X-Ray Photoelectron Spectroscopy of CdZnTe and CdMnTe Materials for Nuclear Detectors

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***Abstract*–Cadmium zinc telluride (CdZnTe) and cadmium manganese telluride (CdMnTe) semiconductor nuclear detectors have the ability to operate at room temperature without cryogenic cooling. Thus, they can be fabricated into portable nuclear detection devices that can be used at seaports and border security, and at nuclear facilities to monitor radiation levels. In this paper, we present results from the use of X-ray photoelectron spectroscopy (XPS) to study the surface compositions of CdZnTe and CdMnTe wafers. Our results showed that Cd, Te and TeO_2 are the dominant species on these materials. Zn was also present on CdZnTe wafer, and Mn is present on the CdMnTe wafer. CdZnTe samples that were etched with high-energy ion beam did not show the presence of TeO_2 on their surfaces.**

I. Introduction

CADMIUM telluride and its ternary compounds with high electrical resistivity have applications in the development of X-ray and gamma-ray detectors. These detectors are used in medical imaging, the detection of radiological and nuclear threats, astrophysics, and radiation monitoring in space travels [1]–[6]. The major advantage is the ability to operate at room temperature without cryogenic cooling. Thus, they can be fabricated into portable nuclear detection devices that can be used at seaports and border security, and at nuclear facilities to monitor radiation levels. In this project, we used X-ray photoelectron spectroscopy (XPS) to study the surface compositions of cadmium zinc telluride (CdZnTe or CZT) and cadmium manganese telluride (CdMnTe or CMT).

Manuscript received December 20, 2020. This work was supported in part by the National Science Foundation (NSF) Major Research Instrumentation (MRI) through award number 1726901; in part by U.S. Department of Energy (DOE), Office of Defense Nuclear Nonproliferation Research and Development, the DNN R&D (NA-22), and DOE NNSA MSIPP award number DE-NA0003980; in part by the U.S. Nuclear Regulatory Commission (NRC) through award 31310018M0035; in part by the U.S. Department of Homeland Security, Domestic Nuclear Detection Office through award number 2012-DN-077-ARI065-05; and in part by the NSF HBCU-UP Program through award number 1818732.

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X-Ray Photoelectron Spectroscopy was used for surface composition studies. Surface composition affects surface current. High surface current is detrimental to energy resolution of the detector. Thus, it is important to study the surface composition of the detector wafer. We used two different CdTe-based wafers, CMT and CZT, during this experiment.

II. Experiment

The samples used in this study were cut from as-grown CMT and CZT crystals using a special machine equipped with a diamond impregnated wire saw. After cutting, the wafers were mechanically polished. The mechanical polishing is in two steps. First, the wafers were polished using 600-grit to 1200-grit silicon carbide abrasive papers in successive steps. The second step involved further smoothening in successive polishing using alumina powder of sizes 3 – 0.1 μm. The final stage of a sample preparation involves thorough rinsing in distilled water and drying with compressed air.

Two sets of data were collected: an unetched sample and an etched sample. Etching is a process where the XPS machine uses high-speed ions to remove very thin surface layers from the sample. The XPS system (Fig. 1) used in this experiment is equipped with a software that identifies the binding energies of the materials that dominate the surfaces of the wafers [7].

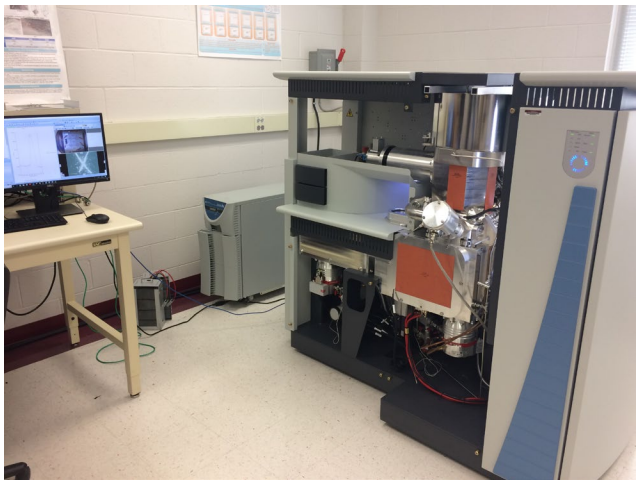

Fig. 1. High-performance XPS Surface Analysis System, by Thermo Fisher [7], equipped with software that identifies the binding energies.

The XPS machine shoots X-rays onto a small area on the wafer. Photoelectrons from that small area are collected and focused into the analyzer. When electrons in the sample

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absorb enough energy, they are ejected from the sample with a certain kinetic energy. The energy of those ejected electrons is analyzed by a detector and a plot of these energies and relative numbers of electrons is produced.

III. Results

The XPS results showed that Cd, Te and TeO_2 are the dominant species on these materials. Zn was also present on CdZnTe and Mn on the CdMnTe wafer. The XPS result for CZT sample prior to ion-beam etching is shown in Fig. 2, and that after etching is shown in Fig. 3. These results show that after etching with high-energy ion beam, there was no presence of TeO_2.

