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Study of effects of polishing and etching processes on $Cd_{1-x}Zn_xTe$ surface quality

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ABSTRACT

The effect of surface preparation on CdZnTe properties was investigated. Surface etching using bromine solutions enhances Te elemental composition, resulting in a Te rich surface layer that is prone to oxidize. This oxidation degrades the performance of the fabricated CZT gamma detector. Roughness results were identical for samples polished with 1 and 3 μm and subsequently etched in 2% Br-MeOH. The optimal concentration of etching was 2% Br-MeOH.

1. Introduction

Certain semiconductor materials are particularly well suited to be employed as X- and γ-ray radiation detectors. These materials display a number of advantages including a wide bandgap, high atomic number, or excellent spatial resolution. Silicon is certainly the best known and most frequently used sensor material with a very good homogeneity [1], but due to its lower atomic number it exhibits average X-ray attenuation properties [2]. Therefore, interest in alternative materials with a higher atomic number 'Z' is continuously growing. Intense research has been carried out to improve the development of wide bandgap compound semiconductor sensors such as GaAs, CdTe, CdZnTe [3–6]. Cadmium zinc telluride (CZT) is a promising material used in a broad range of applications, including medical imaging, industrial process monitoring, national security, environmental safety, and basic science [7–9].

The spectroscopic performance of cadmium zinc telluride (CZT) room temperature radiation detectors can be limited by either bulk or surface imperfections introduced during the growth, harvesting, and fabrication process. Bulk imperfections including impurities, vacancies, interstitials, grain boundaries, and dislocations have been relatively well studied and are known to trap charge and ultimately reduce detector performance [10]. Furthermore, mechanical damage induced by material processing or adsorbed chemical species on the surface is also known to trap charge or increase leakage current [11]. Rough or damaged surfaces exhibit persistent photoconductivity, which could be eliminated using chemical etching solutions [10].

CdZnTe is one of the most important semiconductor alloys used for detection of X- and gamma-rays primarily due to its wide bandgap, high atomic number, and stopping power, and room temperature operability [5]. Material preparation operations such as wafer slicing, dicing, lapping, and polishing create surface damage. This induced surface and sub-surface damage directly affects the detector performance. To reduce the effects of induced surface damage on detector performance, chemical etching is necessary prior to electrode deposition. Chemical etching removes surface and sub-surface damage induced by mechanical deformation of the detector material. For CZT, one of the most common etching solutions is Br-MeOH [10]. Intense research was carried out to determine the optimal conditions for etching CZT detectors to obtain high quality surface finishes [12–15].

The aim of this work is to study the effects of lapping, polishing, and etching on $Cd_{1-x}Zn_xTe$ surface quality. The polished samples were etched with Br-MeOH using different concentrations of bromine. The samples were subsequently

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characterized by scanning electron microscopy (SEM), atomic force microscopy (AFM), and contactless resistivity mapping (CoReMa).

2. Experimental

A single $Cd_{1-x}Zn_xTe$ ($x=0.15$) ingot was grown for this work using the oscillatory vertical Bridgman technique. Elemental Cd, Zn, Te, and Bi (6 N, pure metal) were used as starting materials. An excess of Cd was supplied to control crystal stoichiometry. The initial concentration of Bi in the ingot grown for this work was 1×10^{19} atm/cm^3. A more detailed description on the crystal growth of CZT has been reported elsewhere [16,17].

