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EFFECT OF ETCHING ON THE TlBr CRYSTAL SURFACE AND ITS RADIATION RESPONSE

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ABSTRACT

TlBr detectors were prepared using crystals with surface submitted to different mechanical and chemical treatments. The effect of the surface quality in the detector response was evaluated by systematic measurements of the pulse height spectra and energy resolution for each detector prepared with different surface treatments in the TlBr wafer. The measurements were carried out under ^{241}Am and ^{133}Ba gamma radiation excitation at room temperature. The better radiation responses were found for the TlBr detector prepared with crystal surface submitted to mechanical treatment.

1. INTRODUCTION

Crystals with semiconductor properties have been studied as radiation detectors since the discovery of the conductivity of the AgCl crystal under radiation excitation by Van Heerden. However, the use of semiconductor detectors was viewed with some skepticism due to the little advantage presented compared to the scintillator detectors together with the difficult imposed on the semiconductor detectors operation by charge carrier trapping and space charge accumulation [1]. The excellent characteristics of the high-purity Ge and Si radiation spectrometers overcame these limitations and the development of the semiconductors as radiation detectors has been stimulated. Room temperature semiconductor radiation detectors are mentioned as an attractive alternative for applications, where the Ge and Si are not suitable. However, the charge carrier trapping, space-charge accumulation and polarization are still significant issues for studies of the semiconductor detectors.

Semiconductors to operate suitably at room temperature require large band gap energy to reduce thermally generated leakage currents. Among them, TlBr crystal presents promissing characteristics to be used as room temperature semiconductor detector. It has band gap energy of 2.7 eV, high atomic number (Z_{Tl}=81 and Z_{Br}=35), high density (7.5 g/cm^3) and high resistivity (10^{12} Ω.cm). It has a cubic crystalline structure and melt at 480ºC [1,2].

Although details of TlBr crystal growth are described in the literature [1,3], some difficulty in the preparation of the crystal as a radiation detector is found. TlBr detectors are generally fabricated by slicing and lapping samples to appropriate dimensions. The surfaces are polished mechanically or chemomechanically with an etchant solution. Ohmic contact is generally performed from Au, Pd and Aquadag (colloidal carbon).

Polarization has been a severe problem with a TlBr device. There are several works in the literature [4,5,6], describing studies performed on high purity crystal growth procedure, crystal surface preparation and contact configuration of the TlBr aiming to reduce polarization and improve TlBr crystal performance as a radiation detector. However, further studies are required to overcome this limitation. In this work, the influence of the mechanical and etching treatment on the TlBr crystal surface in its radiation response was studied.

2. MATERIALS AND METHODS

TlBr crystals were grown by the vertical Brigdman technique, using a quartz crucible in vacuum atmosphere. The starting material used was the commercial TlBr salt obtained from Merch, Germany. Crystals around 10 mm diameter and 20 mm long were obtained with a growth rate of 1 mm/h.

The crystal was sliced in wafers, cutting the crystal transversally to direction [110], using a diamond saw, lubricated with glycerin during the process. In order to be used as a radiation detector, the following different treatment procedures were carried out for each wafer surfaces: (a) polishing with alumina lapping abrasive with particle sizes ranging from 0.3 to 3 μm; (b) mechanical polishing for the same procedure and subsequent treatment with bromide acid and peroxide solution and (c) similar mechanical polishing and treatment with bromine methanol solution. The surface of all wafers were evaluated by microscopy (OM) technique, before and after each treatment. Afterwards, the TlBr wafers were prepared as detectors applying conductive graphite painting (VIATRONIC) on both sides of the wafers. Cu wires were connected to the electrodes using graphite paint.

The radiation response was evaluated by pulse height spectroscopy. The TlBr detector was assembled inside an aluminum box and coupled to the A250F charge sensistive preamplifier. The signal was feed to the Ortec 450 amplifier and evaluated using an EG&Ortec Model 918A multichannel analyzer. The measurements were carried out using ^{241}Am (59 keV) and ^{133}Ba (80 e 355 keV) gamma radiation sources. Similar measurements were carried out for two crystals, named crystal 1 and crystal 2. Both surfaces of these crystals were prepared by the same procedure.

