sities of 10^8 to 10^9 (per cm^3) are usual. Thus negative-mass carriers with densities of 3.5×10^6 to 3.5×10^7 are expected and should be detectable, since the cyclotron resonance technique has sufficient sensitivity[3] to detect as few as 10^3 to 10^6 carriers per cm^3.

The experiments suggested here for the detection of negative-mass carriers are of the usual cyclotron resonance type.[3,4] If the absolute values of m^* for negative- and positive-mass carriers are quite different, then the negative-mass carriers, at their resonant frequency (using $|m^*|$), will give a larger effect, by comparison to the nonresonant effect of the positive-mass carriers at the same frequency, than that suggested by their equilibrium populations given above. One can also use circularly polarized infrared or microwave radiation and samples with a preponderance of holes, in which case for one direction of H only the positive-mass holes are detected. Reversal of the magnetic field direction should reveal only the negative-mass signal. The preferable axis for application of H is the (100) direction. The effect, of course, is strongly dependent on orientation.

There will be cases for plane polarized waves where negative-mass effects will appear as distortions of the absorption lines due to the positive carriers. It is not clear whether any line distortions or "extra line" signals in previous work[3,5,6] are due to these effects, since they have not been considered so far. The classical Boltzmann theory for the shape of the absorption lines[7] neglects negative masses entirely, and a more accurate calculation[8] for a specific case does not explicitly introduce effects of this type.

Work of this type should directly confirm the re-entrant type of contours in Ge and Si that has been indicated by cyclotron resonance work on positive-mass carriers, and may prove a very sensitive tool for further band structure studies. With the proper distribution, the cyclotron resonance of negative masses could well lead to rf power generation and amplification.

This technique should provide a sensitive method for measuring the feasibility or efficiency of methods proposed by Kroemer,[2] of populating and utilizing for amplification purposes negative-mass regions of k space.

The author is obliged to Professor Charles Kittel of the University of California, and F. Herman and E. O. Johnson of this Laboratory, for discussions and helpful suggestions on this subject.

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HYDROXIDE ABSORPTION BAND IN ALKALI HALIDE CRYSTALS

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Pure alkali halide crystals should be completly transparent from the fundamental absorption edge in the ultraviolet to the ionic absorption edge in the infrared. Many types of impurity produce absorption bands in the ultraviolet region, however, and absorption measurements in this region provide a sensitive indication of their presence. Such measurements have been made on a series of alkali halide crystals grown from the melt in this laboratory, and on several batches of crystals purchased from the Harshaw Chemical Company. In all of these crystals absorption bands were found at the following wavelengths at room temperature:

KBr: 215.0 mμ; KCl: 203.5 mμ;
NaCl: 190 mμ.

From classical dispersion theory,[1] assuming an oscillator strength of unity for the absorbing centers, the impurity density was calculated to be about 10^{16} cm^{-3} for all the crystals studied.

Absorption bands at these wavelengths could be caused by any anionic impurity containing oxygen, except oxide[2] (O^{--}), but the most probable impurity was thought to be hydroxide, resulting from hydrolysis of the alkali halide in the melt with a small amount of water present in the starting material. The evidence for this view is the following:

(a) Potassium and sodium chlorides, melted in an attempt to remove the last traces of water, often given an alkaline reaction when dissolved in water.[3]

(b) When very careful drying procedures were applied to reagent grade[4] KCl and KBr and crystals were grown from this material in a carefully dried, oxygen-free, nitrogen atmosphere, the absorption bands disappeared. The drying procedure consisted of slowly heating the powdered material under high vacuum[5] for 88 hours in the case of KBr and 21 hours for KCl.

(c) Natural rock-salt and sylvine (KCl) crystals[6] showed no trace of an absorption band. These crystals were known to be formed by very slow evaporation of a saturated solution, and were thus never subjected to temperatures high enough to cause hydrolysis.

(d) The absorption bands have been increased by growing crystals in a nitrogen atmosphere saturated with water, and by adding alkali hydroxide to the melt.

Because of the general appearance of these bands in the synthetic crystals (Harshaw) used for many experiments, and the great care needed to remove the last traces of water from the starting material, it is suggested that hydroxide has been an impurity present in fairly large amounts in all crystals used in previous work on alkali halides. The presence of hydroxide is not shown by spectrochemical analysis.[7] Furthermore it is probable that not much purification takes place during crystallization. Preliminary measurements showed very little difference in the absorption coefficient at the band maximum along the length of the crystal, indicating a segregation coefficient for hydroxide near unity.

Irradiation experiments on KBr and KCl crystals containing different concentrations of hydroxide were carried out at room temperature and at liquid nitrogen temperature. The ultraviolet source used for this purpose was a General Electric *AH*-4 mercury lamp with the outer glass envelope removed. At room temperature, irradiation produced *F*-centers, whose saturation density was approximately proportional to the initial density of the hydroxide impurity. These *F*-centers were stable in the dark, but were quickly bleached by illumination with a tungsten lamp.

At liquid nitrogen temperatures, KBr and KCl behaved differently. The bands obtained on ultraviolet irradiation of a KCl + KOH crystal are shown in Fig. 1. The two bands appearing in the ultraviolet are marked U_1 and U_2 because they seem to be identical with those observed by Delbecq *et al.*[8] when KCl + KH crystals were irradiated by the same source. They concluded that these bands were due to interstitial hydride ions (U_1) and interstitial hydrogen atoms (U_2). The hydroxide absorption band was itself altered by irradiation, and on warming to room temperature, when the U_1 and U_2 bands disappeared, the wavelength of the remaining ultraviolet absorption band corresponded to the oxide absorption band (K_2O).[2] It thus seems probable that irradiation splits the O-H bond, giving oxygen and hydrogen absorption bands, as well as the *F*-band.