An ingot of 27 mm in diameter and 90 mm in length was obtained from which several round wafers of 3–4 mm in thickness were harvested using a diamond wire saw. The as cut wafers were lapped and polished with alumina powders (abrasive size of 1 and 3 μm) using a Logitech PM5. An average of 200 μm of material was removed from both surfaces of the sample. Taking into account that mechanical polishing induces surface damage

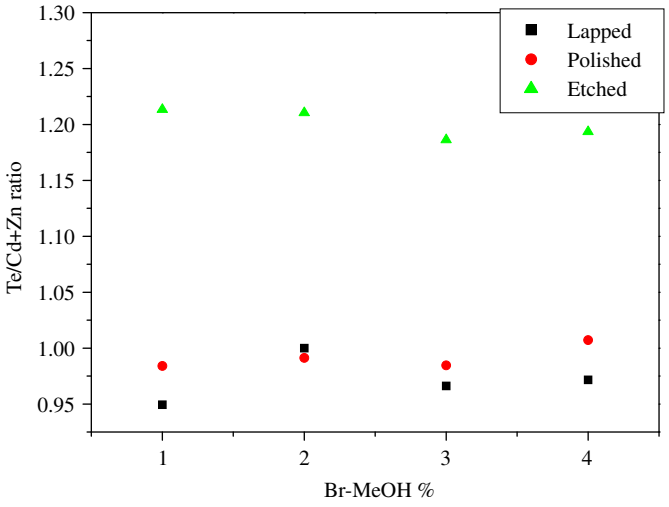

Fig. 2. Te/Cd+Zn ratio compositional data from EDX on BRO—CZT-Bi 250208 treated samples (1 μm alumina polishing powder).

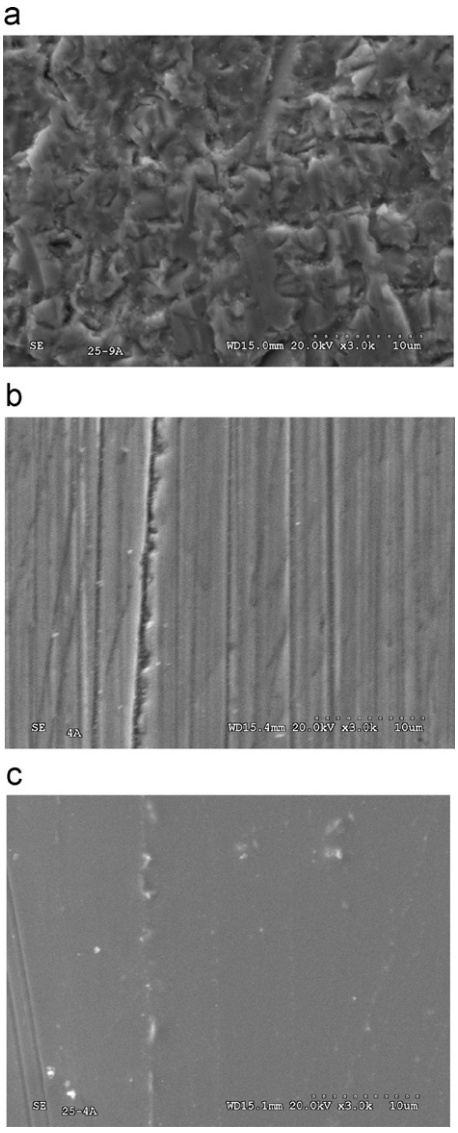

Fig. 1. SEM images of lapped, polished and etched BRO–CZT–Bi 250208 samples: (a) lapped, (b) polished, and (c) etched.

