Title

Student, major; Mentor, department

Research Statement:

We propose to investigate a new type of high-barrier Schottky contact on CdZnTe semiconductor using amorphous selenium (a-Se) as an electron blocking layer to increase barrier height and to reduce leakage current to a very low level, which is crucial for low-noise and high-resolution detection of gamma-rays from nuclear materials.

Background:

The threat of terrorism has prompted scientists to develop portable and high-performance instruments that can quickly detect radioactive materials that terrorists might use to build dirty bombs or nuclear weapons. For this purpose, CdZnTe (CZT) semiconductor based gamma-ray detector are being developed which detects gamma radiations emitted from radioactive materials.[1-4] For high resolution, high count-rate (sensitivity), and low-noise detector, the resistivity of CZT crystal needs to be $\geq 10^{10}$ Ω-cm. However, only ~10% of CZT ingot, grown by Bridgman method, has this required resistivity. About 40 to 60% of the grown crystal shows resistivity in the range of 10^8 - 10^9 Ω-cm, and rest of the material has much lower resistivity. This means a CZT crystal growth run typically produces only 10% of high quality nuclear detector grade crystals, making CZT crystal prohibitively expensive for widespread applications.[5-7]

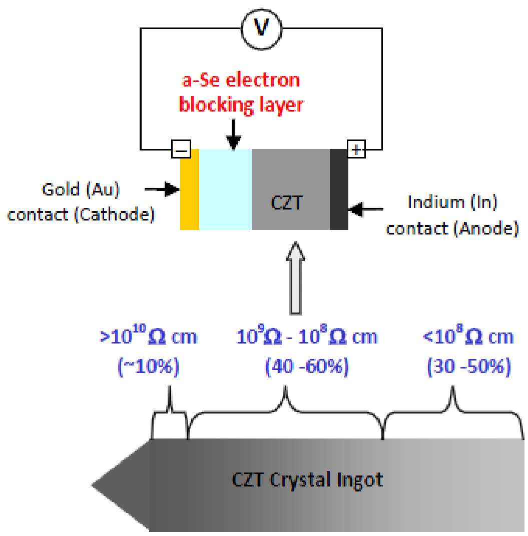

Figure 1. Proposed high barrier metal/a-Se/ CZT Schottky contact concept

High resistivity means, materials resist and minimize uncontrolled (parasitic) flow of electrons across semiconductor device known as "leakage current" which contributes to detector electronic noise.[8-9] Now if we restrict this leakage current extrinsically, we could make use of the lower resistivity CZT crystals. That way we could substantially increase the yield, which will make detectors less expensive and readily available. To address this we propose amorphous selenium (a-Se) electron blocking layer between CZT and cathode (negative) metal electrode to increase barrier height and to reduce the leakage current to a very low level. Figure 1 illustrates our proposed concept.

Project Goals and Objectives:

The goal is to investigate if metal/a-Se/CZT Schottky contact will lessen the requirement of high resistivity of CZT crystals for high performance radiation detectors. To reach the goal, we have set the following specific objectives.

- Fabricate metal/a-Se/CZT Schottky contacts using low resistive (~10^9 Ω-cm) CZT crystals.
- Study current-voltage (I-V) characteristics of fabricated metal-semiconductor contacts; determine resistivity, leakage current, and electron mobility-lifetime product ($\mu\tau_e$).
- Test and evaluate radiation detector performance to determine if our innovative Schottky contacts made any improvement to the detector resolution.

Project Significance and Purpose:

When a-Se (bandgap energy, E_g = 2.2 eV) and CZT (E_g = 1.6 eV) are brought into contact, the Fermi level of a-Se leads to a band bending within the CZT material (Figure 2) and creates a high barrier. This barrier blocks injection of electrons into CZT conduction band (E_c) and injection of holes from CZT valance band (E_v). Thus a-Se layer[10] prevents leakage current that contributes to electronic noise in gamma-ray radiation detection system. Our innovative Schottky contact will relax the requirement of high resistive material for high resolution and consequently lower the manufacturing cost of CZT detectors.

