsim 100$ eV). We accordingly studied only the high-energy component of the emission current, applying a cutoff potential $u = -150$ V to both collector rings.

Figure 1 shows a plot of the electron yield versus the angular orientation of the diamond crystal. In the case of an axial orientation (the solid curve), there is a characteristic peak in the electron yield. This peak rises $\sim 14\%$ above the level of the yield in the case of a disoriented target. Its width at half-maximum is $\Delta\phi_B = 8 \times 10^{-4}$ rad, or

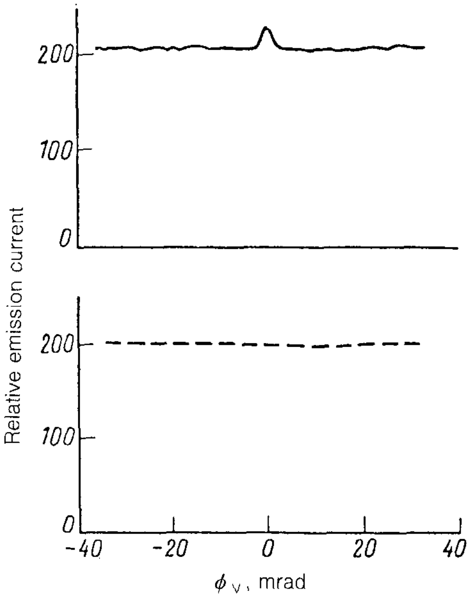

FIG. 1. Orientation dependence of the secondary electron emission from a diamond single crystal 1.8 mm thick for a primary energy $E_0 = 1.2$ GeV. Solid line—$\phi_H = 0$; dashed line—$\phi_H = 21.6$ mrad. Here ϕ_V and ϕ_H are the goniometer rotation angles around the vertical and horizontal axes.

twice the critical channeling angle ($\theta_{cr} = 3.87 \times 10^{-4}$ rad). A similar result had been found in Ref. 4, for a silicon single crystal with a thickness of 1.1 mm, which is comparable to the thickness in the present case in terms of the number of electrons per unit volume. In that previous study, the peak in the emission current in the case of an axial orientation rose $\sim 18\%$ above the corresponding level for a disoriented target. The slight difference in height may be due to structural damage to the diamond crystal, which was bombarded with a dose of 5×10^{21} electrons/cm^2. The same factor may explain why the width of the peak at half-maximum is twice the critical channeling angle.

The dashed line in Fig. 1 shows the orientation dependence of the emission current for a plane. The large thickness of the diamond platelet is evidently masking the characteristic structure in this case.

In summary, this has been the first experimental study of electron emission in the interaction of a beam of high-energy electrons with a diamond single crystal. Diamond is an insulator with a high resistance. It has been shown here that it is possible in principle to orient diamond single crystals with respect to an electron beam by a method based on secondary emission. It has also been shown that this effect can be utilized to evaluate the quality of the crystal structure.

[1]G. F. Dell and M. Fotino, Phys. Lett. B **29**, 324 (1969).
[2]B. Planskov, Nucl. Instrum. Methods **24**, 172 (1963).
[3]V. A. Gol'dshteĭn, I. M. Arkatov, and V. I. Startsev, Prib. Tekh. Eksp., No. 2, 50 (1973).
[4]G. D. Kovalenko, Ukr. Fiz. Zh. **26**, 1839 (1981).

[5]V. I. Vit'ko and G. D. Kovalenko, Zh. Eksp. Teor. Fiz. **94**, 321 (1988) [Sov. Phys. JETP **94**, 2141 (1988)].
[6]I. A. Grishaev, G. D. Kovalenko, and B. I. Shramenko, Pis'ma Zh. Tekh. Fiz. **5**, 1104 (1979) [Sov. Tech. Phys. Lett. **5**, 461 (1979)].
[7]N. P. Kolashnikov, in *Proceedings of the Fifth All-Union Conference on the Physics of the Interaction of Charged Particles with Single Crystals* (Moscow, 28–30 May 1973), Moscow, 1974, 233.
[8]V. G. Gorbenko, Yu. V. Zhebrovskiĭ, A. S. Zelencher *et al.*, Preprint KhFTI Akad. Nauk UkrSSR 78-16, Kharkov, 1978, 35.

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