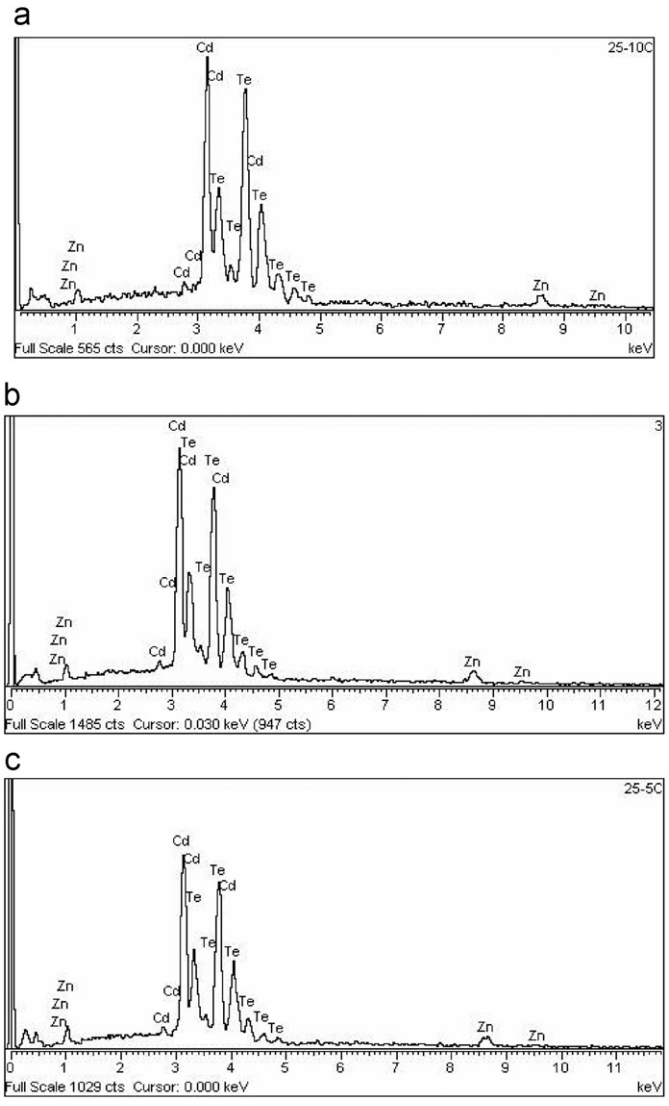

Fig. 3. Typical EDX spectra from BRO—CZT-Bi 250208 lapped, polished and etched samples, (a) lapped, (b) polished, and (c) etched.

