Photoelectromagnetic Effect in Bismuth

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The PEM effect has been observed for the first time in bismuth. Evaporated bismuth films as well as bulk material have been shown to exhibit the effect. The dependence on the wavelength of the incident light and on the intensity of magnetic field have bcen investigated.

WHEN a solid is exposed to light of a frequency close to its fundamental absorption edge, electron-hole pairs may be produced near the surface. If the excess concentration of current carriers is large enough, a diffusion current will flow toward the unilluminated side. A magnetic field perpendicular to this current will cause a voltage to appear in the third orthogonal direction. This is known as the photoelectromagnetic (PEM) effect and has hitherto been reported only in semiconductors.[1,2] It has recently been observed at this laboratory that the semimetal bismuth exhibits the PEM effect.

This phenomena was first observed in vacuum deposited films of bismuth, 1 in. $\times$0.126 in. $\times$0.001 in. in dimensions. Later, samples cut from a polycrystalline zone refined ingot and Taylor process bismuth wire were also found to exhibit the PEM effect.

The method used to measure the PEM voltage was essentially as given below. Light from a globar operated at 200 watts and chopped at 13 cps was sent through a Perkin-Elmer single pass Model 98 monochromator with a CaF_2 prism. After passing through the exit slit, it was collected by the Cassegrain condensing system. A six-to-one reduced image of the slit was thus formed on the specimen, which was mounted between the poles of an electromagnet.

Wood's metal soldered contacts were made to the films. The amplifying system was that which is normally used with the thermocouple of the spectrometer. The output was observed on a Brown recorder. At the narrowest bandwidth, the noise level was approximately one millimicrovolt.

The PEM voltage was determined by averaging the absolute values of two readings due to two magnetic fields, equal in magnitude but opposite in polarity. This method cancelled out photovoltages which were present in the films. The method was checked by measuring these photovoltages at zero field and subtracting this from the observed value with a known field. The agreement between the two methods is within 1%.

Figure 1 shows the spectral dependence in the near infrared region of the PEM effect in a bismuth film. The curve has been normalized for a constant number of photons incident on the sample. The extrapolated position for the cutoff wavelength of the first portion of the curve agrees with the optical properties of bismuth published by Schulz.[3] The secondary peak is in agreement with an absorption peak observed at this laboratory in bismuth films.

Figure 2 shows the magnetic field dependence of the PEM effect. There seems to be two distinct regions for the curve. Below 800 oersteds, the response is linear. Above this value of magnetic field intensity, the dependence becomes more closely quadratic. This is similar to results for InSb.[2]

The assumptions made in the derivation of the equations for the PEM effect in semiconductors would not necessarily hold for a structure with an overlapping conduction band such as bismuth. Further work is now being done in an attempt to theoretically explain this phenomena.

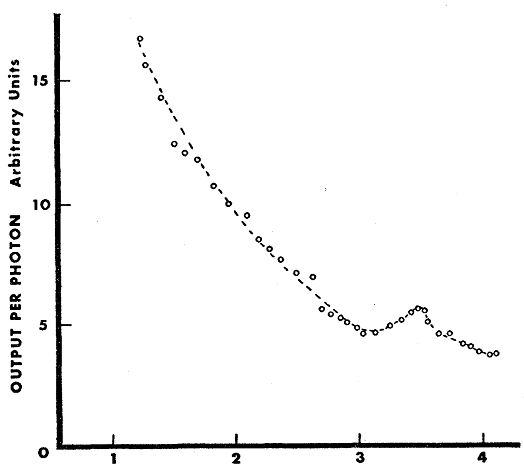

FIG. 1. The PEM voltage as a function of wavelength in the near infrared region. The output has been normalized for equal number of incident photons.

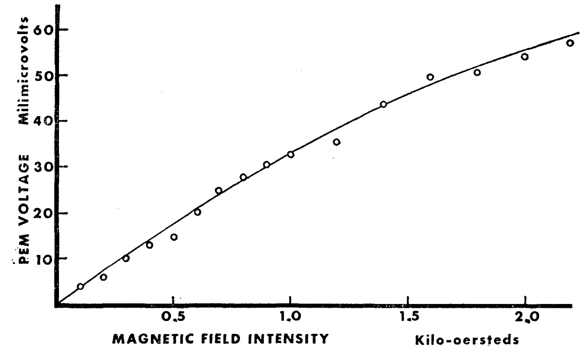

FIG. 2. PEM voltage as a function of magnetic field intensity. Wavelength of the incident radiation was 2 microns.

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[2] S. W. Kurnick and R. N. Zitter, J. Appl. Phys. **27**, 278 (1956).
[3] L. G. Schulz, J. Opt. Soc. Am. **43**, 406 (1953).