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FAR-INFRARED PHOTOCONDUCTIVITY OF UNIAXIALLY STRESSED GERMANIUM

A. G. Kazanskii, P. L. Richards, and E. E. Haller

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FAR-INFRARED PHOTOCONDUCTIVITY OF UNIAXIALLY STRESSED GERMANIUM†

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ABSTRACT

The influence of uniaxial stress on the extrinsic photoconductivity of gallium doped germanium has been investigated. It has been found that the long wavelength cut-off is shifted from 114 μm for zero stress to 200 μm for a uniaxial stress of 6.6×10^3 kg/cm^2 along a [100] direction. At this value of stress the responsivity was $\sim 2 \times 10^4$ V/W and the NEP was $\sim 2 \times 10^{-11}$ W/$\sqrt{\text{Hz}}$ at 190 μm.

Germanium doped with various impurities is widely used for sensitive detectors of far-infrared radiation. The choice of the impurity allows one to change the long wavelength cut-off of such detectors from wavelengths (λ) shorter than 10 μm[1] for deep impurities, to λ = 120 μm,[2] for shallow impurities. For longer wavelengths germanium bolometers are usually used.[3] As a rule, however, sensitive germanium bolometers are slower than impurity photoionization detectors, where the rate of response is determined by the recombination processes. It is therefore desirable to extend photoionization detection to longer wavelengths. This can be accomplished by applying uniaxial stress.

This paper describes an investigation of the influence of uniaxial stress on the impurity photoionization spectrum of doped germanium. Germanium doped with gallium at a concentration of $2 \times 10^{14}\,cm^{-3}$ and a compensation of less than 0.01 was used in our experiments. Radiation from a Fourier transform spectrometer passed through a stainless steel light pipe and was concentrated on the sample by a Winston cone.[4] A cold black polyethylene filter and a Yoshinaga filter were mounted in front of the sample to exclude radiation with wavelengths shorter than 35 μm, and to reduce the influence of background radiation from the top part of the cryostat. The sample and the filters were immersed in liquid helium at 2 K. Ohmic contacts were formed by alloying pure In with the germanium at 250°C in an argon atmosphere. The dimensions of the sample were $1 \times 1 \times 6$ mm. The stress was applied along the long direction of the sample by a calibrated spring and lever.

Impurity photoconductivity spectra are shown in Fig. 1 for several values of uniaxial stress along a [100] axis. The stress causes the cut-

off of impurity photoconductivity to shift to longer wavelengths. This result is explained by the fact that uniaxial stress removes the degeneracy at the top of the valence band.[5] The modification of the valence band structure causes a change in the acceptor binding energy. The theory developed by Price[6] and experiments on Hall effect carried out by Hall[7] show that uniaxial stress decreases the acceptor binding energy. The largest decrease occurs for stress along the [100] direction.

Figure 2 shows the dependence of the photoconductivity threshold (measured at half height) on the value of the uniaxial stress F. The threshold energy decreases monotonically as the stress increases. For stress greater than 4×10^3 kg/cm^2 this shift is approximately proportional to 1/F. About a factor two increase in the wavelength range of impurity photoconductivity can be obtained without serious risk of fracture of the sample.

Uniaxial stress also causes a substantial increase in the conductance of the sample. Experiments showed that the amount of the increase depends on the intensity of the background radiation. The change in the conductance with stress under the conditions described above is shown in Fig. 2. The conductance increases with stress, saturating at stresses greater than 4×10^3 kg/cm^2. This behavior is apparently connected with an increase in the number of free holes, due to the reduction of the acceptor binding energy, and a possible decrease in the rate of recombination with stress.[8] The change in the effective mass of the carriers with deformation[5] should also contribute to the change in the conductance.

We have measured the dependence of the resistance and the peak value of the responsivity on the applied electric field. The results are shown

in Fig. 3 for a [100] stress of 6.6×10^3 kg/cm^2. For fields of more than 0.04 V/cm the resistance of the sample starts to decrease. Figure 3 shows that the responsivity increases monotonically with field up to 0.2 V/cm and then starts to fall. This behavior is due to the substantial decrease in the dynamic resistance in the high field region. The maximum value of the responsivity at 2 K was measured to be approximately 2×10^4 V/W. We also measured the noise voltage with a low noise preamplifier at our chopping frequency of 140 Hz. From this measurement we calculate a value of $\sim 2 \times 10^{-11}$ W/$\sqrt{\text{Hz}}$ for the peak in the NEP which occurs at 190 μm in germanium with a [100] stress of $F = 6.6 \times 10^3$ kg/cm^2.