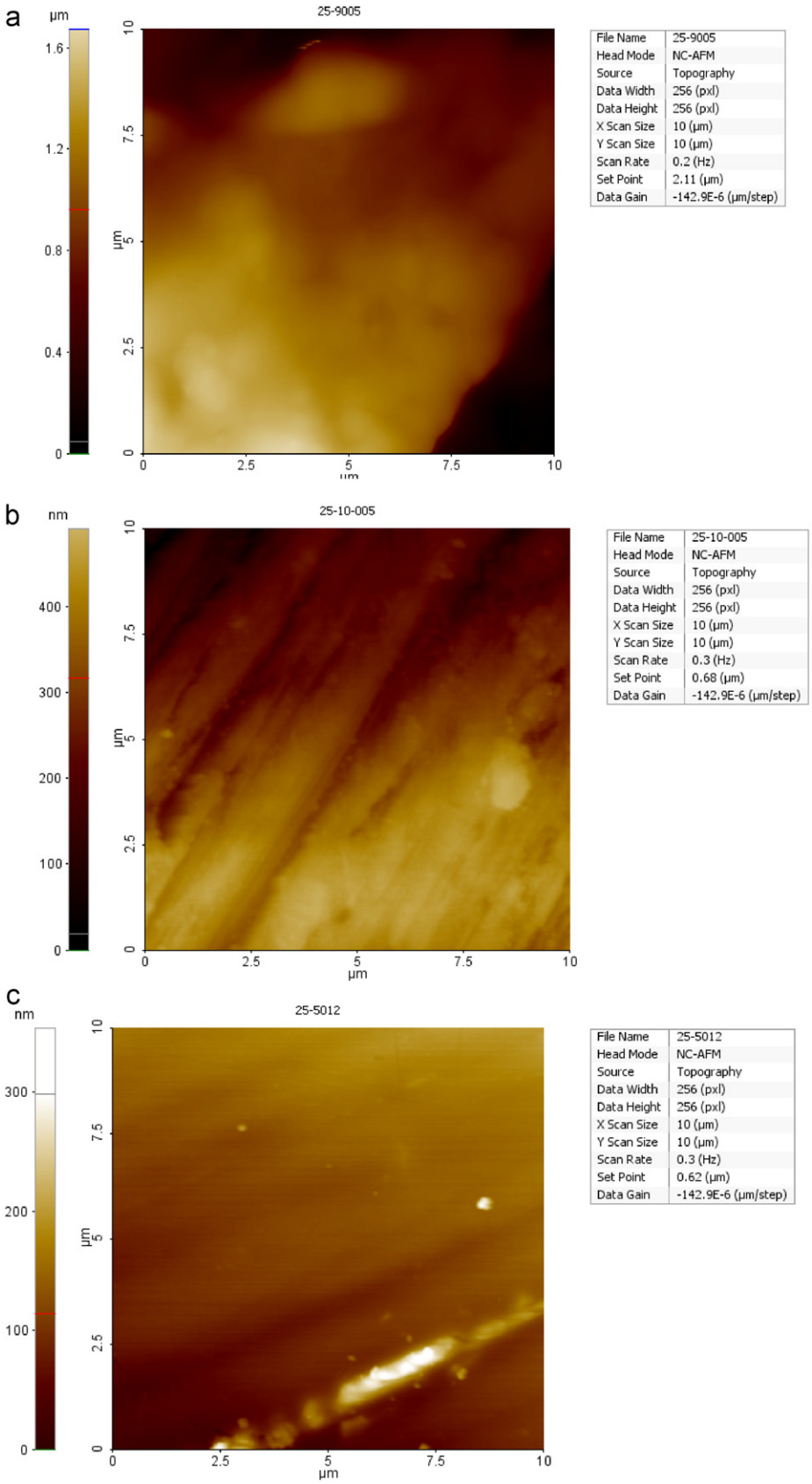

Fig. 4. AFM images of lapped, polished and etched BRO—CZT-Bi 250208 samples: (a) lapped, (b) polished, and (c) etched.

extending into the bulk crystal, the final surface was chemically etched using Br-methanol. Different concentrations of bromine were investigated (1–4%) and each sample was etched for a duration of 30 s. Surface roughness was evaluated using SEM and AFM measurements of the processed samples. (Philips XL-30-FEG and PSI model XE-100 microscopes). The EDX mode of the Philips

XL-30-FEG was also used for evaluating surface composition (error 0.5 wt.%).

3. Results and discussion

Presented in Fig. 1 are SEM images of lapped, polished, and etched CZT samples. This clearly shows how polishing and etching improves surface specularity by reducing roughness. Residual defects on the surface are due to interaction between Br–MeOH and impurities at the CdZnTe surface [15]. This high magnification more quantitatively demonstrates the improved surface specularity provided by the polishing and etching process.

EDX measurements were carried out on lapped, polished, and etched samples to obtain surface composition data. Fig. 2 presents Te/Cd+Zn ratio compositional data for CZT samples polished with 1 μm alumina polishing powder and etched using different concentrations of Br-MeOH solution (1–4%) for a duration of 30 s. Chemical etching using bromine results in a Te rich surface layer that is prone to oxidize. This oxidation correspondingly degrades detector performance. Duff et al. [15] propose using as-polished samples in the fabrication of gamma detectors since they exhibit higher performance than etched samples. EDX results indicate that the concentration of Te at the surface is approximately the same even after polishing using either 1 or 3 μm alumina powder. Typical EDX spectra obtained from lapped, polished, and etched samples are shown in Fig. 3.

Surface morphology was examined using AFM. Results indicate that the CdZnTe surface after etching exhibits a more homogeneous surface compared with lapped and polished surfaces (Fig. 4). The AFM images of the polished surface clearly show mechanical damage caused by the abrasives used in the polishing process. This damage was removed with some success using a Br-MeOH etching solution. The roughness of the CdZnTe surface was quantified by the RMS parameter defined as the root mean square average between the height deviations and the mean line/surface, taken over the evaluation length/area (i.e. over the scanned surface). RMS results are reported in Fig. 5 (error of measurement in the Z direction <1 nm).

