Preface

The foundation of the study of ionizing radiation was pioneered by three brilliant scientists: Wilhelm. C. Röntgen, Henri Becquerel, and Marie Curie. In November 1895, Professor Röntgen discovered a new kind of ray, later named as the x-ray, while studying electrical discharge through gases in a Crookes tube at the University of Würzburg. He noticed that the mysterious new ray has the ability to penetrate through opaque objects. A few months later, Henri Becquerel observed the emission of similar rays, naturally, from uranium salts. His observation eventually led to the discovery of the phenomenon called radioactivity. Then Marie Curie, a doctoral student of Becquerel, conducted extensive research on radioactive materials together with her husband Pierre. She is credited with the discovery of radium and polonium and is the only scientist who has won the Nobel Prizes in both physics and chemistry, to date.

Shortly after the discoveries of x-ray and radioactivity, scientists around the world became really curious and started to investigate the physics behind and the potential applications with great enthusiasm. Resources and efforts were put together in order to develop systems that can detect radiations. The earliest radiation detectors were the gas chambers. The incident ionizing radiations ionize the gas inside the chamber and create ion pairs. Then the charges generated by those ion pairs are measured under the influence of an externally applied electric field.

Substantially better energy resolution was achieved when the scientists started to use semiconductor detectors. The solid semiconductor materials have the ability to shorten the distance traveled by particles within them. So, it was possible to build durable detectors with smaller size and eventually better portability. During the 1960s, germanium had mostly been used as the detector material. Germanium detectors require the measurements to be conducted at low temperatures in order to reduce the thermally generated leakage current. This limitation in usability was a source of motivation to focus on building silicon-based detectors. Silicon has significantly larger bandgap when compared to germanium and thus can be used as sensitive material in radiation detectors to be operated at room temperature. Radiations can also be detected indirectly using a scintillation layer. The scintillation layer converts the incoming high-energy photons into visible light, which then can be detected by photodetectors.

The chapters in this book cover the physics and technologies behind modern semiconductor detectors for mainly x-ray radiation together with their applications. The contents of this book are carefully selected and arranged in such a way that it maintains a profound information flow.

Chapter 1: This chapter briefly shows the differences between the direct and the indirect conversion x-ray detectors and discusses the key properties of the photoconductive materials in direct conversion detectors in details. Two direct conversion detectors based on amorphous selenium (a-Se) and cadmium zinc telluride (CZT) for medical imaging applications are presented.

Chapter 2: Chromium compensated gallium arsenide (GaAs:Cr) is a relatively new detector material. It is possible to fabricate a thick, large area detector with high resistivity and with uniform and stable electric field throughout the sensitive volume using GaAs:Cr. In this chapter, the fabrication process, the material properties, and the performance of a GaAs:Cr based Medipix3RX detector are demonstrated.

Chapter 3: LAMBDA is a Medipix-based state-of-the-art x-ray imager, mainly developed for the experiments at synchrotrons. The authors of this chapter have presented the core technology and the applications of LAMBDA, together with the ongoing research on improving the system using edgeless technology and through-silicon via (TSV).

Chapter 4: In this chapter, the response function of a detector is defined and its importance is highlighted. The response functions of single-probe and multipixel CdTe detectors are estimated.

Chapter 5: Monte Carlo (MC) algorithm is widely used in order to study charge generation and charge transport inside semiconductor materials. MC algorithm-based modeling approaches for direct conversion x-ray detectors for medical imaging are discussed in this section of the book.

Chapter 6: The most important part in a detector system after the sensitive volume is the readout electronics, also known as the front-end electronics. It collects the charge generated inside the sensitive layer and processes it before sending it to the ADC, which then sends the digital information to a display or a storage unit. The authors of this chapter propose a novel inverter-based readout circuitry for radiation detectors.

Chapter 7: One of the most important applications of x-ray detectors is its usage in security scanning. This chapter continues the discussions about the readout electronics for x-ray detectors focused on the baggage-scanning applications. It also summarizes some of the popular imaging techniques and available detectors that are suitable for scanning applications.

Chapter 8: This chapter is devoted to the applications of photon-counting detectors (PCD) in high-resolution x-ray imaging, such as tomography, in a lab-scale environment. Other applications of PCDs in different fields of science are also listed.

Chapter 9: The principles of the cone beam computed tomography are discussed in this chapter along with its applications in medical imaging. The authors have reviewed the advantages and the challenges of the technology.

Chapter 10: The measurements of the polarization angle and the level of linear polarization using scattering polarimetry can play an important role in high-energy astrophysics. This chapter deals with the development and the performance of CdTe/CZT spectroscopic imagers for scattering polarimetry.

This book is written by internationally recognized experts in their respective fields from both academia and industry. The intended audiences are scientists and practicing engineers with some physics and electronics background. This book can also be used as a recommended reading and supplementary material in graduate-level courses. We wish all the readers an interesting journey through the existing and emerging technologies and the applications of semiconductor-based x-ray detectors.

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