

quite conservative, the considerable ionizing radiation emanating from the cF star being ignored.

It is to be noted that ζ Aurigae systems such as the prototype and VV Cephei provide means for similar tests, and that Struve¹⁰ has already pointed out the possibility of interpreting the observational bases of this theory by more conventional mechanisms.

* Carnegie Institution Fellow in Radio Astronomy, 1953-1954.

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² D. ter Haar, Phil. Mag. **45**, 320 (1954).

³ E. F. Freundlich, Proc. Phys. Soc. (London) **A67**, 192 (1954); Phil. Mag. **45**, 303 (1954).

⁴ The contribution to the total energy density along the line of sight made by the star itself has been omitted. Its inclusion would imply a shift of the solar lines from their laboratory wavelength of 200 km/sec.

⁵ J. H. Moore, Lick Observatory Bul. **18**, No. 483 (1935).

⁶ F. B. Wood, Univ. Penn. Astron. Pub. **8**, 1 (1953).

⁷ Kuiper, Struve, and Stromgren, Astrophys. J. **86**, 570 (1937).

⁸ S. Gaposchkin, Publs. Astron. Soc. Pac. **66**, 112 (1954).

⁹ Z. Kopal, Observatory **74**, 14 (1954).

¹⁰ O. Struve, Sky and Telescope **13**, 225 (1954).

K Band in Additively Colored KCl

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THE F -band absorption in alkali halides is accepted to be the result of a $1s-2p$ transition of an electron trapped at a negative ion vacancy in the lattice. Mott and Gurney¹ first suggested that the shoulder on the high-energy side of the F band (the K band²) was associated with $1s-np$ transitions and transitions to the ionization continuum. Dexter³ has calculated the absorption cross section per electron at the F band, and at its presumed series limit using hydrogen like wave functions. No evidence has been presented definitely to contradict the assumption that the K band is an integral part of the F band, and for this reason the most recent review article on color centers⁴ maintains this point of view. The data presented here indicate that the ratio of the absorption of the F and K bands is not a constant. Therefore the two bands are not a result of transitions from the ground state of the same center.

The KCl crystals used in the room temperature work were high purity crystals grown by the Kyropoulos technique. The crystals were additively colored at 600°C in potassium vapor. Next, thin crystals which were cleaved for absorption measurements (made in the Beckman Model DR Spectrophotometer) were wrapped in a light tight aluminum foil and heated to 500°C. After allowing sufficient time for the dispersal of any aggregate or colloidal bands the crystals were quenched. Curve a of Fig. 1 shows the absorption obtained without exposing the crystal to light. Curves b , c , d , and e were obtained after subsequent exposures of the same crystal to light of wavelengths greater than

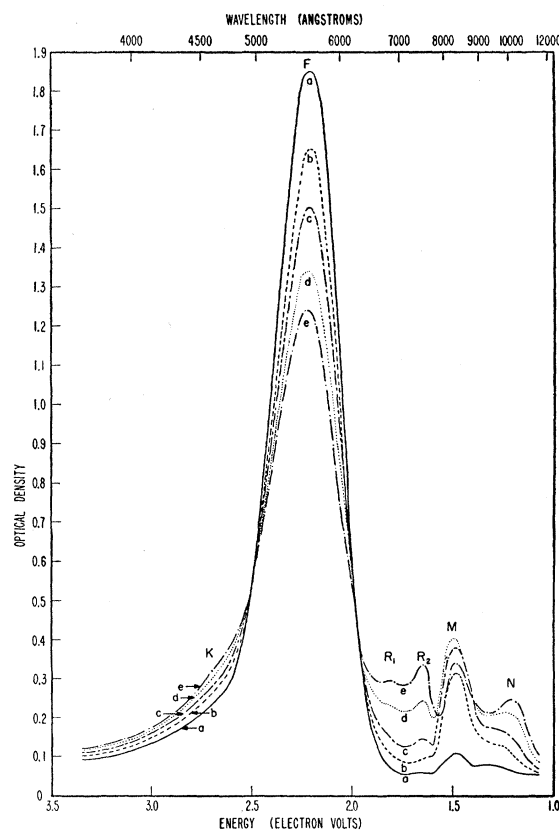


FIG. 1. A sequence of absorption measurements at room temperature of additively colored KCl ($\sim 4 \times 10^{17}/\text{cc}$). Irradiation made with a tungsten lamp through a Corning No. 3482 filter. Curve (a), no optical bleach; (b), illuminated 20 seconds; (c), 40 seconds; (d), 100 seconds; (e), 220 seconds.

5000Å. The crystals used for the liquid nitrogen data were Harshaw crystals colored at 477°C for 28 hours, quenched immediately to room temperature and measured in a Cary automatic recording spectrophotometer. Curve a of Fig. 2 shows the absorption of the crystal measured at -160°C prior to bleaching. In curve b the same crystal after irradiation into the F band at $+50^\circ\text{C}$, is measured again at liquid nitrogen temperature. The Cary spectrophotometer was used as a monochromator with a slit width of 1.5 mm or about 250Å. Both sets of curves show after irradiation a partial bleaching of the F band and an unexpected growth of the K band. The R_1 , R_2 , M , and N bands grow as expected at room temperature, but at 50°C the R_1 and R_2 bands appear to decrease while the M band increases.