3. RESULTS AND DISCUSSION

Figure 1 shows the picture of crystal wafer surface before and after each treatment using optical microscopy. Although the image resolution of this technique is low, the surface defects can be better observed in the surface treated with chemical etching.

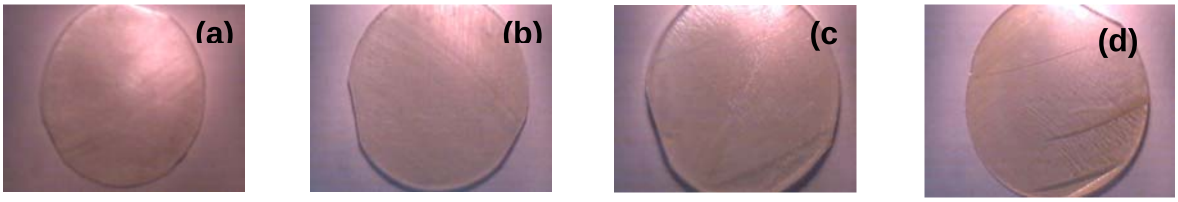

Fig.1 Crystal surface without treatment (a), polished mechanically (b), etching with bromine methanol (c) and etching with acid bromidric (d).

Figure 2 shows the 59 keV ^{241}Am pulse height spectra obtained for each different surface treatments in crystal 1. As it can be observed in this figure, the higher pulse heights were found for the crystal surfaces polished mechanically, suggesting that a better radiation efficiency may be obtained for crystal surface with this treatment procedure compared to that prepared with chemical etching.

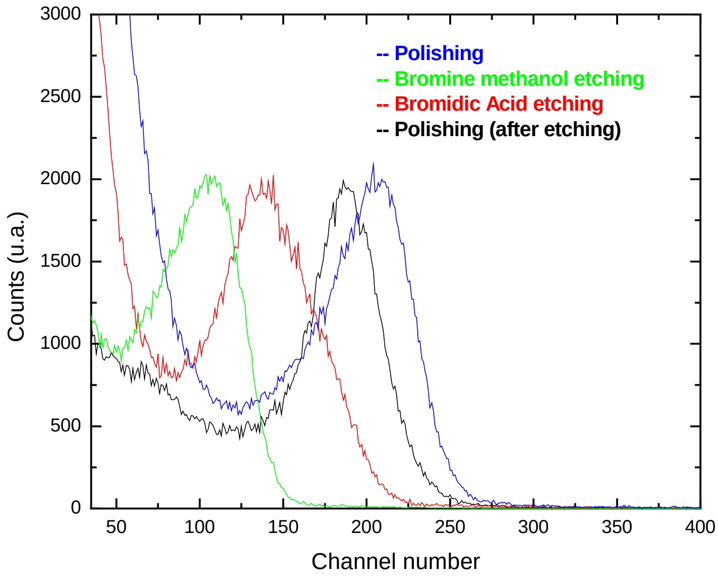

Figure 2. Pulse height spectra obtained from TlBr detectors prepared with different procedures.

Figure 3 shows the gamma spectrometry for the ^{241}Am (59 keV) and ^{133}Ba (80 keV) gamma radiations obtained for each different surface treatment in the TlBr wafer. The lower energy peak at 30 keV that appears in ^{133}Ba spectrum is due to Tl internal transition excited by the higher gamma energy present in the ^{133}Ba. For the crystal surfaces polished mechanically, the three peaks were distinguished clearly, as shown in Fig 3.A and C, while for crystal surfaces treated with chemical etching predominant peaks at 30 keV and 59 keV and single broad peak at 80 keV were observed, as it can be seen in Fig 3 B and D.