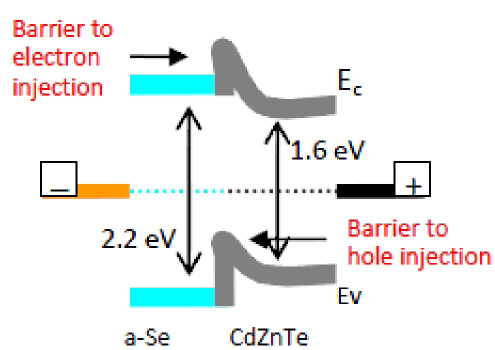

Figure 2. Band bending in metal/a-Se/ CZT Schottky contact concept

Such detectors will be very useful to emergency workers, customs officials, border-protection personnel, and coast guards for detecting illicit radioactive materials. Other applications of CZT detectors are

Homeland security, nuclear safeguard, nuclear waste monitoring, medical imaging (digital mammography) and nuclear power plants.

Furthermore, through this research, I will have an opportunity to apply fundamental concepts that I've learned in the class room. I'll get hands-on experience in semiconductor wafer preparation, characterization, detector fabrication, testing and evaluation. I will also learn how to interpret, present, and communicate results.

Project Design:

CZT grown by the Bridgman method in [mentor's] laboratory will be used for the proposed study. The research project will be divided into the following four major tasks.

Task 1- Deposition of a-Se layer on CZT: CZT wafer of different sizes will be cleaned, polished and etched in order to prepare them for detector fabrication. We will study the surface morphology of these wafers by scanning electron microscopy (SEM) and x-ray diffraction (XRD), and select only those wafers that have defect-free smooth surface. We will deposit a thin layer (1- 2 μm) of a-Se on the selected wafers by thermal evaporation.

Task 2- Detector Fabrication: Next we will deposit gold electrode on top of the a-Se layer by sputtering technique using a metal mask. This is the cathode end of the detector. On the other side of the CdZnTe wafer (which does not have a-Se layer), indium metal will be deposited as anode electrode. Thin palladium or copper wires will be attached to the electrodes by applying graphite paste. Detectors will then be secured on an alumina substrate.

Task 3- Detector Testing: Varying applied voltage, we will measure current output of the device. From the current –voltage relationship, we can confirm the formation of Schottky contact. We will measure the resistivity and the leakage current. We will calculate electron mobility (μ) using following equations. $\mu = d^2/(VT_R)$, where T_R is the measured transit time, V is the applied voltage, and d is the detector thickness.

Task 4- Radiation Testing: We will next evaluate the gamma-radiation detection efficiency using isotopic radiation sources such as ^{241}Am (60 keV) and ^{137}Cs (662 keV). The results will be compared with and without a-Se contacts in order to determine if high-barrier contact on CZT detectors improved detector resolution.

Project Timeline: The project will start on May 1st YEAR and continue until April 30th YEAR.

Task	Description	Months											
		May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	a-Se deposition												
2	Detector fabrication												
3	Detector testing												
4	Radiation testing												
5	Poster and report preparation												

Anticipated Results and Dissemination:

We expect to gather enough preliminary data to determine the feasibility of high barrier a-Se Schottky contact on CZT. If successful, further research will be carried out to optimize the contact. We will present our findings at Discover USC, and publish in journals such as *IEEE Transactions* and *American J. of Undergraduate Research.*

Personal Statement:

Since I have taken [mentor's] ELCT 363 class, where he has talked about his research on semiconductor materials for Homeland security applications, I have become very much interested in this field. I pursued this and gathered all the information I could from [mentor]. Since then I have visited [mentor's] lab and had several interactions with his graduate students. I have read articles given by [mentor] to get a background of nuclear detector, especially CZT gamma-radiation detectors. This Magellan research will allow me to apply the theories to practical research and train me for the challenges of an Electrical Engineer. I am greatly motivated and I would like to continue my study as MS and PhD student after I graduate, which will be a first in my family. Through this Magellan research internship, I will learn how to formulate a research plan, execute that plan, deal with any hiccups, analyze and record data, and communicate the results. Thus this research opportunity will prepare me to be a successful graduate student and a good researcher in future.

References Cited:

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