PYROELECTRIC DETECTION PROPERTIES OF GADOLINIUM MOLYBDATE (GMO)

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The pyroelectric detection properties of gadolinium molybdate (GMO) crystals have been studied near and at its 159°C ferroelectric transition temperature. Responsivity and detectivity figures of merit are calculated from measurements of pyroelectric currents induced by white light irradiation and are compared with room temperature figures of merit for TGS and SBN detectors. Since GMO does not exhibit a dielectric anomaly, it can be used as a threshold detector by heating through the transition temperature from a pre-selected temperature increment below the transition. Voltage-sensitive pyroelectric currents at the transition, found previously, permit voltage control of the threshold.

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Introduction

Radiation detectors utilizing the pyroelectric effect in ferroelectric materials have been developed in the past decade. The output of these devices is derived from the change in spontaneous polarization of a ferroelectric material from the heating induced by incident radiation. Such detectors have fast response, low noise characteristics, and exhibit uniform response over wide spectral regions. The history of this development and the properties of currently used detectors have been reviewed in a recent article by Beerman (1).

Since \( \frac{dP}{dT} \), the slope of the polarization vs. temperature curve (pyroelectric coefficient, \( \lambda \)) increases rapidly near the ferroelectric transition temperature, \( T_c \), one might expect a pyroelectric detector to be most sensitive at temperatures close to \( T_c \). However, for a simple detector consisting of a ferroelectric crystal in series with a load resistor, the responsivity (defined as the change in voltage across the load resistor per unit intensity of the incident radiation) depends on the ratio of \( \frac{dP}{dT} \) to the capacitance of the crystal (2). Since in most ferroelectric materials the dielectric constant becomes very large as \( T \rightarrow T_c \), their response decreases as \( T \) is approached and, in fact, the responsivities of TGS and SBN detectors go through a maximum well below \( T_c \) (1).

Recently, gadolinium molybdate (GMO), one of a group of ferroelectric rare-earth molybdates, was shown not to exhibit a dielectric anomaly on heating through its 159°C transition temperature (3). This unusual property suggested the possibility of using GMO close to its transition temperature for pyroelectric detection since it would not be loaded by a dielectric anomaly as are other better known materials. Further, since the ferroelectric transition of GMO is first order, a large current spike is obtained on heating through \( T_c \) which could be exploited for switching applications and threshold detection. Of course, any first order ferroelectric can be used in this way, in principle. However, the applied electric field, needed in repetitive measurements to keep the sample fully polarized on cooling back through the transition, largely or wholly destroys the first order character of the transition in most materials whereas in GMO, the first order character is, if anything, enhanced by the applied field.

In this paper, the properties of GMO, operated as a "normal" and as a "threshold" detector are described. No attempt is made to suggest specific applications nor were any attempts made to optimize for maximum sensitivity. To estimate the relative merits of GMO detectors, we have measured the parameters that determine the responsivity and detectivity figures of merit, \( R_M \) and \( D^* \) (1). These figures of merit depend only on material properties and not on detector configurations or circuit.

\[ \text{By threshold detection, we mean setting the steady-state temperature at some value below } T_c \text{ so that a fixed minimum amount of radiation heating, the "threshold", is required to trigger the large response at } T_c. \]