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The effect of etching time on the CdZnTe surface

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ABSTRACT

The surface quality of CdZnTe plays an important role in the performance of sensors based on this material. In this paper the effect of chemical etching on $Cd_{0.9}Zn_{0.1}Te$ sensor performance was examined. Sample surfaces were treated with the same concentration 2% Br-MeOH for different etching times (30 s, 2, 4, 6, 8 min). The surfaces were characterized by Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), and *I–V* Measurement. These results demonstrate that the best surface quality can be obtained by chemical etching for 30 s. Under these experimental conditions, the surface composition Te/Cd + Zn approaches 1, the roughness is lower than 3 nm, and the leakage current shows a value lower than 10 nA.

1. Introduction

The material showing the greatest promise today for production of large volume X-ray and gamma-ray spectrometers is Cadmium Zinc Telluride (CZT). This is due to several interesting material properties including large absorption coefficient, high resistivity, high average atomic number (which ensures a high absorption efficiency with only a moderate thickness of 1–2 mm), large band gap, and room temperature operability [1,2].

The combination of these advantages makes CZT an excellent detector for medical, security, and astrophysics applications. CZT crystals are attractive to use in homeland security applications because they detect radiation at room temperature and do not require low temperature cooling as do silicon- and germanium-based detectors.

Despite these inherent advantages, the use of CZT material is still limited by some important problems such as the presence of secondary phases, impurities, low resistivity, and surface quality. Each of these factors causes degradation of detector performance. Therefore it is now important to determine the factors influencing and limiting the characteristics of the CdZnTe.

Surface treatment is a critical and sensitive process in the fabrication of cadmium zinc telluride (CZT) radiation detectors, and plays a critical role in determining the detectors performance. Furthermore, surface properties influence the uniformity of the electric field inside the device and can significantly affect charge transport and signal formation. Various studies have shown that surface properties control many aspects of device operation and performance. For example, the maximum bias voltage is often limited by surface leakage current. As a result the size of the depletion region within the detector is limited. Furthermore, high leakage currents affect the electric field line distribution near the contacts, and can degrade the charge collection efficiency of the anode. Therefore, it is desirable to have the leakage current of the detector as low as possible [3].

In this paper the effects of surface treatment on the properties of CdZnTe have been studied. The material preparation operations such as cutting, lapping, and polishing create surface and subsurface damage. To remove this damage layer, a chemical etching process is used. Chemical etching is needed prior to the metal deposition process in order to form a tellurium-rich surface, while removing surface contaminants and oxides. The standard chemical solution for etching CZT is Br-MeOH [4]. The enrichment of elemental Te on the surface is one favorable characteristic useful for electrode deposition and adhesion. However, this surface layer of Te can also lead to increased leakage current, which is unfavorable to the performance of CdZnTe detector [5]. In this work we attempt to study the effects of the etching time on the surface of CZT.

2. Experimental

A boule of $Cd_{1-x}Zn_xTe$ ($x = 10\%$) grown by the Bridgman method [6] was cut into $5 \times 5 \times 3\ mm^3$ wafers, using a Well 3032 machine with a diamond wire of 170 μm diameter.

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The samples were first lapped to remove the saw damage, and to obtain flat surfaces with controlled thickness. This process was carried out using a Logitech PM5 machine with a standard glass plate operating at 50 RPM. The abrasive used for bulk material removal was 3 μm Al_2O_3 powder, supplied by Logitech, UK.

The objective of the mechanical polishing was to reduce the thickness of the amorphous subsurface damage layer and to improve the surface quality. This treatment is also performed with the same Logitech system, but using a pad (Chemcloth,) and, again, 3 μm Al_2O_3 powder.

Taking into account that the mechanical polishing also imparts a degree of surface and sub-surface damage, the samples were chemically etched with 2% Br-MeOH solution for different periods of time of 30 s, 2 min, 4 min, 6 min, and 8 min; the sample react with Br-MeOH solution following Eq. (1). Therefore the sample surface changes from Cd-rich to Te-rich due to the deposition of Te product on Cd Face. Afterward the samples were rinsed with methanol to dissolve the Br remaining on the surface and then dried with nitrogen gas:

$$Cd_{0.9}Zn_{0.1}Te\,(surface) + Br_2 \Rightarrow 0.9CdBr_2 + 0.1ZnBr_2 + Te \qquad (1)$$

Immediately after etching, Au was deposited on both sides of the CZT samples by the electroless method (1 g of $AuCl_3$ in 25 cm^3 of H_2O) for measuring *I–V* characteristics. In this process the sample is immersed in the $AuCl_3$ solution for 2 min. The Au reacts with the CZT surface forming a conductive TeAu layer, considering that cadmium is removed from the surface and replaced by gold [1].After Au deposition, the sample was dried with nitrogen. Then anode and cathode surfaces were protected by a thin wax film. Afterward the edges were lapped manually with Al_2O_3 powder 3 μm to remove the gold from the edges. The wax is then removed through dissolution in trichloroethylene.