Results show that the RMS roughness is approximately the same even after the polishing process, most notably in results for CZT polished using 1 μm polishing powder. It is important to note the roughness values were significantly lower than after lapping process, as expected. It was also observed that poor surface morphologies were obtained for higher etching concentrations. As a result, roughness values after etching were higher than roughness of the same samples after polishing process. The lowest roughness values were obtained for low concentrations of Br-MeOH: between 1 and 2% for both polishing conditions (1 and 3 μm). Roughness results were identical for samples polished with 1 and 3 μm etched in 2% Br-MeOH during 30 s considered as optimal condition of etching. CoReMa results show no remarkable change in resistivity between lapped and polished samples (10^9 Ω cm). After chemical etching, the resisitivity was approximately 10^8 Ω cm, indicating that the electrical properties of the CdZnTe samples had changed.

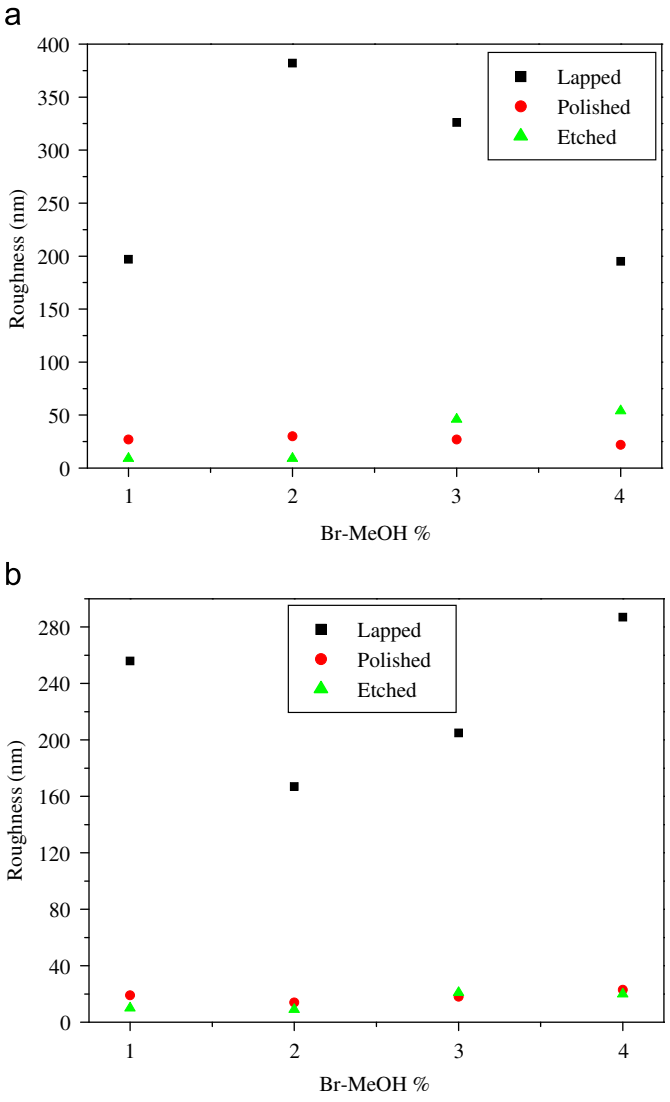

Fig. 5. AFM Roughness results of BRO-CZT250208: (a) 1 and (b) 3 μm alumina, with different etching concentration Br-MeOH.

4. Conclusion

In this work the surface preparation of CdZnTe was studied to establish optimal etching (Br-MeOH) conditions for post polishing processing. Surface etching using 2% Br–MeOH for a duration of 30 s is considered the optimal condition for etching. Resistivity results show the degradation of BRO–CZT–Bi 250208 electrical properties after etching.

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