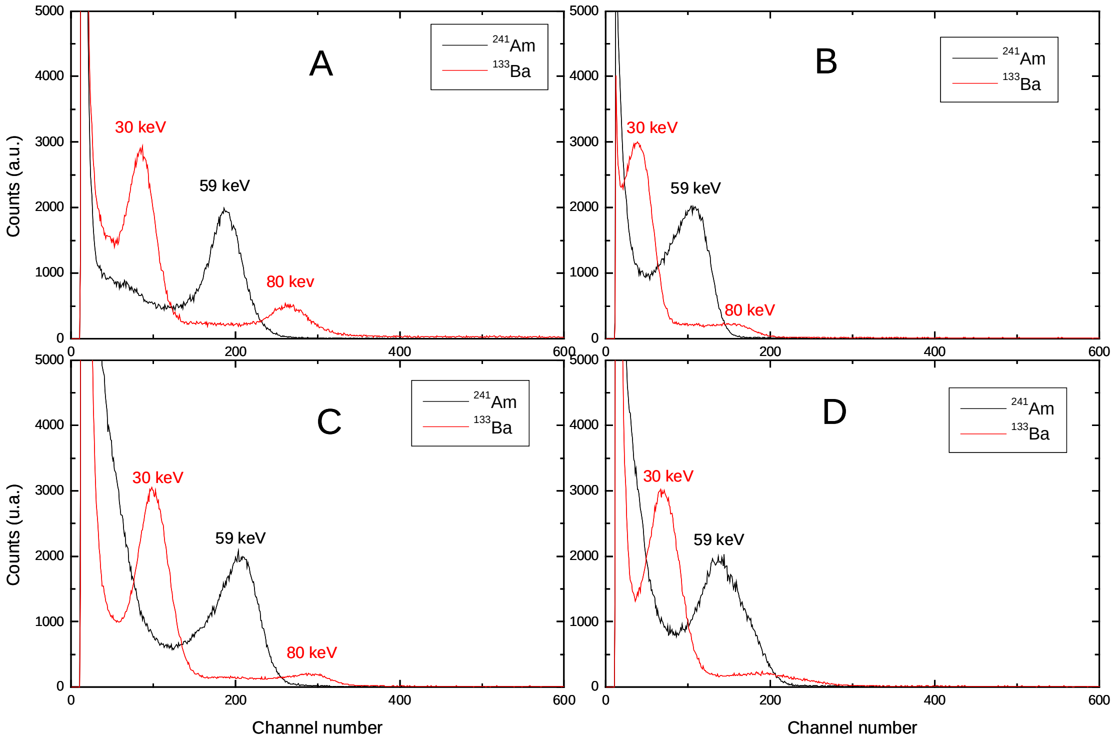

Figure 3. Energy spectra for 59 keV (^{241}Am, black curves) and 80 keV (^{133}Ba, red curves) obtained for crystal 1 with different surface treatment. Crystal surface polished mechanically (A), etching with bromine methanol (B), polished mechanically again (C) and etching with acid bromidric (D).

The measurement of the crystal surface after the removal of the ohmic contact of the surface treated with chemical etching (Fig. 3C) was carried out in order to confirm the results obtained with the crystal surface polished mechanically, before chemical etching (Fig. 3A), demonstrating that the crystal surface polished mechanically presents better performance for the radiation response. The enhancement of the 30 keV resolution and the degradation of the 80 keV resolution in the crystal shown in Fig 3 C, compared to that of the Fig. 3A, is due to a smaller thickness of the crystal, since the crystal surface should be polished twice, before the chemical etching and after the removal of the ohmic contact of the crystal surface. The thicker the crystal thickness, the better the charge collection for lower energies and the worse the energy absorber for larger energies.

The gradual degradation in the detector resolution has been observed in the room temperature semiconductor detector over a period of several hours after applying bias voltage by several authors [2,3,4]. This no-stability in the energy resolution is attributed to the polarization phenomena. However, in this work, the detector prepared using the crystal 1 shows stability for at least 30 days. Further studies should be carried out for determine the stability time of this detector.

