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Germanium Blocked Impurity Band Infrared Detectors

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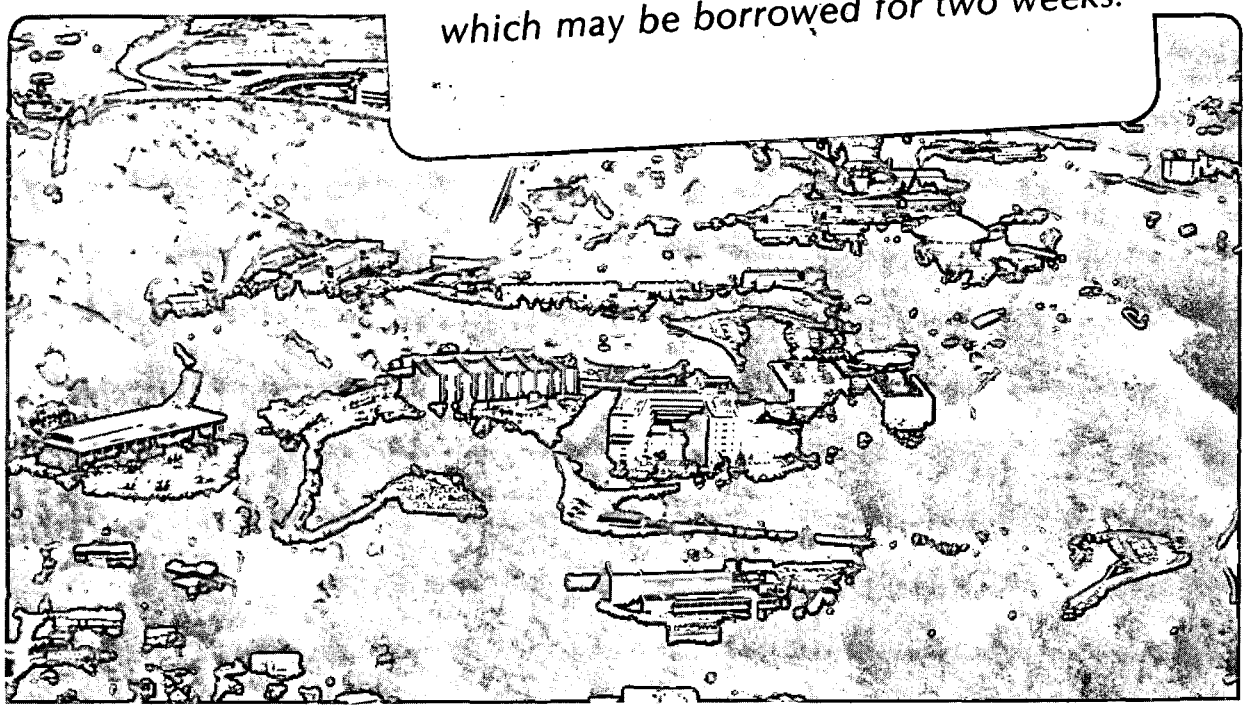

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GERMANIUM BLOCKED IMPURITY BAND INFRARED DETECTORS*

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Germanium blocked impurity band (BIB) photoconductors have been fabricated and characterized for responsivity, dark current, and noise equivalent power. BIB photoconductors theoretically provide an extension of the spectral response, a reduction in sensitivity to cosmic radiation and a reduction in noise characteristics compared with conventional photoconductors. Silicon BIB detectors have been successfully developed by researchers at Rockwell International, which do indeed meet their theoretical potential (1-3). In the proper configuration, these same Si BIB detectors are capable of continuous detection of individual photons in the wavelength range from 0.4 to 28 μm (4). Until the BIB concept was developed, detection of individual photons was only possible with photomultiplier tubes which detected visible light. Due to the successes of the Si BIB detectors, it seemed natural to extend this concept to Ge detectors, which would then allow an extension of the spectral response over conventional Ge detectors from ~ 100 μm to ~ 200 μm (5,6).

The Ge BIB photoconductors fabricated in this study consisted of a multilayered structure of a pure Ge epitaxial layer grown on a heavily doped Ge substrate. The substrate was doped with Ga at a concentration of 5×10^{15} cm^{-3} with a residual compensating donor concentration of ~ 10^{10} cm^{-3}. The epitaxial Ge layer was grown by chemical vapor deposition using GeH_4 gas as the Ge source and had a residual net acceptor concentration of 2×10^{13} cm^{-3}. Ohmic contacts were produced on the epilayer and substrate surfaces by boron implantation--the device structure is shown in Fig. 1.

The level of doping in the heavily doped layer should be high enough that an impurity band begins to form. Hopping conduction in this impurity band would normally result in an undesirably large dark current in the photoconductor when under bias. However, the pure epitaxial layer serves to block current from the impurity band, while allowing carriers in the valence band to pass through. Hence, conductivity due to photogenerated carriers is detectable, while conductivity due to hopping conduction is blocked--thus, the term "blocked impurity band" detector. The ability to dope the IR-active layer more heavily than in conventional detectors results in: 1) an extension of

the spectral response, 2) a reduction in detector volume (without compromising photon absorption), which reduces the sensitivity to cosmic radiation, and 3) a fixed gain of unity, which decreases noise arising from variations in gain. These three characteristics make BIB detectors unique and provide exciting possibilities in improvements over conventional and stressed detectors. The physics and operation of BIB detectors are described in detail elsewhere (1,2,6,7).