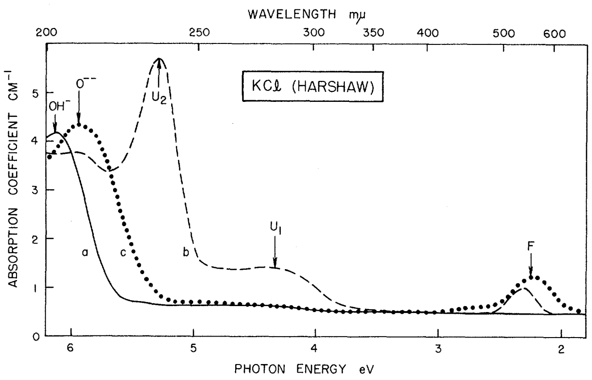

FIG. 1. Absorption spectra of KCl crystal, irradiated at 78° K: (a) untreated crystal, measured at 78° K, (b) crystal irradiated for 127 minutes with *AH*-4 lamp at 78° K, measured at 78° K, (c) after warming to 300° K.

The absorption bands obtained on irradiation of KBr + KOH at liquid nitrogen temperature are shown in Fig. 2. For this material, the α band was within the wavelength range of the spectrophotometer used,[9] and appeared very strongly. The band marked U' is coincident with a band found, in a separate experiment, upon irradiation of KBr + KH at liquid nitrogen temperature with the *AH*-4 light source. By analogy with the results obtained by Delbecq *et* *al.* with KCl + KH, this band is assumed to be due to hydrogen; and the ultraviolet absorption band which remains after warming the crystal to room temperature is assumed to be the oxide absorption band, by analogy with the results obtained after irradiation of KCl + KOH at liquid nitrogen temperature. The V_1 band also appears very strongly on low temperature irradiation. The reasons for its appearance are not at present clear.

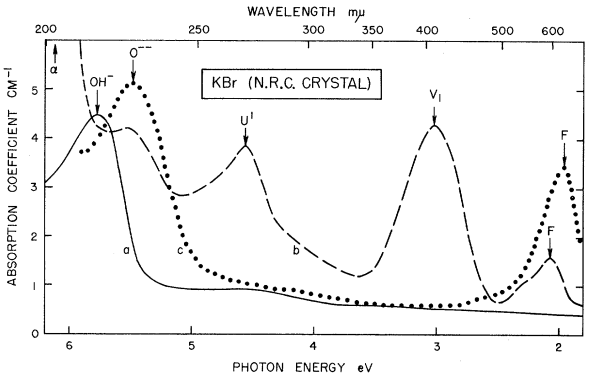

FIG. 2. Absorption spectra of KBr crystal, irradiated at 78° K: (a) untreated crystal, measured at 78° K, (b) crystal irradiated for 88 minutes with *AH*-4 lamp at 78° K, measured at 78° K, (c) after warming to 300° K.

The author wishes to thank Mr. R. Boulet for growing the crystals and Dr. J. H. Simpson for much helpful discussion.

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MAGNETIC FIELD EFFECTS ON BOW SHOCK STAND-OFF DISTANCE

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Combined theoretical and experimental investigations have been carried out by the authors to find the effects of applying magnetic fields to the ionized flow about a blunt body of revolution. Reported here is the effect of the magnetic field on the shock wave stand-off distance.

The effect of a magnetic field on a bow shock wave of an unyawed body of revolution was studied theoretically by the following model[1]:

(a) The fluid in the free stream has negligible electrical conductivity and has uniform velocity (U) parallel to the axis of symmetry.

(b) The shock wave is treated as a mathematical discontinuity.

(c) In the shock layer, the Mach number is low enough so that the density (ρ) and enthalpy are approximately constant. The viscosity and thermal conductivity are neglected, but the electrical conductivity due to the ionization is not neglected. Consistent with the prior assumptions of constant density and enthalpy in the shock layer, the assumption is made that the electrical conductivity is constant.

For this model, the flow in the shock layer is governed by the following equations:

$$\nabla \cdot \vec{q} = 0,$$

$$\nabla \times [(\nabla \times \vec{q}) \times \vec{q}] = (\sigma/\rho) \nabla \times [(\vec{q} \times \vec{B}) \times \vec{B}],$$

$$\nabla \cdot \vec{B} = 0,$$

$$\nabla \times \vec{B} = \sigma \mu (\vec{q} \times \vec{B}),$$

where $\vec{q}$ = velocity vector, $\vec{B}$ = magnetic field vector, σ = electrical conductivity, and μ = magnetic permeability. To simplify the mathematical analysis, the shape of the shock and the magnetic field upstream from the shock are taken to be known and the shape of the body and the magnetic field at the body are found.

For a spherical shock of radius c and the magnetic field in the free stream that due to a dipole located at the origin of the sphere,

$$\vec{B} = 2\alpha c^3 \cos\theta \vec{e}_r / r^3 + \alpha c^3 \sin\theta \vec{e}_\theta / r^3 \text{ for } r > c,$$

the nonlinear differential equations were solved on the Remington Rand 1103A digital computer