Detectors of this type show considerable promise for extending the wavelength range of infrared astronomical measurements from space platforms, which are constrained to focal plane temperatures or response speeds that are too high for efficient bolometer operation. Measurements are in progress to determine the detector performance under the low background conditions which are appropriate for these applications.

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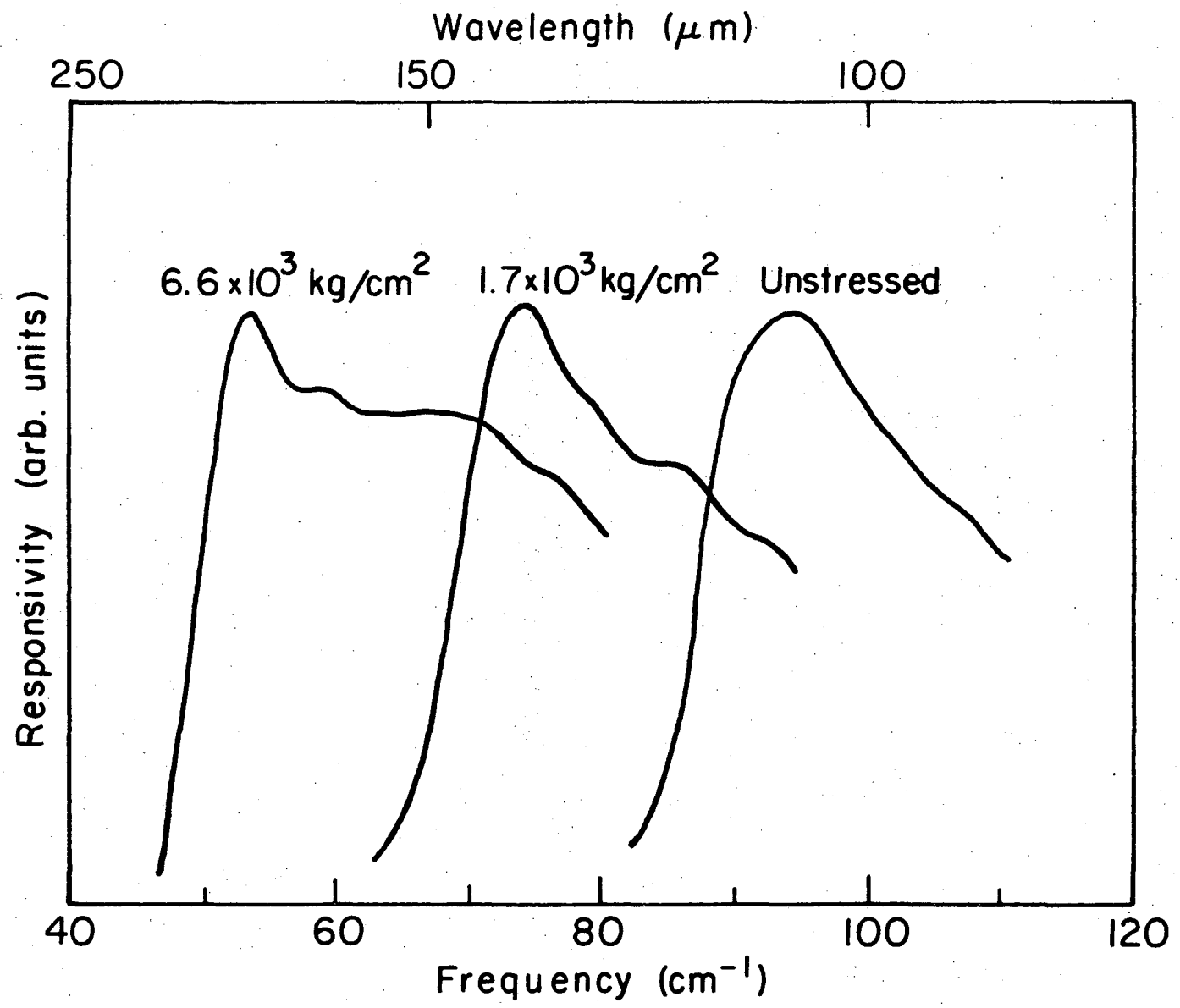
Figure Captions

Fig. 1. The spectral responsivity of uniaxially stressed germanium for different values of stress. (The measured spectra were normalized to the output of a Golay detector and then scaled so that the peak responsivity is the same for each.)