Ge:Ga BIB detectors were fabricated as shown in Fig. 1 and tested in a liquid helium cooled cryostat under low background conditions (~ 10^8 photons-$cm^{-2}s^{-1}$) using narrow band filters at 99 μm. The dark current of a typical BIB detector as a function of applied bias at 2.3 K is shown in Fig. 2. For a comparison, the dark current for a detector made of the same 5×10^{15} cm^{-3} Ge:Ga material but without a pure epilayer, is also shown. At low bias (< 80 mV) the detector with the epilayer has a much lower dark current than that without the epilayer, indicating that the highly resistive epilayer is functioning properly in decreasing the dark current from the heavily-doped material. The responsivities of these BIB detectors at 2.3 K were on the order of 10^{-2} to 1 AW^{-1}, which is approximately 10-100 times less than conventional Ge:Ga photoconductors. The noise equivalent power was on the order of 10^{-14} $AHZ^{-1/2}$, which is approximately 100 times greater than conventional Ge:Ga detectors.

In summary, it has been shown that the multilayered Ge BIB detector does indeed act as a reasonable photoconductor although the present characteristics are not optimum. Future work will include fabricating detectors from more heavily doped IR-active substrate material [(Ga) = 2×10^{16} cm^{-3}) to achieve the increase in spectral response to ~ 180 μm. The present detectors, doped to 5×10^{15} cm^{-3}, did not show an increase in spectral response compared with conventional Ge:Ga detectors, which show a peak response at ~ 100 μm when doped to 2×10^{14} cm^{-3}. In addition, the source(s) of the dark current must be determined and device characteristics optimized.

Acknowledgments

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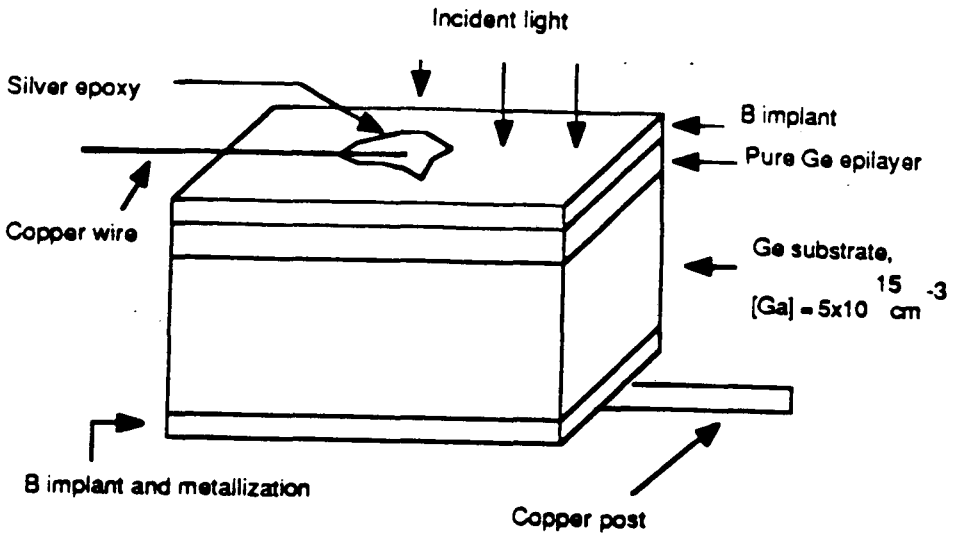

Fig. 1. Schematic of the Ge BIB detector with ohmic contacts. (XBL 884-1159)

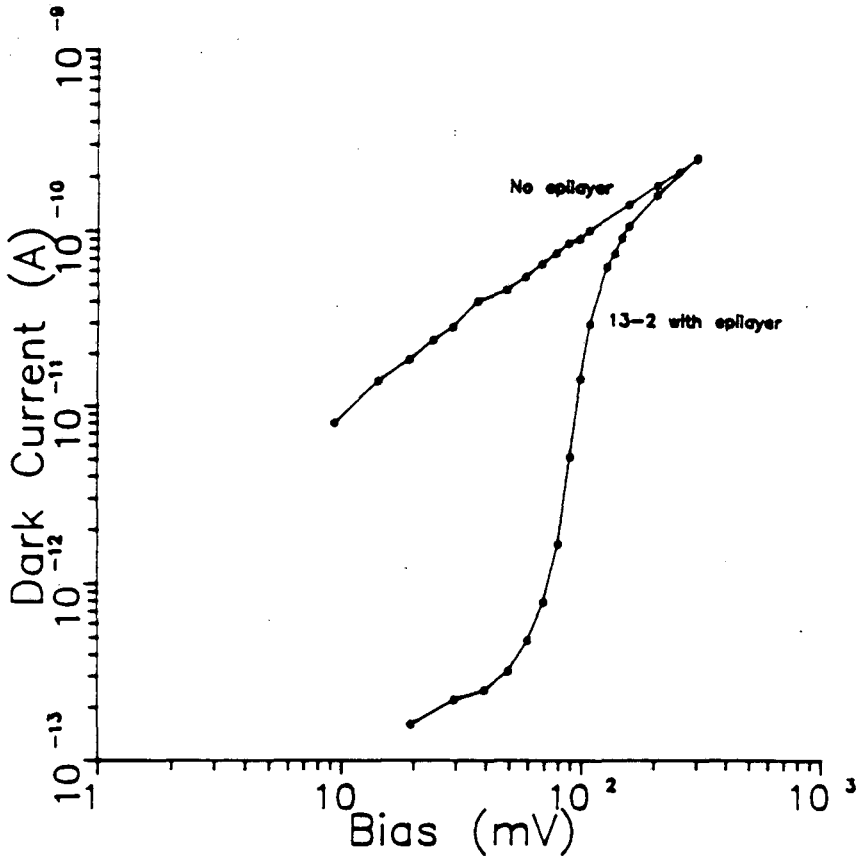

Fig. 2. Dark current as a function of bias for a BIB detector (13-2 with epilayer) and for the same material without an epilayer, at 2.3 K. (XBL 884-1160)

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