After each lapping, mechanical polishing, and chemical etching process the samples were characterized using a Scanning Electron Microscope (Hitachi S-3000N) coupled to an Energy Dispersive X-ray (EDX) Analyser (Oxford Instruments, INCAx-sight model) for surface quality and elemental composition. An Atomic Force Microscope (PSI100 Park Systems) was used for analyzing surface roughness. The *I–V* results have been obtained using Keithley 2400 sourcemeter.

3. Results and discussion

The surface quality of samples was analysed by SEM, showing in Fig. 1 an image of the crystal prepared by lapping, polishing, and etching. It is clearly visible that while the lapped sample has a very rough surface, the mechanically polishing process produces a more reflective surface, but with a high density of scratches on the surface. The chemical etching reduces the scratches and produces a smoother surface.

Usually, Br-MeOH solution is used to remove the surface damaged layer introduced by cutting and mechanical polishing to obtain a clean surface prior to electrode deposition. This will in turn produce a Te rich surface. The surface composition, obtained by EDX, is shown in Fig. 2. The area under each peak is proportional to the concentration of each element.

Using this technique, the surface composition for each sample has been obtained and is presented in Fig. 3. The results indicate that the surface concentration of Te/Cd + Zn varies greatly for each process. We also observe that the surface is enriched with Te for the chemical etching processes (30 s and 2 min), while the Te concentration is reduced for the others processes. Chemically etching the surface for 30 s produces the largest concentration of Te.

In order to understand the effect of chemical etching on surface roughness, the samples were also examined with an Atomic Force Microscope (AFM). Presented in Fig. 4, the surface roughness decreases when the surface is etched with 2% Br/methanol solution for 30 s. However this trend changes and the roughness increases when the sample is etched for more than 2 min. It is clear that 30 sec of chemical etching is sufficient to significantly reduce the damage imparted by the mechanical polishing, as evidenced by the reduced surface roughness observed after etching. For durations of chemical etching greater than 2 min, the surface morphology is degraded as the roughness tends to increase. In fact, it has been shown that the roughness of the surface degrades detector efficiency [3].

Both previous results show that the 30 sec and 2 min chemical etching processes produce the desired surface composition: low surface roughness with high concentration of Te for subsequent electrode deposition. With these arguments, it is important to study

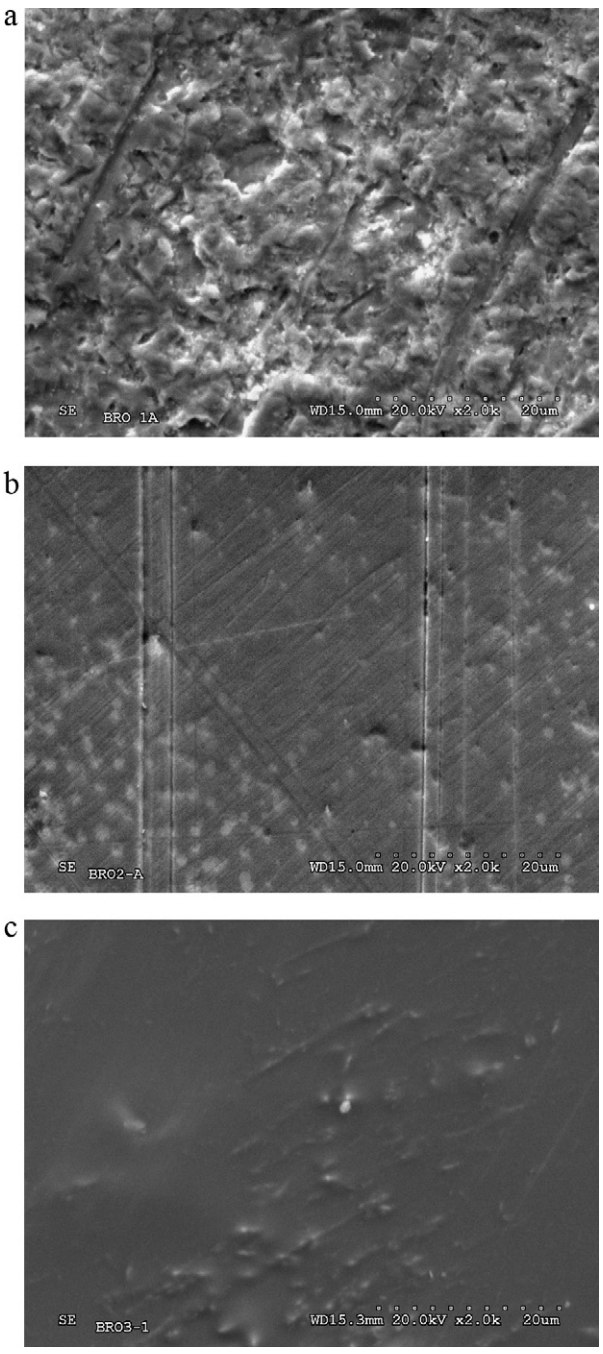

Fig. 1. SEM images of CZT samples: after lapping (a), mechanical polishing (b) and chemical etching process (c).

