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# ENERGY DEPENDENCE EVALUATION OF A ZnO DETECTOR FOR DIAGNOSTIC X-RAY BEAM.

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## ABSTRACT

In the last decades the international organizations of human health and radiation protection have recommended certain care for using X-ray as a diagnosis tool. The current concern is to avoid any type of radiological accident or overdose to the patient. This can be done assessing the parameters of the X-ray equipment and there are various types of detectors available for that: ionizing chamber, semiconductor devices, etc. These detectors must be calibrated so that they can be used for any energy range and such a procedure is correlated with what is called the energy dependence of the detector. In accordance with the stated requirements of IEC 61267, the standard radiation quality beams and irradiation conditions (RQRs) are the tools and techniques for calibrating diagnostic X-Ray instruments and detectors. The purpose of this work is to evaluate the behavior of the energy dependence of a detector fabricated from a zinc oxide (ZnO) nanofilm. A Pantak industrial X-ray equipment was used to generate the RQR radiation quality beams and test three ZnO detector samples. A 6430 sub-femto-ammeter, Keithley, was used to bias the ZnO detector and simultaneously perform the output readings. The results showed that the ZnO device has some increase in its sensitivity to the ionizing radiation as the X-ray effective energy decreases unlike other types of semiconductor electronic devices typically used as an X-ray detector. We can be concluded that, after calibration, the ZnO device can be used as a diagnostic X-ray detector.

## 1. INTRODUCTION

Nanotechnology encompasses many different scientific fields with applications in engineering, physics, chemistry, medicine, among others [1]. Currently, there are several methods for the preparation of nano-material or some type of nanofilm-based sensor, and the technique of sputtering is an example [2, 3]. Zinc oxide (ZnO) is a semiconductor material that exhibits some characteristics, its structure can be like nanoballs or nanotubes, for while [4, 5], and in the recent years it has had scientific interest because that. Moreover, even with amorphous material, the literature has shown that there are many possibilities to apply ZnO in microelectronics [6]. Furthemore, researchers aim to develop radiation detectors to present more hardness to the radiation, providing a signal with low voltage operating, economic [7, 8, 9] etc. Accordlingly, the purpose of this study is to evaluate the response of the energy dependence of a ZnO detector under diagnostic radiation beams. Then, the proposed radiation detector must be calibrated in accordance with the requirements of IEC 61267, the standard radiation quality beams and irradiation conditions (RQRs) are the tools and techniques for calibrating diagnostic X-Ray instruments and detectors. Samples of ZnO detector were prepared and mounted on an BNC connector to test them and evaluate their responses to the spectra suggested by the IEC 61267.

## 2. MATERIALS AND METHODS

### 2.1. ZnO nanofilm

The ZnO nanofilms were made by sputtering metallic zinc target (99% purity) using the equipment AJA ATC Orion 5 UHV Sputtering System at the physics laboratory, Federal University of Sergipe, as can be shown in Figure 1. The operating pressure was 30 mmTorr by setting the target at a 6.2 mm distance from the glass substrate, and the temperature was mantained at 400 ° C. A BNC connector was soldered to the ZnO device to be able to handle and connect the device to the electric current reading system (Figure 2).

