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RADIOLUMINESCENCE AND SCINTILLATION PROPERTIES OF ZINC DOPED WITH ALUMINUM

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ABSTRACT

The present paper is carried out to determine the Radiolumincscence and scintillation properties of Zinc Oxide (ZnO) and Zinc Oxide doped with Aluminum ZnO(Al). The samples were prepared as a disc from Powder, which prepared by US Research Nanomaterials, Inc. The samples were characterized by Multichannel Analyzer (MCA) using different radiation sources Americium-241 (^{241}Am), Cesium-137 (^{137}Cs), Barium-133 (^{133}Ba) and Europium-152 (^{152}Eu). When the thicknesses of ZnO used are 3 mm, 6 mm and 22 mm, the number of radiation counts are 344 M, 88 M, and 6.6 M, respectively by using ^{241}Am, and 1.2 T, 6.7 M and 6.6 M respectively when using ^{152}Eu.Two samples are used as radiation detector using ZnO(Al) 2 mm and 6 mm, in which the counts 5.96 M and 5.93 M respectively using ^{241}Am,54 M and 5.4 M using ^{152}Eu. The ^{133}Ba and ^{137}Cs was applied for 3 mm ZnO and gives 1.5 T and 6.1 M number of counts respectively. The number of counts for both the ZnO and ZnO(Al) decrease with increasing thickness of the samples. However, the luminescence and scintillation properties were observed and quantified of the prepared ZnO/ZnO(Al). And, the gamma spectrum peaks recorded were inconclusive.

KEYWORDS: Radiolumincscence, Zinc Oxide (ZnO), Scintillation, PMT.

INTRODUCTION

Scintillation materials are a type of phosphorus material that is used to detect radiation. Along with photon detectors such as photomultiplier tube (PMT), avalanche photodiode, or a Sb-Cs PMT, scintillator materials are used in scintillation detectors. Based on the height of the signal and its shape, the energy and timing of the arrival of individual particles or photons can be known to ionize radiation. The accuracy of the detector, i.e. energy and time resolution, depends largely on the characteristics of the scintillator. The energy resolution is related to the light yield, i.e. the number of photons emitted per unit of energy from ionizing radiation (e.g. 100 Kev). The detector counting efficiency (DE) is related to the amount of radiation emitted from a radioactive source to the measured amount in the detector. The DE can be used to calculate the expected counting rate in the detector when source strength is known or to calculate the strength of the source by measuring the count rate in the detector. The DE is the ratio of the observed or measured rate of counting (or total events in a known time interval) to the rate of count (or total events) exited by radiation source.

Different scintillators have been developed. One of them, inorganic scintillators which used for practical applications. Most of the inorganic scintillators are consisted of insulator doped with rare-earth elements [1]. In these cases, the scintillation decaying time is constant, approximately several tens of nano-seconds at least. Recently, scintillator materials based on a wide band gap semiconductor may attract great attention, such as zinc oxide (ZnO), CdS[2, 3], GaN[4], CsPbCl3 [5, 6], and semiconductors with naturally forming quantum wells [7]. For Zinc oxide, due to the large excitation binding energy (~ 60 meV) [8], fast and relatively efficient exciton emission is available at room temperature. In particular, ZnO ceramics scintillators have been developed using different methods and different dopants [9, 10].

In this study, synthesized zinc oxide ceramics using a pressure synthesis method was done. This technique is known for its synthesize dense ceramics due to the pressure. The dense ceramic scintillator is useful from the point of view for probability of ionizing radiation interaction. Moreover, the dense packing of large crystals in the ceramic leads to a decrease in scattering of scintillation within the samples, allowing to estimate the light yield by measurements of height pulse spectra. We report the scintillation properties and structure of the ZnO ceramic pressure synthesis without and with the dopants.

MATERIALS AND METHODS

Raw powders of zinc oxide (99.999%), Al_2O_3 powders (99.99%) were used without further purifications. The ceramics were synthesized after mixing the raw powders with equal proportions and pressing into pellets. Ceramic of undoped zinc oxide and Al-doped ZnO were synthesized at 295 K using a pressure device. The raw powders were coated in Plastic Scintillator Casting Resin Capsule covered by Aluminum foil.

