mic ray flux. From the angular distribution of the protons and their energy spectrum they believe that these particles were not released from the Van Allen belt, but were accelerated near the sun. Our observations suggest that an acceleration process may have existed which accelerated both electrons and protons. The radio emission might then be generated through a synchrotron radiation from the high-energy electrons. The electrons could lose their energy through synchrotron radiation while the protons could not. The protons observed at the earth would represent leakage from this region. The level at which the plasma frequency equals 26 Mc/sec is about 1.6 solar radii. Therefore, it would appear necessary to assume some nonthermal process, such as the synchrotron process, in order to obtain appreciable radio noise generation so far above the plasma level.

On July 11, 14, and 15, 1959, intense solar cosmic rays were again observed by the Minnesota group[4] and by Brown and D'Arcy[5] as well. Although we observed intense radio emission during this period, the emission did not persist for a long enough period or the brightness distribution of the sun was too complex for us to obtain an accurate determination of height.

Th author wishes to thank Mr. Delano Ball, Mr. Paul Brissenden, and Mr. Jack Warren who shared the 120°F temperatures which were common during the course of these observations. He also wishes to acknowledge the loan of a Navy-owned motor generator unit which furnished the station's ac power.

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DISLOCATION PINNING IN *n*-TYPE GERMANIUM

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A new type of dislocation pinning which depends on the type and extent of doping has been found in germanium. The recovery process in heavily-doped, *n*-type and heavily-doped, *p*-type germanium has been examined through the observation of thermally-induced glide.[1] Samples were prepared from essentially dislocation-free germanium[2] grown in this Laboratory. The *p*-type material was doped with about 2.5×10^{19} gallium atoms per cm^3 and the *n*-type with about 2.8×10^{19} arsenic atoms per cm^3. Each sample was lightly bent around a [111] axis to a radius of about 250 cm at about 500°C. The dislocation density, as observed by means of etch pits developed on a (111) face in each sample, ranged from about 5×10^4/cm^2 to about 1.5×10^5/cm^2. Each sample had a well-defined neutral region and was oriented so that the slip occurred predominantly on a single set of slip planes. The etches used were HF-HNO_3 (1:3) at 70°C for *p*-type, and for *n*-type the same etch, followed by a boiling etch of the same acids diluted with eight parts of water. The etching process proceeded for about 2 seconds in each case. Well-defined etch pits are not readily produced in the heavily-doped, *n*-type material with the usual etchants.

After the initial bending, etching, and etch pit observation, each sample was annealed at approximately 600°C for 5 minutes. Thermally-induced glide was observed in the *p*-type sample, but there was none present in the *n*-type. Further annealing of each sample for 5 minutes at 650°C produced no glide in the *n*-type, but additional glide in the *p*-type. Annealing each sample for 5 minutes at 700°C produced a barely perceptible change in the etch pit configuration of the *n*-type sample and considerably more glide in the *p*-type sample. Figure 1 shows the etch pit configuration on the *n*-type sample at this point in the annealing process and Fig. 2 that of the *p*-type sample. It will be noted in Fig. 1 that there is a well-defined neutral region which has not changed in width with annealing. Thus, all of the internal driving stress remains in the *n*-type sample. In Fig. 2 it is possible to see the old etch pits (these mark the locations of the dislocations prior to

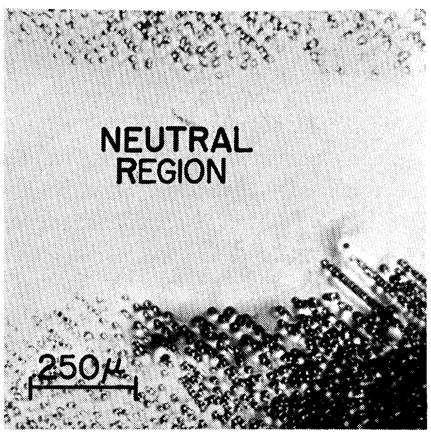

FIG. 1. Etch pit pattern in bent sample of heavily-doped, n-type germanium.

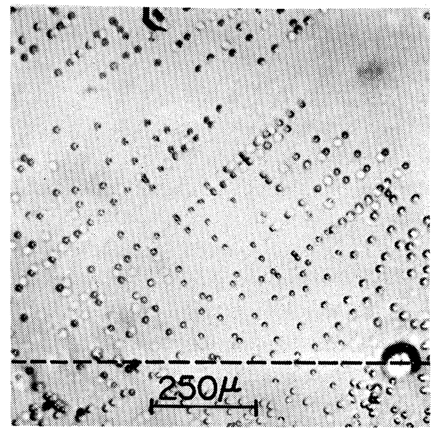

FIG. 2. Etch pit pattern in bent sample of heavily-doped, p-type germanium. The dashed line shows the lower boundary of the neutral region before annealing.

the current anneal) and some of these can be paired with adjacent etch pits which mark the present dislocation position. Also, the same figure shows that there is almost no neutral region remaining; almost all of the residual stress has been relieved. The dashed line indicates the lower boundary of the neutral region before annealing.

To explain this pinning by the arsenic donor impurities, a reasonable assumption is that the substitutional arsenic, being normally of valence five, forms a fifth valence bond at the composite dislocation with one of the three-bonded Ge atoms in the dislocation line. The trivalent Ga atoms cannot form such bonds. The tetrahedral covalent radii of both As and Ga are nearly the same as that of Ge, but there is doubt[4] as to what radius should be used. Any elastic pinning[5] should be the same for Ga as for As, since the actual radii should deviate the same amount from the tetrahedral radii, although in the opposite sense. During the plastic deformation, the dislocations are dragged through the field of donor impurity atoms and come to rest after the driving stress has been removed, pinned in a position of minimum energy. Mott[6] has given a theory from which the average distance between pinning points can be calculated. Assuming the pinning energy to be approximately 1 ev, and using the measured donor concentration, 2.8×10^{19} cm^{-3}, we obtain an average distance between pinning points of 1470 A. Since glide is observed in the n-type material at 700°C and above, it appears that diffusion of the As atoms away from the dislocation line reduces the pinning and allows dislocation glide.

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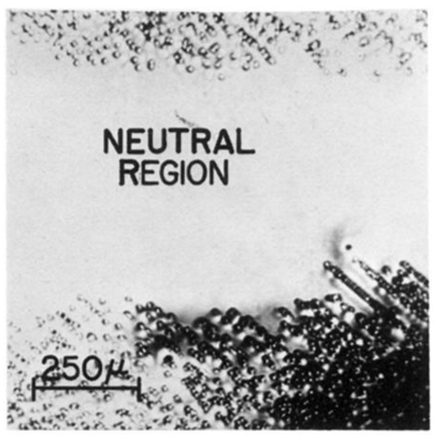

FIG. 1. Etch pit pattern in bent sample of heavily-doped, n-type germanium.

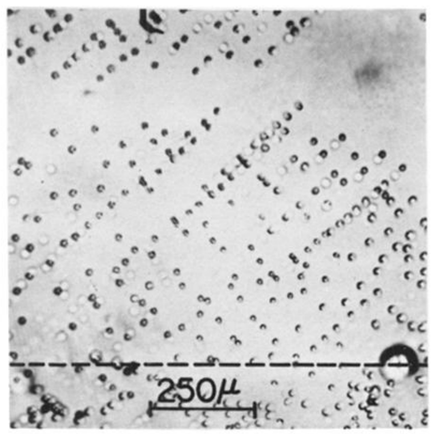

FIG. 2. Etch pit pattern in bent sample of heavily-doped, *p*-type germanium. The dashed line shows the lower boundary of the neutral region before annealing.