TABLE I. Line widths and line-width parameters.

		ΔH (gauss)	T_2 (seconds $\times 10^{-4}$)
Octadecane	$CH_3(CH_2)_{16}CH_3$	0.37	1.0
Hexadecane	$CH_3(CH_2)_{14}CH_3$	0.29	1.3
Tetradecane	$CH_3(CH_2)_{12}CH_3$	0.15	2.7
Dodecane	$CH_3(CH_2)_{10}CH_3$	0.05	8

frequency was 20 mc. The field was swept sinusoidally at 400 cycles with an amplitude much less than the line width, and the data for the derivative plot[2] of the absorption mode[1] was obtained using a twin-tee narrow band filter in the audio amplifier.

Preliminary measurements have yielded the results given in Table I. T_2 was calculated using the Bloch formulation.[1] All measurements were made at room temperature. The line width for octadecane agrees with that reported by Andrew.[3]

We are now continuing our investigation using proton control of our electromagnet and the steady-state pulsing technique.[4] With this combination of methods, measurements can be extended to narrower line widths. Very narrow line widths (i.e., less than 0.05 gauss) are expected in the short chain hydrocarbons that are being investigated.

* This work was made possible through partial support by the AEC.
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New Segregation Phenomena in Metals

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(Received June 18, 1951)

LEAD-BISMUTH alloys containing radioactive bismuth have been examined for segregation of the polonium resulting from the decay of the Bi^{210}. Three types of segregation have been established.

(*1*) *Crystal boundary segregation.*—Bicrystals of bismuth-lead alloys were prepared, a small proportion of the bismuth being the radioactive isotope Bi^{210}. The decay product of Bi^{210} is polonium which, when these experiments were performed, was present in a concentration of approximately one atom of polonium in 10^{10} atoms of bismuth or of the alloy. Autoradiographs of the bicrystals showed that, in spite of its very low concentration, polonium segregates at the crystal boundary. A typical autoradiograph is shown in Fig. 1.

(*2*) *Surface segregation.*—Measurements of the alpha-emission from specimens of similar composition show that the concentration of Po at the surface increases rapidly during annealing, or slowly at room temperature, in alloys of Pb with 10 or 20 percent Bi. The region under examination is restricted to a very thin layer by the extremely short range of alpha-particles. It is concluded that there is a tendency for polonium to segregate at the surface.

(*3*) *Inhomogeneous crystallization.*—When crystals of bismuth containing polonium at a concentration of 10^{-10} are allowed to solidify under conditions of linear growth, the concentration of polonium varies periodically; the periodicity is related to variations in the speed of solidification. A similar effect has also been observed in gold-silver alloys; Au^{198} used as a tracer has shown periodic changes of composition in alloys containing 1/10 percent, 10 percent, and 20 percent gold. The autoradiographs show bands transverse to the direction of growth. An example is shown in Fig. 2.

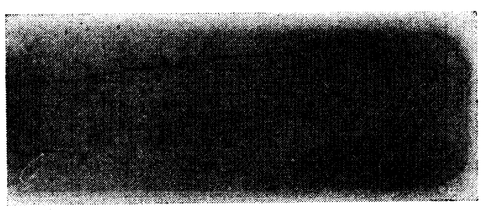

FIG. 1. A typical autoradiograph, showing crystal boundary segregation.

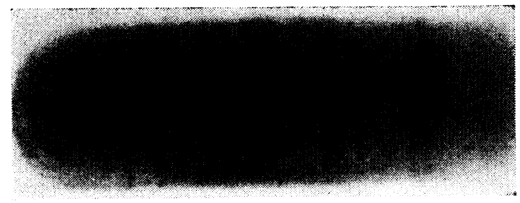

FIG. 2. An autoradiograph showing bands transverse to the direction of growth.