The gamma ray radioluminescence spectra have been obtained using a multi-channel analyzer (MCA). The photons emitted were delivered through a Photomultiplier Tube (PMT) (PMT HAMAMATSU 7696, AE1216) were equipped with an Analog Amplifier (Model 2026 Spectroscopy Amplifier). The measurement system details are described elsewhere [11]. The height pulse spectra are obtained to detect the scintillation equipped with synthesized ceramics or ZnO/ZnO(Al) as reference in the following setting: The ceramic is attached to PMT (R7696, AE1216, Hamamatsu) using Mendel-Glaser as a cover. Detection signals from PMT were fed into preamplifier (113, Ortek) then Amplifier (575A, Ortek). Finally, the amplified signals were arrived at a multi-channel analyzer (TRUMP-2K-32) to obtain the pulse height spectra as histogram. As for the ceramics, the pulse height spectra for the 59.54 Kev gamma ray from ^{241}Am, all ^{152}Eu peaks, and 662 Kev gamma-ray from ^{137}Cs disappeared because they are small and show a relatively poor light yield. Detection signals from PMT are recorded with digital storage. The details of the measurement system are described elsewhere [12].

RESULTS AND DISCUSSION

Figs a.1 and a.2 show the pulse height spectra of the scintillation detectors equipped with the ZnO ceramics for 59.54 Kev gamma-ray from ^{241}Am. The pulse height spectrum of ZnO(Al) for 59.54-keV gamma-ray is also shown in Fig b. for comparison. Although, in contrast to the case of NaI (TI) for which a clear full-energy peak is observed (Red color marked), clear full-energy peak cannot be observed in the case of ZnO ceramics. This is because homogeneity and transparency are low in the ceramics. Supposed that the full-energy peak placed at 30 channels, i.e., at the spectrum shoulder for the undoped ZnO, the light yield of the undoped ZnO ceramics is estimated to be

11000 photons/59.54-keV gamma-ray, based on the comparison with NaI(TI) whose light yield is $40*10^4$ photons/59.54-keV. The spectrum of pulse height for doped samples did not differ significantly. We observed a peak in pulse height spectrum for ceramic scintillators, which may be due to homogenous packing structure without pores. This peak cannot be observed for the ceramic synthesized under pressure.

