PROCEEDINGS OF THE INTERNATIONAL CONFERENCE
NANOMATERIALS: APPLICATIONS AND PROPERTIES
Vol. 4 No 1, 01NNPT04(3pp) (2015)

A Novel Nanowire Metal Converter for Improvement the Efficiency of the Gas-filled Radiation Detectors

H. Zarei[1], S. Saramad[1,*], K. Eskandari[2]

[1] *Department of Energy Engineering and physics, Amirkabir University of Technology, Tehran, I.R. Iran*
[2] *Nanobiotechnology Research center, Baghiatallah University of Medical Sciences, Tehran, I.R.Iran*

(Received 31 May 2015; published online 27 August 2015)

Metal nanowires, due to their special physical properties and also high surface to volume ratio, can have considerable applications in designing and development of novel nano devices. For the radiation shielding, higher absorption coefficient of nano structures in comparison to bulk ones is an advantage. In gas detectors, designing a proper converter with higher efficiency which absorbs higher energy of gamma and X-rays and convert it to free electrons is one of the major requirements. Since the nano wires have higher surface to volume ratio in comparison to the bulk ones, so it is expected that with the same thickness, the generated electrons have higher chance to escape from the surface. In this work, the random Copper nanowires with diameter of 40 nm are deposited on very thin glass slide. This nano structure with thickness of 30 μm is tested with X-rays energy between 12 to 22 keV. The results clearly show that this nano structure for the energy of 20 keV can release electrons three times more than the bulk ones. This novel nanoconverter with higher quantum efficiency can have many applications in high energy physics, medical imaging, and astronomy.

Keywords: X- ray, gas detector, Copper nanowires, nanoconverter

PACS numbers: 61.80.Cb, 62.23.Hj

1. INTRODUCTION

In recent years, the study of one-dimensional (1D) nanostructure, especially metal nanowires, has attracted much attention, due to their special physical properties and also high surface to volume ratio different from the bulk material. The metal nanowire has potential applications for fabricating and development of novel nano electronic and phonic device [1-3].

In gas-filled radiation detectors, due to the low atomic number and density of gas, designing a proper converter that absorbs higher energy of gamma and X-rays and convert it to free electrons is one of the major requirements. Due to the high surface to volume ratio of nanowires in comparison to the bulk one, it is expected that with the same thickness, the generated electrons have higher chance to escape from the surface. Up to now, Edalatkhah and *et al* .have only reported the simulation of silver nanowire as a novel nano converter in an electron multiplier detector for hard x-ray imaging [4]. To the best of our knowledge, there are no other reports on the experimental study of any nanostructures, or metal nanowires as a photo nanoconverter.

In this work, Cu $(OH)_2$ nanowire (Cu NWs) synthetized by wet chemical method were introduced as the novel nanoconverter that absorbs higher energy X-rays and convert it to electrons. To study, the nano converter thin film (NCTF) consists of random Copper nanowires deposited on very thin glass slide was exposed to X-rays energies between 12 to 22 keV. The physical behavior of the Cu NWs was investigated by a plastic scintillators coupled to a photomultiplier tube (PMT). The proposed nano converter can be used in the wall of gas-filled radiation detector as a converter with higher efficiency in comparison to the conventional bulk ones.

2. EXPERIMENTAL

2.1 Apparatus

The morphology of the synthetized nanowires were characterized by using scanning electron microscopy (SEM) (Seron-AIS2100) (Korea). The converting properties of synthesized samples was studied with the PHYWE X-ray tube (Germany) and R6094 HAMAMATSU phot multiplier tube (Japan).

2.2 Chemicals

$CuSO_4$. 5H2O, NH_4OH, NaOH and polyvinyl alcohol (PVA), of Merck Company are used for fabrication of Cu nano wires without further purification and the thin glass slide with a thickness of 150 μm as a substrate of the NCTF was obtained from Sail Brand (China).

2.3 Testing setup and Radiation evaluation of nanostructure

Nanostructure preparing A Cu $(OH)_2$ nanowire was prepared by wet chemical method according to the literature [5]. In this method, No organic template and catalyst are needed to synthesize the nanowires. To obtain a homogenous colloidal suspension, the direct mixing of the Cu NWs into the PVA was applied as a photo Nano converter substrate. PVA was dissolved in deionized water at 70 °C for 1 hour to provide 2% (w/v) homogeneous PVA solution. Cu NWs powder were mixed with 2% (w/v) PVA and allowed to centrifuge. Finally, the NCTF is prepared by deposition of 200 microliters of the mixture of Cu NWs on very thin glass slide (150 μm). The thickness of Cu NWs in NCTF is estimated about 30 μm.