Fig. 2. The stress dependence of the threshold for impurity photoconductivity (measured at half height) and the conductance of the sample.

Fig. 3. The electric field dependence of the resistance of the sample and the (peak) responsivity at $\lambda = 190\ \mu m$ ($F = 6.6 \times 10^3\ kg/cm^2$).



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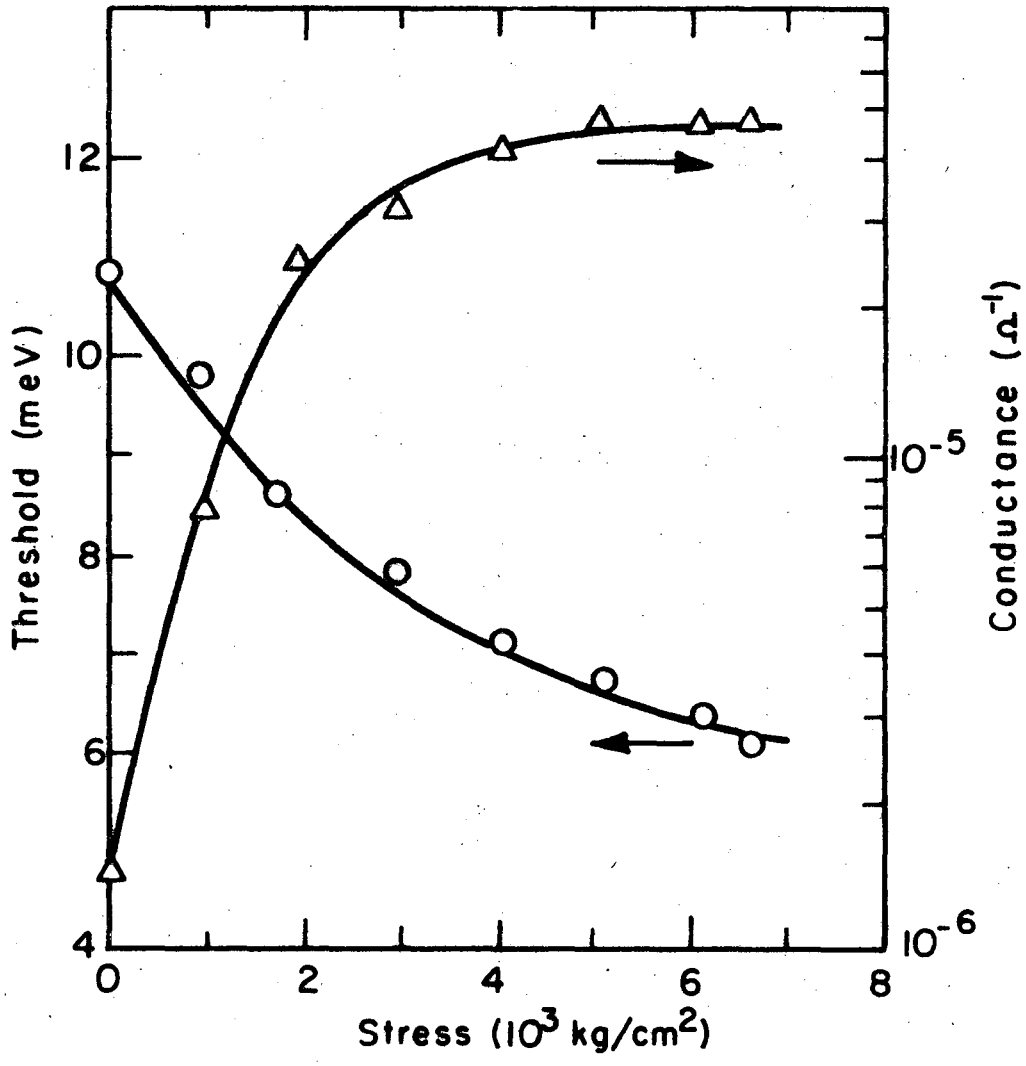
Threshold (meV)
12
10
8
6
4
0
2
4
6
8
Stress (10^3 kg/cm^2)
10^{-5}
10^{-6}
Conductance (Ω^{-1})

