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Author: Tony Young

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Tony Young
University of Wollongong

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By

Tony Young

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Abstract

Improving the spatial resolution in PET will increase the chance of accurate diagnosis of cancer. PET detectors are comprised in part of detectors such as photomultiplier tubes or solid state photodetectors optically coupled to scintillation materials, such as BGO or LSO. In this thesis a study of recently developed photodiode detectors, SPAD4 photodiodes, and LYSO crystals has been undertaken to investigate these properties.

As part of this research IV (current-voltage) and CV (capacitance-voltage) characterization measurements were carried out on the photodetectors and results indicate they are of excellent quality. Ion Beam Induced Charge Collection (IBICC) measurements were undertaken to fundamentally investigate the effect of bias on the efficiency and uniformity of charge collection within the photodetector. A reverse bias operating voltage of 50 V was eventually chosen as the optimum bias voltage for the SPAD4 photodiode for the gamma ray spectroscopy and timing resolution experiments that followed the IBICC characterisation. Charge collection uniformity was found to be excellent at this optimum voltage.

An investigation into the surface treatment of LYSO crystal and cladding was also completed. Physical measurements and simulations were conducted and the results are compared. Past simulation results have demonstrated that scintillation crystals produced a higher output when the surface was rough as opposed to the industry standard smooth polished surface [1]. Physical measurements and comparisons have also been completed with saw cut finish crystals and chemically etched crystals [2, 3]. Simulations were completed with “Scintillation Program”, a simulation code developed at the CMRP, and DETECT2000. Measurements completed for this thesis produced no significant change in the deduced scintillator light output after roughening a crystal side.

Timing resolution in commercial PET scanners ranges from 8 to 16ns. Experimentally with a photomultiplier tube coupled to a photodiode, timing resolution as low as 9.4ns FWHM has been achieved [4]. Coincidence timing resolution measurements using standard NIM (Nuclear Instrumentation Module) electronic modules were taken with a

NaI-photomultiplier tube and the LYSO-SPAD4 photodiode module. The best result obtained was a FWHM coincident time resolution of 22 ns, which is similar to past results.

The SPAD4 photodiode and LYSO crystal combination show promise as the basis for a future PET detectors module, although further work needs to be completed to improve the timing performance.

Table of Contents

List of Figures

List of Tables

Notation/Abbreviation

CMRP = Centre for Medical Radiation Physics

UOW = University of Wollongong

PET = Positron Emission Tomography

CT = Computed Tomography

MRI = Magnetic Resonance Imaging

IBICC = Ion Beam Induced Charge Collection

PMT = Photomultiplier Tube

PD = Photodiode

LYSO = Lutetium Yttrium Oxyorthosilicate

LSO = Lutetium Oxyorthosilicate

BGO = Bismuth Germanium Oxide

GSO = Gadolinium Silicate

FWHM = Full Width at Half Maximum

IV = Current Voltage

CV = Capacitance Voltage

SLICE = Scintillator Light Collection Efficiency

Int = Integration

Diff = Differentiation

CFD = Constant Fraction Discriminator

TFA = Timing Filter Amplifier

TAC/SCA = Time to Amplitude Converter/Single Channel Analyser

Na–22 = Sodium 22

Cs–137 = Caesium 137

I-125 = Iodine 125

NECR = Noise Equivalent Count Rate

Publications List

Lerch, M.L., Simmonds, P.E., Young, T., Takacs, G.J., Rozenfeld, A., Perevertaylo, V. & Meikle, S., Modelling the readout performance of a new silicon photodetector for use in PET, IEEE Transactions on Nuclear Science (2007), Submitted.