

Minimization of the Surface Leakage Currents of High-Resistivity (Cd,Mn)Te Crystal Plates

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We report a method for minimization of the surface leakage current and reduction of the time-dependent degradation of (Cd,Mn)Te, a material under consideration for semiconductor X-ray and Gamma-ray detector applications. Preliminary characterization of the resistivity of the plates was achieved by use of an EU- ρ - $\mu\tau$ -SCAN. For semi-insulating samples the resistivity was in the range 10^8 – 10^9 Ω -cm. Electrical contacts were made on the lower and upper surfaces of each sample. After protection of the contacts, lateral surfaces were subjected to reaction with a variety of chemical substances. Subsequent chemical treatments of (Cd,Mn)Te single crystal platelets were studied to optimize passivation of the inter-electrode surfaces. The control voltage–current (I – V) characteristics were measured repeatedly at hourly and daily intervals. It was found that chemical etching in 10%Br-MeOH, then 1%Br-MeOH, and finally passivating the surfaces of the crystals with $(\text{NH}_4)_2\text{S}$ reduces the surface leakage current.

Key words: Passivation, (Cd,Mn)Te, surface leakage current, detectors

INTRODUCTION

Semi-insulating (Cd,Mn)Te crystals were grown by use of a vertical Bridgman method. (Cd,Mn)Te is a p -type semiconductor with low resistivity because Cd vacancies, which act as acceptor centers, are produced when Cd atoms escape during the growth process.¹ To increase crystal resistivity, we compensated for the free holes by doping with indium. Samples cut from (Cd,Mn)Te crystal were used for the investigation. The size of the platelets was $5 \times 5 \times 2$ mm³. We annealed samples in Cd to reduce the concentration of acceptors and to improve the overall quality of the crystal by reducing the number of second-phase defects and inhomogeneities.² The material's resistivity was mapped by a contactless method, by use of an EU- ρ -SCAN; it was in the range 10^8 – 10^9 Ω -cm.

EXPERIMENTAL PROCEDURE

Two types of electrical contact were used for the electrodes:

1. an amorphous/nanocrystalline layer (300 μm thick) of heavily-doped ZnTe:Sb plus an Au layer (200 μm thick), as shown in Fig. 1, both evaporated on to the surfaces of the platelets under ultra-high vacuum (10^{-7} – 10^{-10} Pa) by molecular beam epitaxy (MBE); and
2. a chemically deposited Au layer.

Before depositing the contact layers by MBE, we prepared the surfaces of the crystal platelets by use of a four-step procedure:

- grinding with 9.5- μm Al_2O_3 powder,
- mechano-chemical polishing in a 2% solution of Br in methanol + glycol,
- selective etching (approx. 15 s) in a 1% solution of Br in methanol, and
- thorough rinsing in methanol.

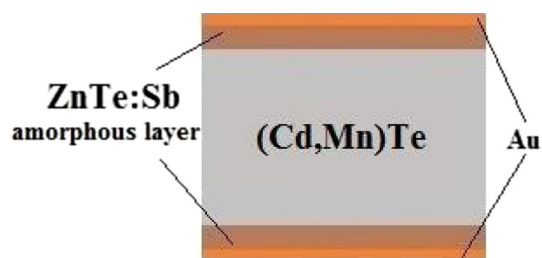


Fig. 1. Sample with contact layers deposited by MBE.

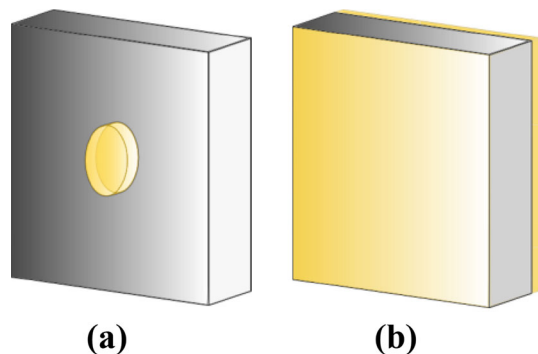


Fig. 2. Samples with electrodes as (a) center-spot contacts and (b) fully covering both parallel faces of the platelets.

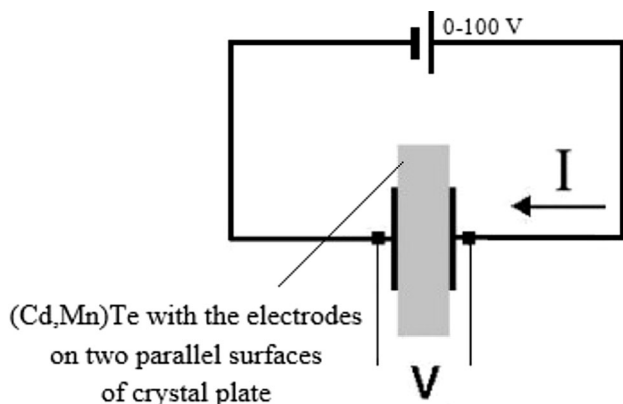


Fig. 3. Geometry of the electrodes for measurement of the current-voltage characteristics. Current flow is represented by I , and voltage by V .

Chemical deposition of Au as the only contact layer was preceded by a four-step procedure:

- grinding with $9.5\text{-}\mu\text{m}$ Al_2O_3 powder,
- mechano-chemical polishing in a 2% solution of Br in methanol + glycol,
- etching in a 10% solution of Br in methanol, and
- thoroughly rinsing in methanol.

Subsequently, Au was chemically deposited from a solution of $\text{AuCl}_3\cdot\text{HCl}\cdot 4\text{H}_2\text{O}$ (gold chloride

acid + distilled H_2O_2) in a reaction between the solution and the crystal's surface.

Contacts with the amorphous layer and with chemically deposited Au were prepared in two configurations:

1. center spot, and
2. fully covering both parallel faces of the platelets.

Figure 2a and b depict both cases.

Before any chemical treatment of the surfaces between electrodes (lateral surfaces), the electrodes were coated with a protective layer. A variety of chemical treatments:

1. etching in a 10% solution of Br in methanol (60 s);
2. etching in a 10% solution of Br in methanol (30 s) then etching in a 1% solution of Br in methanol (120 s); and
3. etching in a 10% solution of Br in methanol (30 s), etching in a 1% solution of Br in methanol (30 s), and passivation with ammonium sulfide $(\text{NH}_4)_2\text{S}$ (120 s)

were tested to optimize passivation of the inter-electrode surfaces. We used a Keithley 617 Programmable Electrometer with a very high input resistance ($> 10^{14} \Omega$) and with an internal voltage source (up to 100 V) to study evolution of the current-voltage characteristics over time by performing replicate measurements after hours and days. We used “two-electrode” measurements, in which the applied voltage is distributed between the first contact region, the bulk, and the second contact region (Fig. 3).

Secondary ion mass spectroscopy (SIMS) was used to investigate the time evolution of the level of oxidation of the (Cd,Mn)Te crystal surfaces after the different treatments. The best combination of chemical substances (based on use of $(\text{NH}_4)_2\text{S}$) for passivation was determined.

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