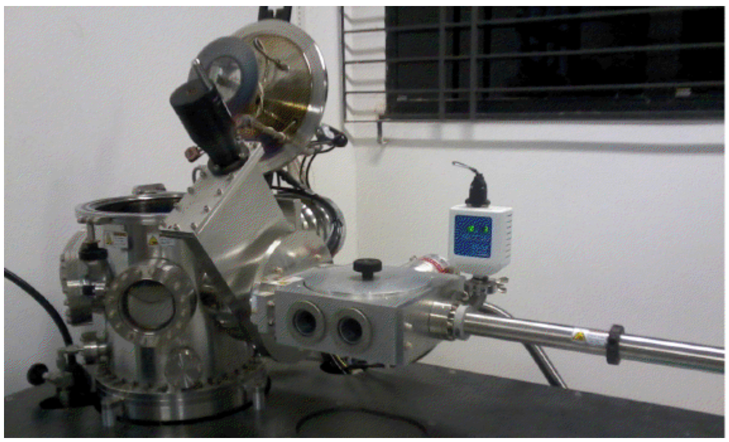

**Figure 1 – Model equipment AJA ATC Orion 5UHV Sputtering System.**

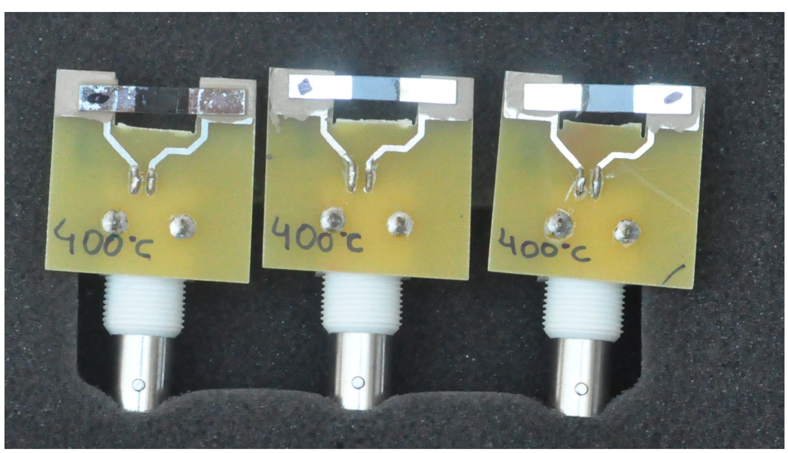


**Figure 2 – ZnO nanofilms soldered to printed circuit board with BNC connector.**

### 2.2. Energy Dependence Evaluation

To check the energy dependence it was used the standardized X-ray beams named radiation qualities RQR4 to RQR9. Table 1 describes some characteristics of these radiation qualities: peak potential of the X-ray tube, the effective energy of the radiation beam, and additional aluminum filtration gave im milimeters for each radiation spectrum.

**Table 1 – Characteristics of radiation qualities IEC 61267 of direct beams implemented at the radiation laboratory.**

| Radiation Quality | Voltage (kV) | Effective energy (keV) | additional filtration (mmAl) |
|---|---|---|---|
| RQR 4 | 60 | 28,8 | 2,90 |
| RQR 5 | 70 | 30,0 | 2,90 |
| RQR 6 | 80 | 31,4 | 3,05 |
| RQR 7 | 90 | 32,7 | 3,14 |
| RQR 8 | 100 | 34,1 | 3,30 |
| RQR 9 | 120 | 36,6 | 3,90 |
| RQR 10 | 150 | 40,2 | 4,40 |

An industrial X-ray generator Pantak HF320, at the Radiation Laboratory (CNEN/CRCN-NE) was used to generate the IEC radiation qualities. A 6430 Keithley source-meter was used to bias the ZnO detector and simultaneously take the electrical output signal. Figure 3 illustrates a schematic diagram of the measuring procedure.

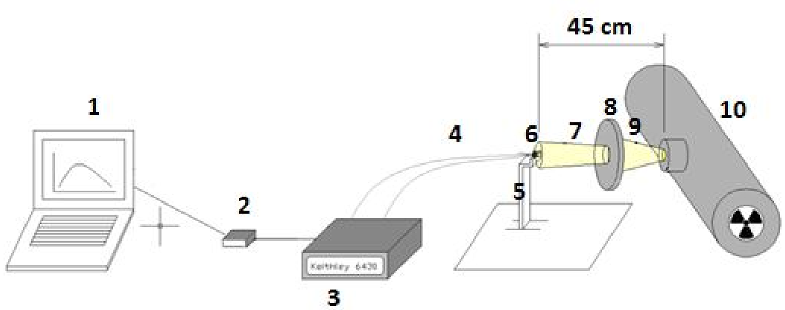


**Figure 3 – Schematic diagram of the measurement procedure.**
Legend: 1-Computer; 2-RS232-USB adapter; 3-Keithley 6430; 4-PTFE cable; 5-Sample support; 6-Nanofilm; 7- Collimated X-ray; 8-Collimator; 9-Filtered X-ray beam; 10-X-ray tube.

