recombination from the trap at a rate found to be proportional to (hole concentration)^2. Trap concentration is roughly proportional to sample conductivity.

[1] J. R. Haynes and J. A. Hornbeck, Phys. Rev. **90**, 152 (1953).

X4. Decay in Photoconductivity Associated with Hole Traps in N-Type Silicon. J. R. HAYNES AND J. A. HORNBECK, *Bell Telephone Laboratories.*—Preliminary photoconductivity measurements on *n*-type silicon indicate that hole traps behave differently in several respects from electron traps in *p*-type silicon.[1] The hole traps decay with nearly a single time constant, showing that multiple trapping is not an important mechanism. At room temperature the trap concentration (N) varies from $2 \times 10^9 > N > 10^{15}$ cm^{-3} among specimens and is not correlated with resistivity. Decay times (τ) are found in the range 7×10^{-2} to 500 sec, and there is evidence for at least two and probably more trapping levels. More detailed studies have been carried out with two similar specimens having two trapping levels. In these, N varies with temperature (T) in accordance with a "deep" trap 0.3 ev from the conduction band, and measurements of trapping cross section (3×10^{-18} cm^2) and τ place the trap 0.71 ev from the valence band. Investigation of τ *vs* temperature shows that the simple relation $1/\tau = \nu \exp(-U/kT)$ is obeyed, but U is not the trap depth; the measurements also indicate that at room temperature and lower some recombination occurs in the trap causing a deviation from this relationship. Measurements on one sample place a shallow trap $\sim$0.64 ev from the valence band with a cross section $\sim 40 \times 10^{-16}$ cm^2.

[1] J. R. Haynes and J. A. Hornbeck, Phys. Rev. **90**, 152 (1953).

X5. The Photoconduction of Zinc Oxide Semiconductor: an Oxygen Adsorption Process. DONALD A. MELNICK, *University of Pennsylvania.*—The photoconductive process of porous, sintered, semiconducting zinc oxide has been studied as a function of time (0.3 to 10^7 sec), pressure of ambient oxygen (10^{-5} to 760 mm), temperature (110° to 373°K), intensity (factor of 10^3), and duration of excitation. The following conclusions are reached: (1) confirmation is given to the postulate[1] that physically adsorbed oxygen forms an acceptor impurity, removing electrons from the interstitial zinc donors. The oxygen thus becomes chemically adsorbed and tightly bound. The narrow "necks," which connect the sintered grains and control the sample's resistance, have a sufficiently high surface to volume ratio for the acceptor concentration to exceed the donor concentration. (2) The oxygen can be desorbed by light of forbidden gap energy, presumably because holes are attracted to the charged chemically adsorbed oxygens, converting them to weakly bound physically adsorbed. (3) The rate of chemical adsorption of oxygen is given by the Elovich equation, $dq/dt = a \exp(-bq)$. (4) The nature of the adsorption equation causes inner more weakly illuminated layers to represent longer time constants and to contribute appreciably to the final photoconductance. The array of time constants usually assumed for photoconductive processes is, therefore, found to be unnecessary.

* This work partially supported by the U. S. Office of Naval Research.
[1] S. R. Morrison. (Submitted to J. Chem. Phys.)

X6. Photoresponse of Aromatic Films.* J. F. ANDREW AND S. MROZOWSKI, *University of Buffalo.*—The variation of resistance of charred organic films under infrared illumination studied previously and believed to be a mixed photo and bolometric type response[1] has been investigated further and the study extended to much thinner films. It was suspected that charred films have a very porous structure and that the time constant is determined by the heat losses into the pores. Liquid backings were used which penetrate into these pores. It has been found that the response (limiting value for long illumination) is cut down by the presence of the liquid as much as by a factor 4 in some cases. In general, liquids with higher thermal conductivity are more effective in reducing the response, the effect being, however, also a function of the ability of the liquid to penetrate the pores. Films mounted in vacuum show a somewhat larger response; for very thin films a slight change caused by solid backing could also be established. The dependence of the response on the intensity of illumination, dark current and temperature were studied. Response in region of purely vibrational absorption ($7–8\mu$) was found. All findings lead to the conclusion that the response of charred organic films is of an essentially bolometric nature.

* Supported by the U. S. Office of Naval Research.
[1] Mrozowski, McMichael, and Kmetko, Phys. Rev. **91**, 234 (1953).

X7. Dielectric Constants of Powders at uhf.* ROBERT S. SMITH, *University of Pennsylvania.*—A new approximate method of calculating the dielectric constant of powder has been devised to treat the case of inhomogeneous particles of various shapes. It yields the usual Clausius-Mossotti relationship for homogeneous spherical particles. For a matrix composed of homogeneous randomly-oriented cylinders the measured dielectric constant ϵ is

$$\epsilon = 1 + \frac{\delta \frac{1}{3}\left(4\frac{\epsilon_0 - 1}{\epsilon_0 + 1} + \epsilon_0 - 1\right)}{\delta \frac{1}{3}\left(\frac{4}{\epsilon_0 + 1} + 1\right) + (1-\delta)\left(1 + \frac{8}{9}\frac{\epsilon_0 - 1}{\epsilon_0 + 1}\frac{\ln \delta^{-\frac{1}{2}}}{(\delta^{-1} - 1)}\right)}, \quad (1)$$

where ϵ_0 is the bulk dielectric constant and δ the fractional density. For a matrix composed of conducting spheres coated with a dielectric shell of constant ϵ_0,

$$\epsilon = 1 + \frac{3\delta(\epsilon_0 - 1)(1-\delta') + 9k\delta'}{(1-\delta)(\epsilon_0 + 2) + 3\delta(1-\delta')}, \quad (2)$$

where δ' is the conducting fraction of the spherical particle. Measurements of powdered zinc oxide at several hundred megacycles in the range $0 < \delta < 0.5$ fit either formulas (1) or (2) within the experimental error but are inconsistent with those of Clausius-Mossotti, Weiner, Bruggeman, or Bottcher.

* Supported in part by the U. S. Office of Naval Research.

X8. R', Colloidal, and Z Bands in KCl. D. R. WESTERVELT, *North American Aviation, Inc.*—The thermally induced absorption peak which has been termed the Z band in photochemically colored alkali halides[1] and the colloidal band in those additively colored[2] has been further studied. In both cases the band is destroyed by 35-kev x-rays. R_1 and R_2 bands are not an initial step in its formation, since these are immediately destroyed by heating. The broad R' band forms rapidly during simultaneous annealing and F-light exposure; during continued heating, however, the R' band narrows and the final results of annealing in the light and of the much slower process in the dark are the same. Once the $F \leftrightarrow Z$ equilibrium is established, prolonged annealing at the same temperature has no effect on the Z-peak location or band width, but raising the annealing temperature shifts the peak to longer wavelengths. Cooling to liquid nitrogen temperature sharpens the peak, although less than in the case of the F band; and in some cases the peak is shifted to longer wavelengths by cooling, contrary to all previously observed behavior in the alkali halides. Observed differences in the colloidal and Z bands apparently result from unavoidable thermoluminescence and the competition of recombination processes in bombarded crystals. This paper is based on studies conducted for the Atomic Energy Commission.

[1] D. R. Westervelt, Phys. Rev. **91**, 218 (1953).
[2] Scott, Smith, and Thompson, J. Phys. Chem. **57**, 757 (1953).

X9. A Search for Luminescent Emission from the F Center. CLIFFORD C. KLICK, *Naval Research Laboratory.*—Measurements have been made on the quantum efficiency of lu-