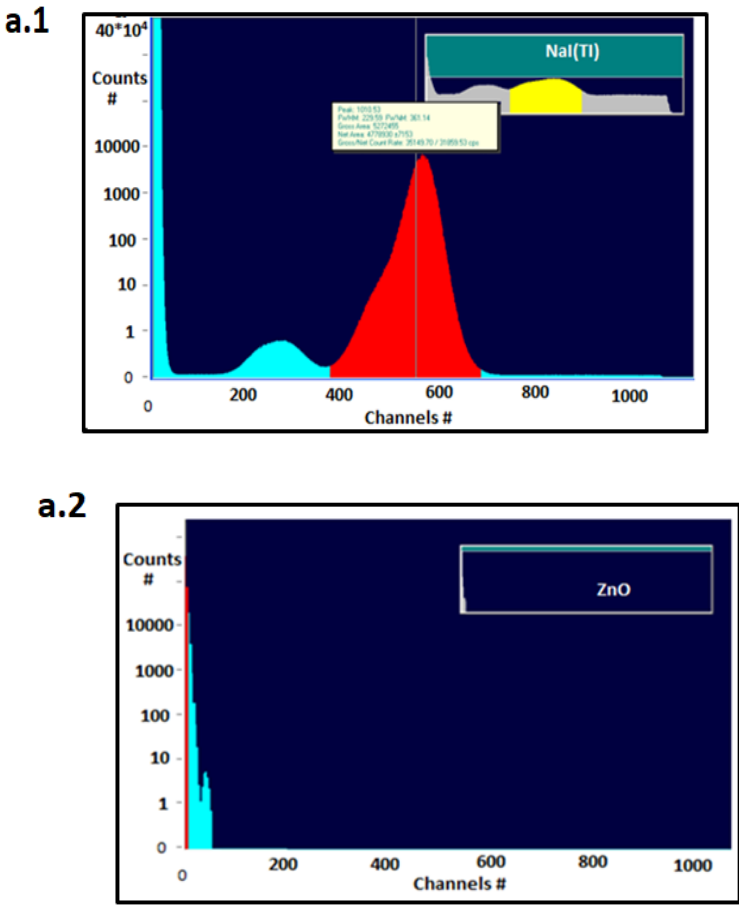

Fig. a. Pulse height spectra of (a.1) NaI(TI) and (a.2) undoped 3mm ZnO ceramics for 59.54-keV gamma-ray from ^{241}Am.

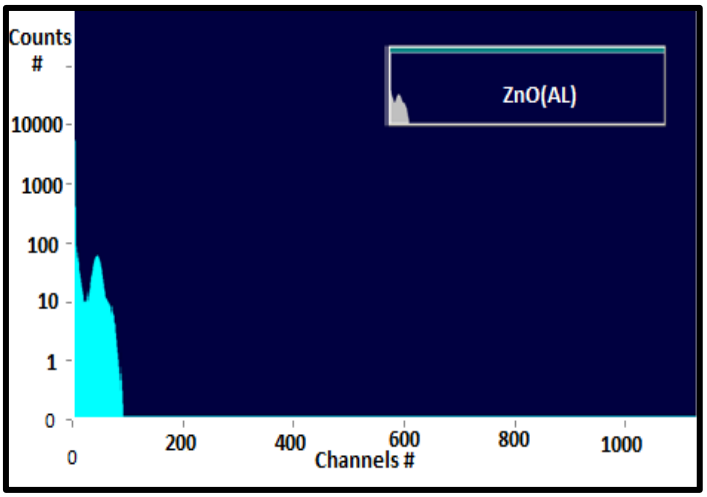

Fig. b. Pulse height spectra of 3mm ZnO(Al) ceramics for 59.54-keV gamma-ray from ^{241}Am.

Figs. c.1 and c.2 shows the pulse height spectra of the scintillation detectors equipped with the ZnO ceramics for photoelectric peaks at the energy 121keV, 344keV, 964keV and 1408keV gamma ray from ^{152}Eu. In theory, there are another three photoelectric peaks of ^{152}Eu at 779keV, 1112keV and 1085keV. However, the last three peaks were unable to be seen because the ability of NaI(TI) to distinguish gamma-rays with close energies "The energy resolution of a detector", it's not too high. The pulse height spectrum of ZnO(Al) for gamma-ray from ^{152}Eu is also shown in Fig. d, for comparison. Although, in contrast to the case of NaI(TI) for which a clear full-energy peaks are observed, clear full-energy peak cannot be observed in the case of ZnO ceramics and ZnO(Al). This is because transparency and homogeneity are low in the ceramics as mention before.