## 3. RESULTS AND DISCUSSION

Figure 4 displays the results in a graph whereas for the 3 samples whereas in the Tables 2, 3 and 4 are presented the values for each ZnO detector sample. One can observe that as the effective energy of the radiation beam increases the sensitivity of the samples decreases practically in a linear way. This effect stems from the fact that the higher the energy of X-ray photons has the greater penetrating power, which reduces the probability of interaction with the nanofilm material.

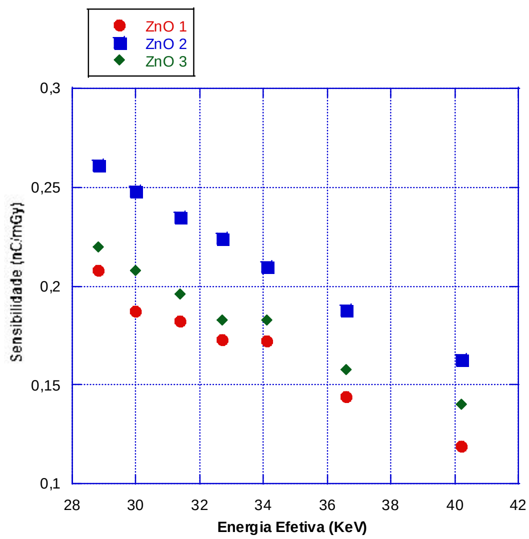


**Figure 4 – Energy dependence of ZnO nanofilms for RQR radiation qualities.**

**Table 2 – Values of the sensitivity to the RQR qualities for ZnO sample 1.**

| Radiation Quality | sensitivity (nC/mGy) | Normalized sensitivity to RQR 9 |
|---|---|---|
| RQR 4 | 0,208 ± 4% | 1,444 |
| RQR 5 | 0,187 ±4% | 1,298 |
| RQR 6 | 0,182 ±6% | 1,264 |
| RQR 7 | 0,173 ±5% | 1,202 |
| RQR 8 | 0,172 ±6% | 1,194 |
| RQR 9 | 0,144 ±8% | 1,000 |
| RQR 10 | 0,119 ±10% | 0,826 |

**Table 3 – Values of the sensitivity to the RQR qualities for ZnO sample 2.**

| Radiation Quality | sensibility (nC/mGy) | Normalized sensitivity to RQR 9 |
|---|---|---|
| RQR 4 | 0,261 $\pm$ 3% | 1,388 |
| RQR 5 | 0,248 $\pm$3% | 1,319 |
| RQR 6 | 0,235 $\pm$4% | 1,250 |
| RQR 7 | 0,224 $\pm$5% | 1,192 |
| RQR 8 | 0,210 $\pm$3% | 1,117 |
| RQR 9 | 0,188 $\pm$6% | 1,000 |
| RQR 10 | 0,163 $\pm$7% | 0,867 |

**Table 3 – Values of the sensitivity to the RQR qualities for ZnO sample 3.**

| Radiation Quality | sensibility (nC/mGy) | Normalized sensitivity to RQR 9 |
|---|---|---|
| RQR 4 | 0,220 $\pm$ 3% | 1,291 |
| RQR 5 | 0,208 $\pm$4% | 1,316 |
| RQR 6 | 0,196 $\pm$5% | 1,240 |
| RQR 7 | 0,183 $\pm$5% | 1,158 |
| RQR 8 | 0,183 $\pm$6% | 1,158 |
| RQR 9 | 0,158 $\pm$8% | 1,000 |
| RQR 10 | 0,140 $\pm$8% | 0,886 |

## 4. CONCLUSIONS

Samples of ZnO nanofilm-based detector were prepared by sputtering technique to evaluate the energy dependence if they are submitted to the diagnostic X-ray beams. The results show that the sensitivity to the RQR radiation qualities decreases systematically with the increasing of the effective energy. Although the samples were deposited in a glass substrate to test them under the ionizing radiation, it is possible to made it in an acrylic one to allow that the device has higher mechanical robustness. Furthermore, one can conclude that, after calibration, the ZnO detector can be used for measurements in the energy range of diagnostic X-ray. This study only represents the first results about the device and it can derive a lot of investigation to make such a ZnO a novel radiation detector for monitoring diagnostic X-ray equipment.

## 5. REFERENCES


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