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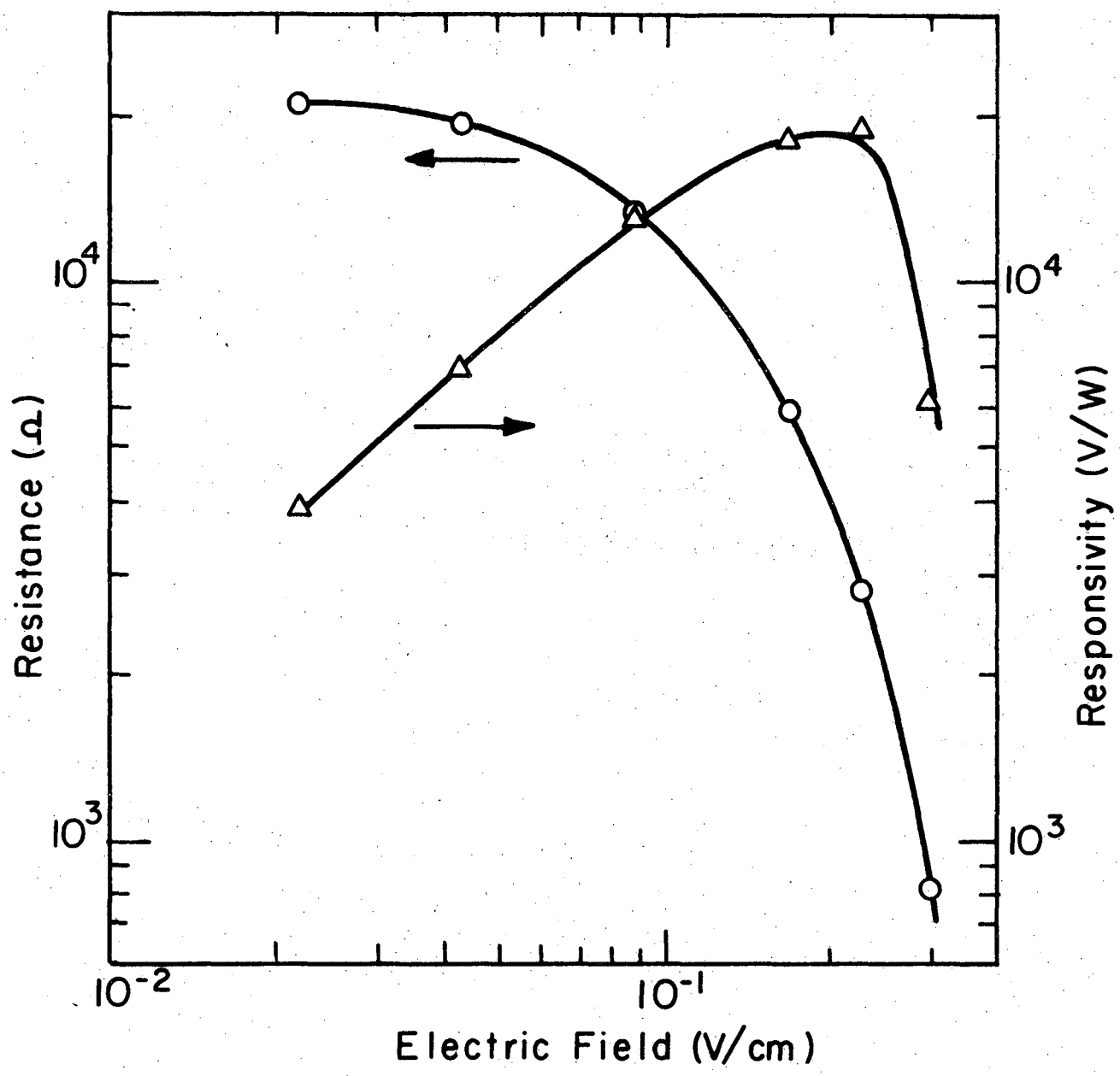

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