Paramagnetic Resonance Absorption Crystals Containing Color Centers*

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(Received June 14, 1951)

HUTCHISON[1] has published results of microwave absorption experiments on alkali halide crystals (LiF and KCl) which were heavily irradiated with neutrons. This treatment produced a very high density of color centers. The resulting microwave absorption at 9350 Mc showed a peak absorption at a magnetic field giving a g factor of 2.00. This corresponds to the result which would be expected on the basis that the spins of the trapped electrons are nearly free. It is also consistent with the observed paramagnetic susceptibility of crystals containing color centers.[2] A perhaps unexpected result was that the absorption was not symmetrical about the peak. On the highfield side a sloping plateau about 500 gauss wide and about one-quarter the height of the peak was found.

We have measured absorption at a frequency of 9480 Mc on crystals of KBr which may have an appreciably smaller density of color centers. The apparatus used in this work was of high sensitivity as compared with the conventional equipment. The method involves sweeping the external magnetic field and displaying the absorption curve directly on a cathode-ray oscilloscope.[3] Details of the apparatus and measuring techniques will be published in a forthcoming paper. The first sample tried (of volume 0.5 cc) had been electrolytically colored (current being passed through the crystal at about 500°C), and had of the order of 10^{19} centers per cc. This sample was kindly provided to us by J. Gelatis and E. Klokholm of the Laboratory for Insulation Research. Our sensitivity was such that we were able only to detect the peak position and not to study its shape. The g value was found to be 2.00 ± 0.04.

Another sample of KBr was bombarded with high energy electrons and gamma-rays (18-Mev peak energy) on the microwave linear accelerator at the Massachusetts Institute of Technology for about 4 hours. Optical absorption measurements indicated between 10^{19} and 10^{20} centers per cc. The peak of the optical absorption band was at 6300A, indicating that the predominant optical absorption was due to F-centers.[4] In this sample, the microwave absorption was sufficient to allow accurate determination of the shape of the absorption curve as well as its position. In contrast to Hutchison's results, we found complete symmetry of the absorption curve about its peak. Moreover, our sensitivity was such that we could have seen a plateau which was less than 10 percent of the height of the peak absorption. The g

value was the same as for the earlier sample. The width of the curve at the half-power point was 210 gauss at room temperature and 150 gauss at 77°K.

We are tempted to conclude from our results that the plateau observed by Hutchison was a consequence of the extreme treatment given his samples. Clarification of these differences will probably require an increase in the sensitivity of the apparatus.

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and the ONR.
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Effect of Recombinations in Electron Avalanches

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THE calculation of the ion number using the equation

$$n = e^{\alpha x} \tag{1}$$

leads to an excessive ion density at the avalanche head which is, in some cases of sparking field strength, higher than the Avogadro constant.[1] This equation is derived without taking into account the possibility of recombinations between ions and electrons during the progress of the avalanche. The following estimate shows that such recombinations would considerably decrease the ion number and consequently the ion density.

If dn_a represents the ion number produced by ionization in a length dx, and dn_c the number of recombinations in time dt required for an avalanche progress by dx, then the actual increase of the ions would be

$$dn = dn_a - dn_c, \tag{2}$$

where $dn_a = n\alpha dx$ and $dn_c = c\rho^2 Q dt$, c being the recombination coefficient,[2] ρ the ion density, and Q the volume of a sphere having a radius as given by Meek for the radius of the avalanche head: $r = (0.133x/p)^{\frac{1}{2}}$.

Assuming $\rho = n/Q = 3n/4\pi r^3$, Eq. (2) becomes

$$dn = \left[\alpha n - \frac{3cn^2 p^{\frac{3}{2}}}{4v\pi(0.133x)^{\frac{3}{2}}}\right] dx, \tag{3}$$

where $v = dx/dt$ is the velocity of the avalanche and p is the pressure in mm Hg. With $k = 3cp^{\frac{3}{2}}/4v\pi(0.133)^{\frac{3}{2}} = \text{const.}$ the differential Eq. (3) becomes

$$dn + (kn^2 x^{-\frac{3}{2}} - n\alpha)dx = 0. \tag{4}$$

Its solution is:

$$n = \frac{e^{\alpha x}}{2kx^{-\frac{1}{2}}\left(-1 + \frac{\alpha x}{1!1} + \frac{\alpha^2 x^2}{2!3} + \frac{\alpha^3 x^3}{3!5} + \cdots\right) + 1}. \tag{5}$$

Comparison of the ion numbers given by Eqs. (1) and (5) shows that the effect of recombinations should reduce $e^{\alpha x}$ by a factor rapidly increasing with x.