The better performance observed for the crystal with surface polished mechanically is not in agreement with the results obtained by Oliveira et al [4] . These authors found the best result of radiation response for the crystal polished, etched and annealed. Further studies should be carried out to verify this difference in the results.

In order to confirm the results obtained for crystal 1, similar measurement of the energy spectra were carried out using crystal 2. Figure 4 shows the energy spectra obtained for crystal 2. As it can be observed, the spectra present a poorer quality compared to that found for crystal 1, but they present similar behavior to that observed for crystal 1. The better energy spectra were found for the crystal surface polished mechanically, where two peaks can be observed clearly, while for the crystals with surfaces treated with chemical etching, no peak is observed in the spectra. The worst spectra quality found for crystal 2 may be due to the lower resistivity found for this crystal.

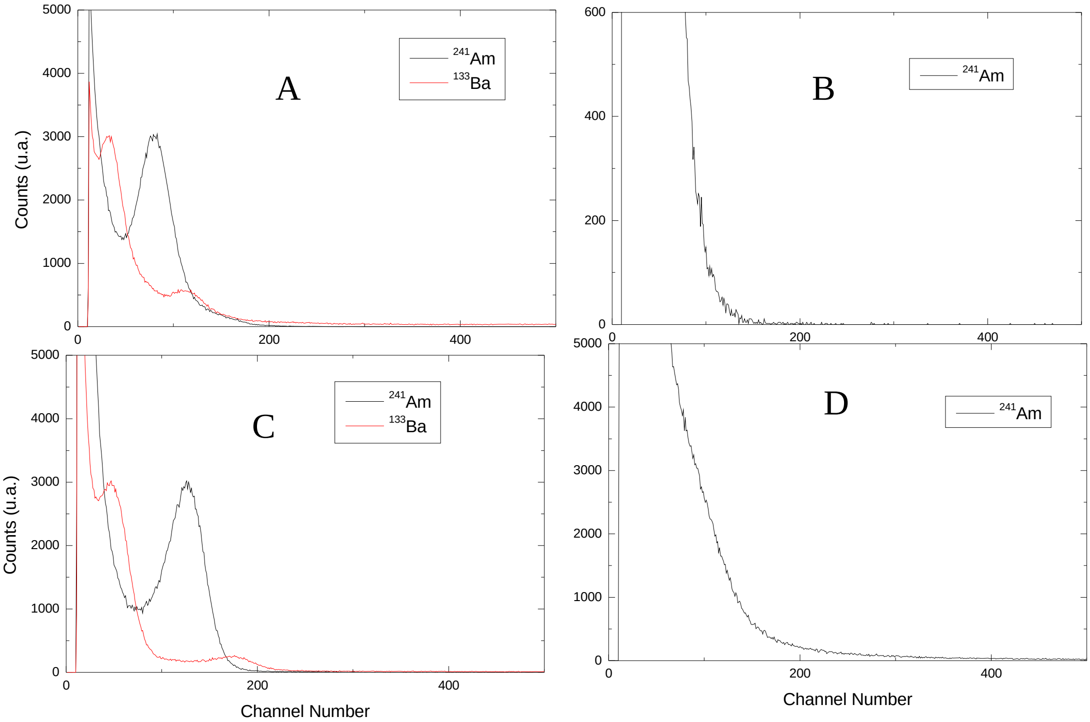

Figure 4. Energy spectra for 59 keV (^{241}Am, black curves) and 80 keV (^{133}Ba, red curves) obtained for crystal 2 with different surface treatments. Crystal surface polished mechanically (A), etching with bromine methanol (B), polished mechanically again (C) and etching with acid bromidric (D).

4. CONCLUSIONS

The best radiation response was obtained for the detector prepared with the crystalline surface prepared with mechanical polishing. The best results of the pulse height and energy resolution were found for the TlBr detector obtained with the crystal surface polished mechanically.

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