The data presented here do not yet allow a description of the K center, but indicate that the center is not due to a transition of an electron in the ground state of the F center to excited states or to the conduction band. It should be pointed out that the data of Molnar⁵ indicate that the K band grows as the F band is bleached, but apparently no significance was attached to the increase in absorption in the K band region. It is unlikely that

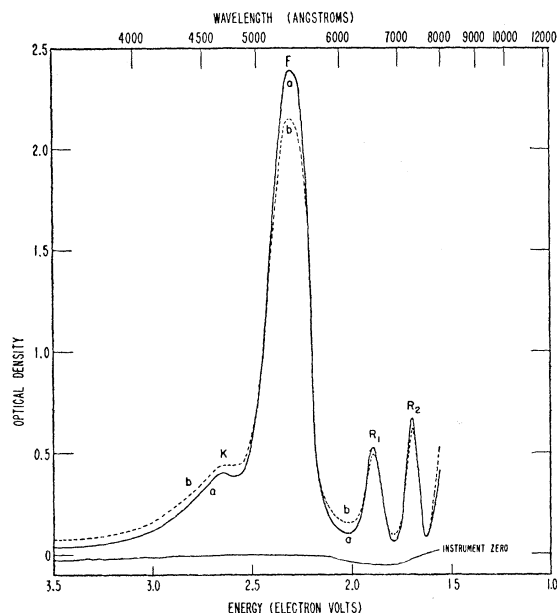


FIG. 2. Absorption measurements on additively colored KCl at -160°C . Curve (a), no optical bleach; Curve (b), after $2\frac{1}{2}$ -hour bleach with F light (5600 \AA) at $+50^{\circ}\text{C}$.

the K band observed here could be the V -type center as suggested by Duerig⁶ since the crystals were colored additively and should contain no holes. The K band appears then to be some combination of an electron and negative ion vacancy in such a way as not to form a normal F center. Further work is planned to determine the nature of the center.

The additive coloration, by R. J. Ginther, of the crystals used in the room temperature measurements is deeply appreciated.

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Injection Breakdown in Iron-Doped Germanium Diodes

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IRON dissolved in germanium introduces two deep energy levels in the forbidden band. It is possible to produce both n - and p -type samples of Fe-doped Ge which exhibit high resistivity when cooled to liquid nitrogen temperature. Thermal ionization energies characteristic of n and p samples are $\sim 0.27\text{ eV}$ and $\sim 0.34\text{ eV}$, respectively. Studies of the recovery of photo-

conductivity after exposure to light indicate that n -type samples are much more photosensitive and slower in recovery than are p -type samples, suggesting that states introduced by Fe act as hole traps in n -type crystals.¹ The purpose of this letter is to describe briefly an experiment with diodes which tends to confirm the presence of hole traps in high-resistivity n -type Fe-doped Ge.

Diodes were formed by fusing an indium contact on one face of an $\sim 1/8$ -in. cube of germanium. The "ohmic" base contact on the opposite face was of fused tin. Sixty-cycle ac voltage was applied to the diodes and current-voltage characteristics were observed on a calibrated oscilloscope. At 300°K the diodes show normal behavior with high reverse saturation currents due to the low carrier lifetime ($\sim 5\text{ }\mu\text{sec}$) in the Fe-doped crystals. When cooled to liquid nitrogen temperature (77°K), in the dark, a typical diode behaves like a high resistance for small voltages of either polarity. (The equilibrium value of resistivity for the Fe-doped Ge at this temperature is $\sim 10^{12}\text{ ohm-cm.}$) On increasing the applied ac voltage (to $\sim 15\text{ volts peak}$) injection currents of several microamperes are seen on the forward cycle. At sufficiently high voltage ($\sim 50\text{ volts peak}$) a breakdown process takes place after which the effective resistivity of the Ge drops to about 100 ohm-cm. This breakdown condition is maintained until the applied voltage is reduced to less than several volts. Light ($h\nu > 0.7\text{ eV}$) falling on the diode greatly reduces the voltage necessary to initiate the breakdown condition.

Figure 1 shows the current-voltage characteristic of a typical diode before breakdown. The diode is immersed in liquid nitrogen. Pre-breakdown injection current of about 1 microampere is noticeable on the forward cycle. Breakdown is initiated by a short light pulse from a neon lamp. Figures 2 and 3 show current-

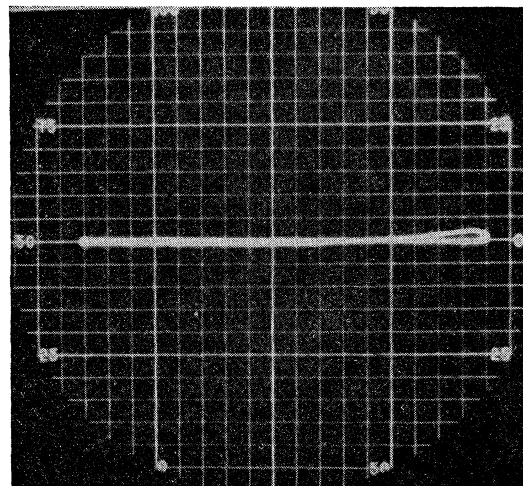


FIG. 1. Current-voltage characteristic before breakdown. Horizontal scale calibration is $2\text{ volts per small division}$. Vertical scale calibration is $2\text{ microamperes per small division}$.