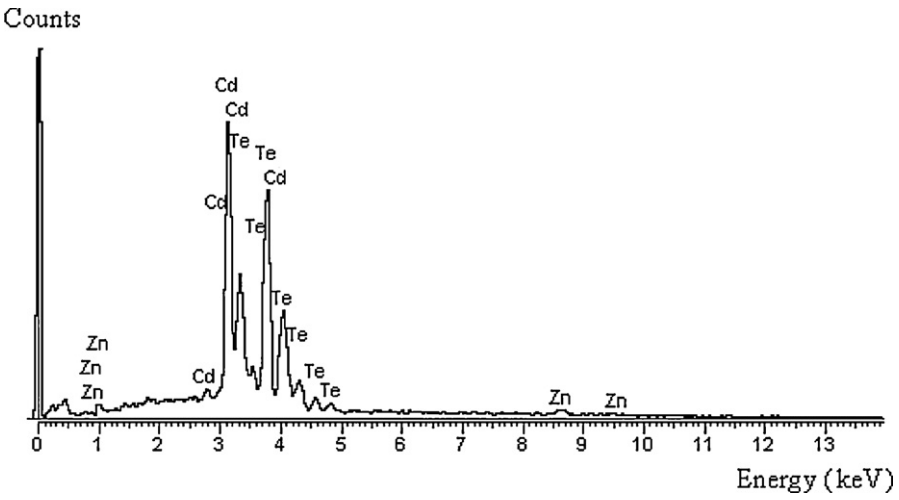

Fig. 2. EDX analysis spectra of sample chemically etched.

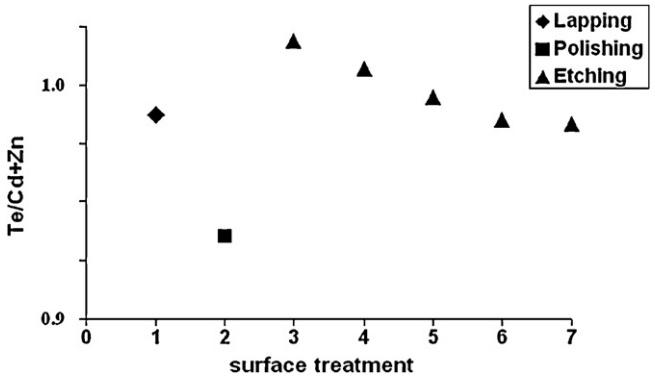

Fig. 3. Chemical composition from EDX after lapping, polishing, and chemical etching process with different times.

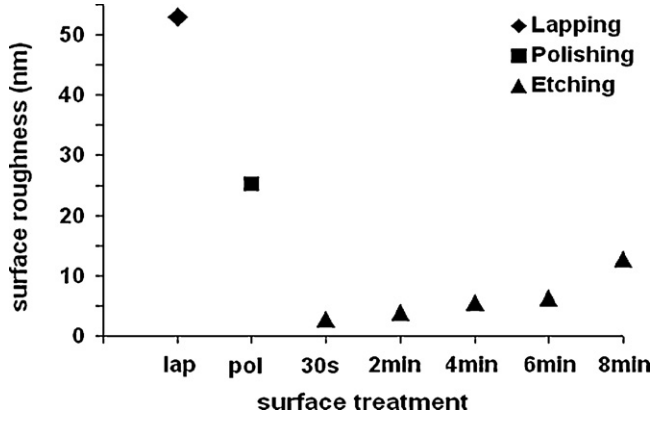

Fig. 4. Roughness values after lapping, polishing, and chemical etching process with different times.

the leakage current of the samples submitted to the processes discussed above.

Fig. 5 compares the *I–V* characteristics for detectors polished and etched for different periods of time. It can be seen that the chemically etched detector shows a reduction of the dark current in comparison with the polished one. This data suggests that leakage current increases with increased time etching.

These results support the conclusion that an etching time between 30 s and 2 min produces the minimum leakage current in

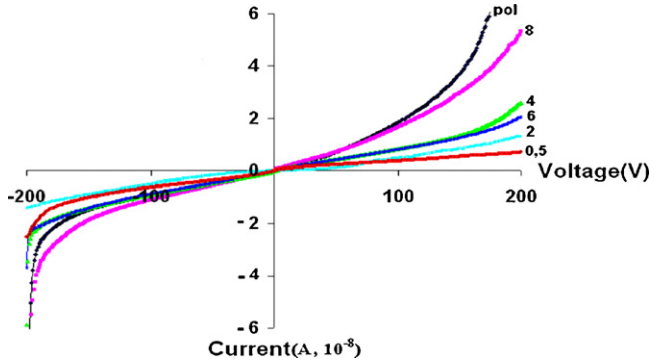

Fig. 5. *I–V* curves after different surface treatment (time in min).

the detector. This is in agreement with the results obtained regarding Te enrichment and surface roughness.

4. Conclusion

The surface quality of CZT surfaces after different treatments was investigated. The results show that the surface etched in 30 s contains the largest Te concentration which is favorable for electrode deposition. Smooth CZT surfaces can be obtained by mechanically polishing and using Br-methanol for 30 s. In order to maintain low leakage current, the same 30-s chemical etching can be used. These values have both been observed to increase with increasing etching time.

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