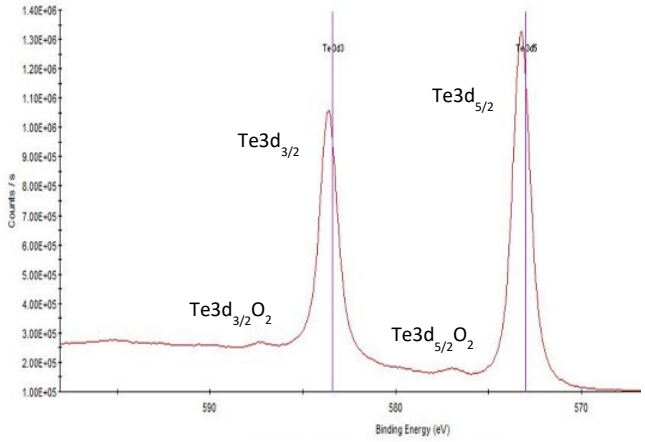

Fig. 2. Te peaks for unetched CZT wafer. There are TeO_2 small peaks to the left of the Te peaks.

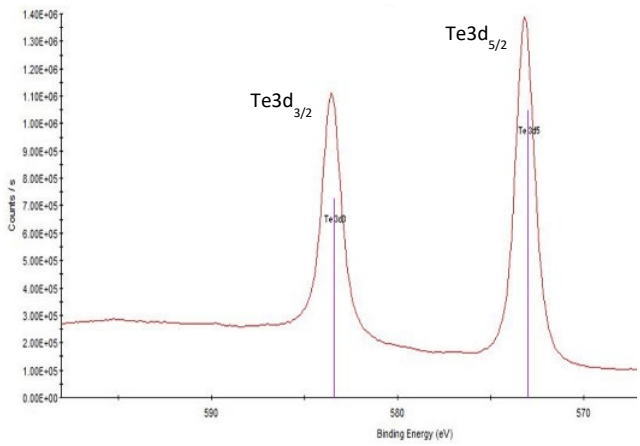

Fig. 3. Te peaks for etched CZT wafer. The TeO_2 peaks are not present.

The results for the CMT samples are shown in Figs. 4 and 5. The XPS scan of Mn peaks for unetched CMT wafer is shown in Fig 4. The $Mn2p_{1/2}$ and $Mn2p_{3/2}$ peaks are not well formed in this scan. The Te and TeO_2 peaks for unetched CMT wafer are shown in Fig. 5. This CMT wafer was chemically etched using a solution of hydrogen bromide in hydrogen peroxide and ethylene glycol mixture.

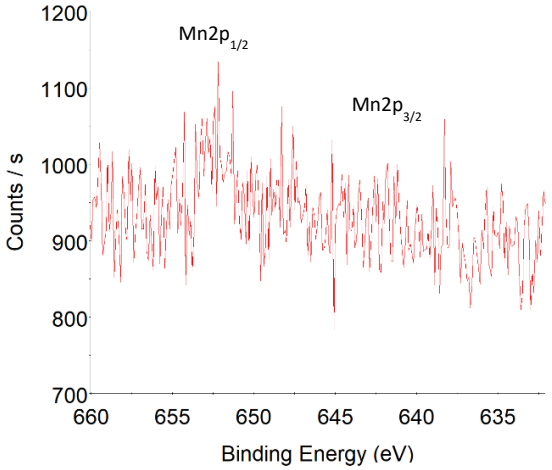

Fig. 4. XPS scan of Mn peaks for unetched CMT wafer. The $Mn2p_{1/2}$ and $Mn2p_{3/2}$ peaks are not well formed in this XPS scan.

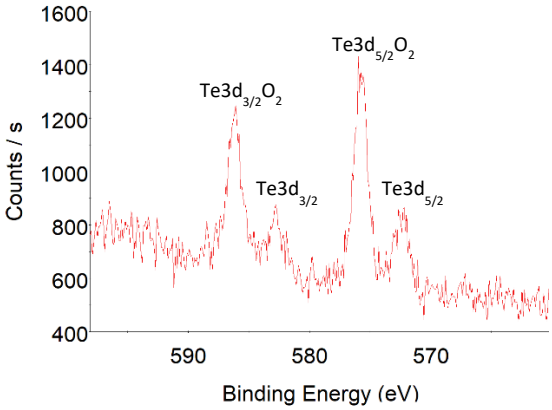

Fig. 5. XPS scan of the unetched CMT wafer showing Te and are TeO_2 peaks.

IV. Summary

We have presented results from the use of XPS to scan for the surface compositions of CdZnTe and CdMnTe wafers. Our results showed that Cd, Te and TeO_2 are the dominant species on these materials. Zn was present on CdZnTe and Mn on the CdMnTe wafer. The CdZnTe wafers that were etched with high-energy ion beam did not show the presence of TeO_2 on their surfaces.

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