Photovoltages Larger than the Band Gap in Zinc Sulfide Crystals

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PENSAK[1] has discovered a photovoltage larger than the band-gap voltage in some films of cadmium telluride made by vacuum evaporation. A necessary condition for the effect is that the vapor be directed obliquely at the substrate on which it is condensed. The direction of the resulting photovoltage is related to the direction of evaporation.

X-ray diffraction examinations of the films disclosed only cubic cadmium telluride and neither x-ray diffraction nor polarizing microscope studies were able to detect a bulk anisotropy in the films related to the direction of vapor arrival. Nevertheless, the hypothesis was formed that if stacking faults existed in the film and if the normals to the planes of the stacking faults were oriented with respect to the direction of arrival of the vapor, then there would exist in the films a structural vector (the cadmium-tellurium bond vector perpendicular to the stacking fault) which could define the direction of the electric field produced by illumination. A consideration of the crystal field would indicate that there is a residual dipole layer at each stacking fault, and that at successive stacking faults the polarity has the same sign. We are therefore led naturally to the conclusion that the photovoltage developed at successive stacking faults would be additive, provided that the stacking faults are perpendicular to a common axis.

It was also believed that a clear test of these ideas could only be made on large crystals of the same structure type. Since suitable zinc sulfide crystals were available, the study was transferred to them.

These zinc sulfide crystals were clear fibers or platelets grown from the vapor. They contained random stacking faults. In some places there were ordered arrangements of stacking faults with periodicities of as many as 40 double layers. They were single crystals only in the sense that the [111] cubic and [0001] hexagonal directions were coincident and the boundaries between the phases were coherent. X-ray diffraction studies by the method of Coster, Knol, and Prins,[2] using tungsten L_β radiation, showed that the growth direction was also that of the sulfur-zinc vector in the bonds perpendicular to the stacking faults.

Under ultraviolet illumination many of these crystals produce greater-than-band-gap photovoltages. While the stacking faults are often too closely spaced to permit resolution under the light microscope, the photovoltages were higher in the crystals in which microscope and x-ray studies indicated a higher number of stacking faults. The photovoltages were, in particular, high for crystals containing repetitive stacking faults. At room temperature fields of 100 volts cm^{-1} could be obtained. This corresponds to, very approximately, 0.1 volt per stacking fault. The direction of the electric field was the same as the growth direction, i.e., sulfur to zinc across the stacking fault.

While, historically, the experiments with evaporated cadmium telluride films[1,3] led to a successful search for a high photovoltage in zinc sulfide crystals, it would be incorrect to conclude that the photovoltages observed in the films are caused by stacking faults. The possibility remains, but there is no direct evidence for it.

These structural and electrical studies are being continued.

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[1] L. Pensak, Phys. Rev. **109**, 601 (1958).
[2] Coster, Knol, and Prins, Z. Physik **63**, 345 (1930).
[3] B. Goldstein, Phys. Rev. **109**, 601 (1958).

Chirality Invariance and the Universal Fermi Interaction*

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WE have shown[1] that the imposition of the requirement of chirality invariance[2] on each covariant in the four-fermion interaction Hamiltonian leads to the essentially unique expression[3]:

$$G\{[\bar{A}\gamma_\mu(1+\gamma_5)B]^\dagger[\bar{C}\gamma_\mu(1+\gamma_5)D]+\text{H.c.}\} \qquad \text{(I)}$$

where G is the coupling constant and A, B, C, D are four Dirac *particle* fields. In the standard terminology of parity-conserving interactions, (I) represents the combination $V-A$ (V is vector, A is axial vector). We assumed that (I) holds between any two of the pairs[4] np, Λp, $\mu^-\nu$, $e^-\nu$ (i.e., the *particles* are taken to be the neutron, proton, Λ hyperon, negative muon, neutrino, and electron) with the same value of G. Such a universal $V-A$ four-fermion interaction is invariant under "combined inversion,"[5] yields a two-component neutrino of negative helicity, leads to conservation of leptons, and gives the maximal violation of parity—apart from conserving chirality.

In comparing the predictions of the $V-A$ theory with experiment, we pointed out at the Padua-Venice Conference that the theory could explain all beta-decay experiments (allowed as well as forbidden, parity-conserving as well as parity-nonconserving) except the electron-neutrino correlation[6] in He^6 and the electron asymmetry from polarized neutron decay,[7] all the muon experiments except the very preliminary experiment at Columbia[8] on the positron polarization from μ^+ decay,