In a plane parallel air-gap of $d = 1$ cm under breakdown field strength $X_0 = 31.6$ kv/cm, $\alpha = 16.5$ cm^{-1}, $v = 1.25\times 10^7$ cm/sec, $p = 760$ mm Hg, and a recombination coefficient[2] $c = 3\times 10^{-10}$, the denominator becomes about 1.0000025 for $x = d = 1$ cm; i.e., the number of ions is about 0.00025 percent less than that computed from Eq. (1).

In a 5-cm air-gap under $X_0 = 27.6$ kv/cm, $\alpha = 6.5$ cm^{-1}, $v = 1.25\times 10^7$ cm/sec, $p = 760$ mm Hg, and $c = 3\times 10^{-10}$, the denominator is about 40 for $x = d = 5$ cm; i.e., the ion number is about 40 times less than that given by Eq. (1).

Further, in a 10-cm gap under $X_0 = 26.5$ kv/cm, $\alpha = 4.25$ cm and other values as above, the ion number is about 5×10^4 times less than that given by Eq. (1).

The reduced ion number indicates that the critical lengths[1] (x_k) swept by the avalanches under breakdown conditions are greater than those given when assuming Eq. (1).

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The Crab Nebula as an Observed Point Source of Cosmic Rays

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STUDY of the diurnal variation of very high energy cosmic rays is considered to be an available method to find the direction of a cosmic-ray source, because lower energy rays are largely scattered in the terrestrial as well as other kinds of magnetic field. For this purpose, the diurnal variation of cosmic rays underground was studied from the data obtained in the Shimizu tunnel by Nishina, Miyazaki, and two of the authors[1] from 1939 to 1944.

The observations contain 1720 incidences detected at 1200 meters water equivalent below the earth's surface during the period from October 27, 1939, to July 4, 1940. No solar-time variation was obtained, only a sidereal-time variation as shown in Fig. 1(a). If the period of observation is divided into three parts as shown in Fig. 1(b), the times of maximum intensity are 4 hr, 5 hr, and 7 hr, respectively. Time differences among these three maxima are not larger than 4 hours, and the probability of getting such a coincidence of maxima by chance is 6.5 percent.

Assuming the rays were not deflected, the effective solid angle of the instrument can be projected on the celestial sphere, as shown in Fig. 2. five hr 20 min local sidereal time corresponds to the mean of the three maxima mentioned above. Near the direction of the axis of the instrument one can find the Crab nebula,

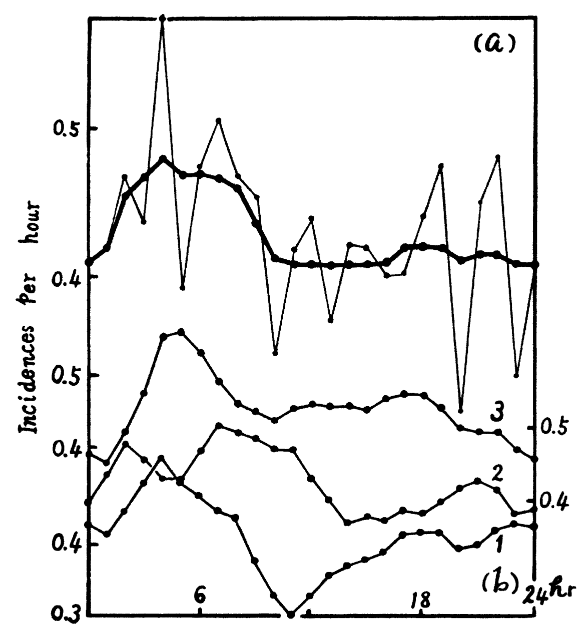

FIG. 1. Sidereal-time variation of cosmic rays at 1400 m H_2O equivalent depth. (a) Total period. Fine line: hourly values. Thick line: weighted (1:2:3:2:1) running average. (b) Weighted running averages. 1: October to December, 1939, 2: January to March, 1940. 3: April to July, 1940.