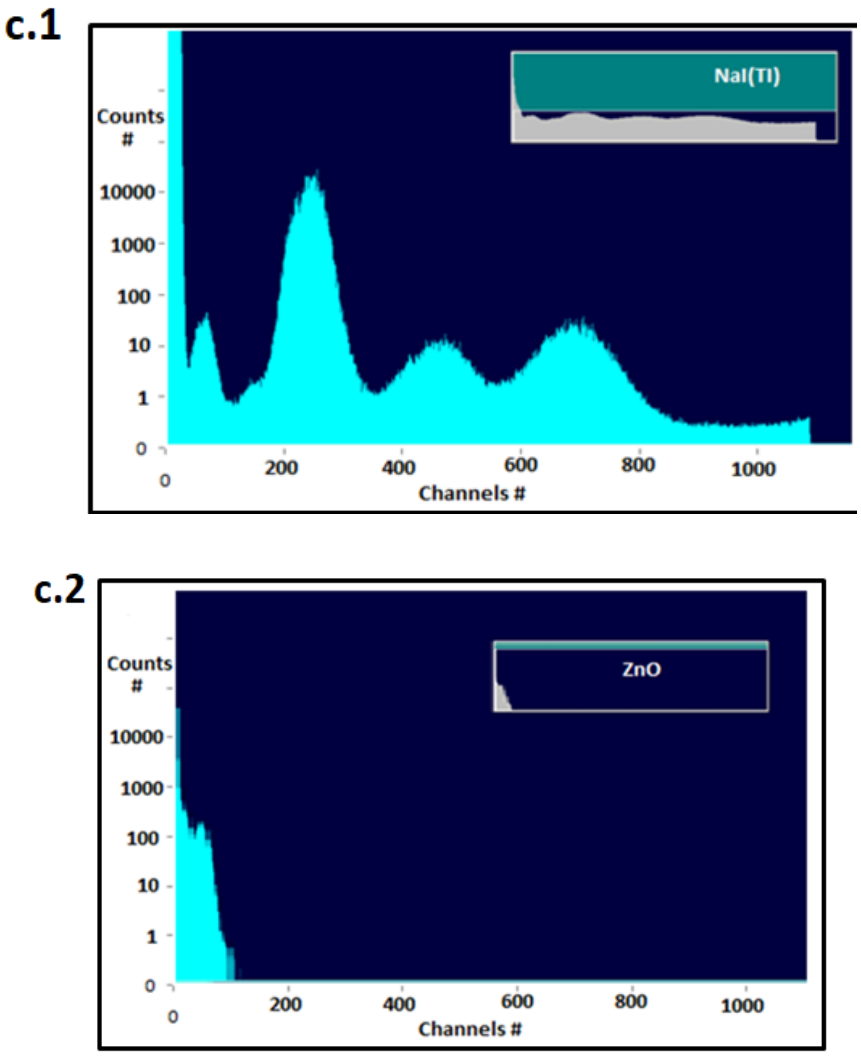

Fig. c. Pulse height spectra of (c.1) NaI(TI) and (c.2) undoped 3mm ZnO ceramics for gamma-ray from ^{152}Eu.

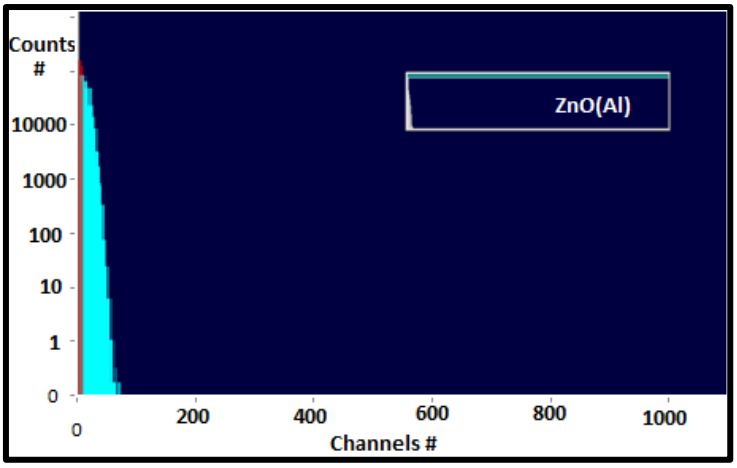

Fig. d. Pulse height spectra of 3mm ZnO(Al) ceramics for gamma-ray from ^{152}Eu.

CONCLUSION

Radio luminance and scintillation properties of ZnO and ZnO(Al) are identified. In this study, gamma rays were used ^{241}Am, ^{137}Cs, ^{133}Ba and ^{152}Eu to bombard each of the samples. ZnO and ZnO(Al) were used as the scintillator crystals in experiments. All luminescence events that are followed by the luminescent light are recorded by PMT and MCA. The light yield is estimated to be 11000 photons/59.54-keV gamma-ray for the undoped ceramics, and the light yield of the doped ceramics was not significantly different from that of the undoped ceramics. These results indicate that that zinc oxide (ZnO) and zinc oxide doped with Aluminum (ZnO(Al)) cannot be used as gamma radiation detector with ceramic shape by using pressure method.

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