PMT test this nano structure was tested by plastic

* ssaramad@aut.ac.ir

and Cesium Iodide (CsI) scintillator in the presence of X-rays energies between 12 to 22 keV. In the purposed setup, the nano converter sheet was attached to a scintillator. The physical behavior of the nano converter sheet was studied in both sides by recording the optical response of scintillator by combination of *PMT test* this nano structure was tested by plastic and Cesium Iodide (CsI) scintillator for X-rays energies between 12 to 22 keV. The setup was optically sealed and to evaluate the background noise in each test, a pulse height spectrum without X-ray is also taken. In setup (1) the physical behavior of the nano converter sheet is studied from the both sides with a suitable scintillator coupled to a photomultiplier tube (PMT). The electric pulse generated in the anode of the PMT is connected to a spectrometer consist of a preamplifier, amplifier and a multichannel analyzer (MCA). In this test for decreasing the back scattering of electrons and efficient detection of the low energy electrons generated in the nano converter, a plastic scintillator with lower atomic number is selected. In setup (2), in order to estimate the absolute number of X-rays to extract the Quantum Efficiency (QE) of the converter (ratio of the converted electrons to incident X-rays), a CsI scintillator with suitable thickness (300 μm) is used.

3. PRESULT AND DISCUSSION

The morphology of the synthetized Cu NWs were investigated by SEM at 20 kV (figure 1). The image shows that most nanowires have diameters of 8 nm, and the lengths of 400 nm.

Figure 2 shows the recorded spectrum from the both sides of the NCTF with a 256 channel MCA in setup (1) after subtraction of the background noise during 90 s.

Since, the X-rays recorded by the plastic scintillator are the same from the both sides, so any difference in the spectrum can be related to the generated electrons that escape from the nano converter surface and reach to the scintillator. As it is clear from the spectrum in Figure 2, the free electrons when the X-ray is incident from the glass side (IG) have higher energy in comparison to the case that the X-ray is incident from NW side (INW). Since, the NW's have the dominant effect in electron conversion and the electrons generated in INW can lose part of their energy because of interaction with electrons of the glass slide, so as it is expected the INW electrons have lower energy in comparison to IG ones.

In addition, since the minimum range of the generated electrons is greater than the thickness of glass slide so it is expected that the number of high energy electrons in IG is approximately equal to lower ones (INW), which is consistent with the spectrum in Figure 2. Table 1 shows the QE of the nano converter sheet versus energy. As it is clear from this table the NCTF has the optimum QE of 9.7% at 20 keV. But, even if we consider the thickness of the converter 30 μm of bulk Cu, for the X-ray energy of 20 keV, the QE is 3%, which is three times less than QE of NCTF at the same energy. This clearly shows that the higher absorption coefficient of nano structures and also it's higher surface to volume ratio in comparison to bulk ones make them an excellent candidate for future converters.

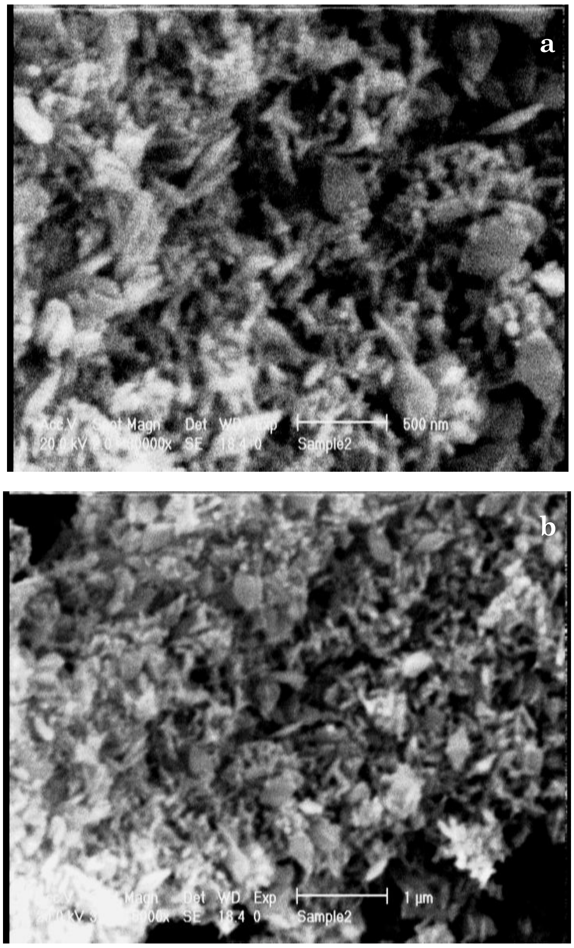

Fig. 1 – SEM images of the synthetized Cu NWs in two different scales; (a) 500 nm and (b) 1 μm.

Table 1 – Generated electron to X-ray absorption ratio in NCTF for different X-ray energies.

	12 keV	**14 keV**	**16 keV**	**18 keV**	**19 keV**	**20 keV**	**22 keV**
QE	1.9 %	3.4 %	5.6 %	8.3 %	8.5 %	9.7 %	9.4 %

4. CONCLUSIONS

In the current work, for the first time, we proposed a novel converter which converts X-ray to electron in nano scale based on physical attachment of Cu NWs on very thin glass slide. The result show that the Cu NWs can more effectively absorb the X-ray and convert it to free electrons because of its higher surface to volume ratio. The experimental conversion efficiency of the proposed metal nanowire is 2 to 9.7 percent for X-ray energies between 12 to 22 keV. The QE of the bulk Cu (30 μm) is three times less than QE of NCTF with the same thickness. Moreover, simple synthesis of nanowire, cost-effective could be other advantages of proposed method. This novel converter with higher detection efficiency can have many applications in high energy physics, medical imaging, and astronomy.

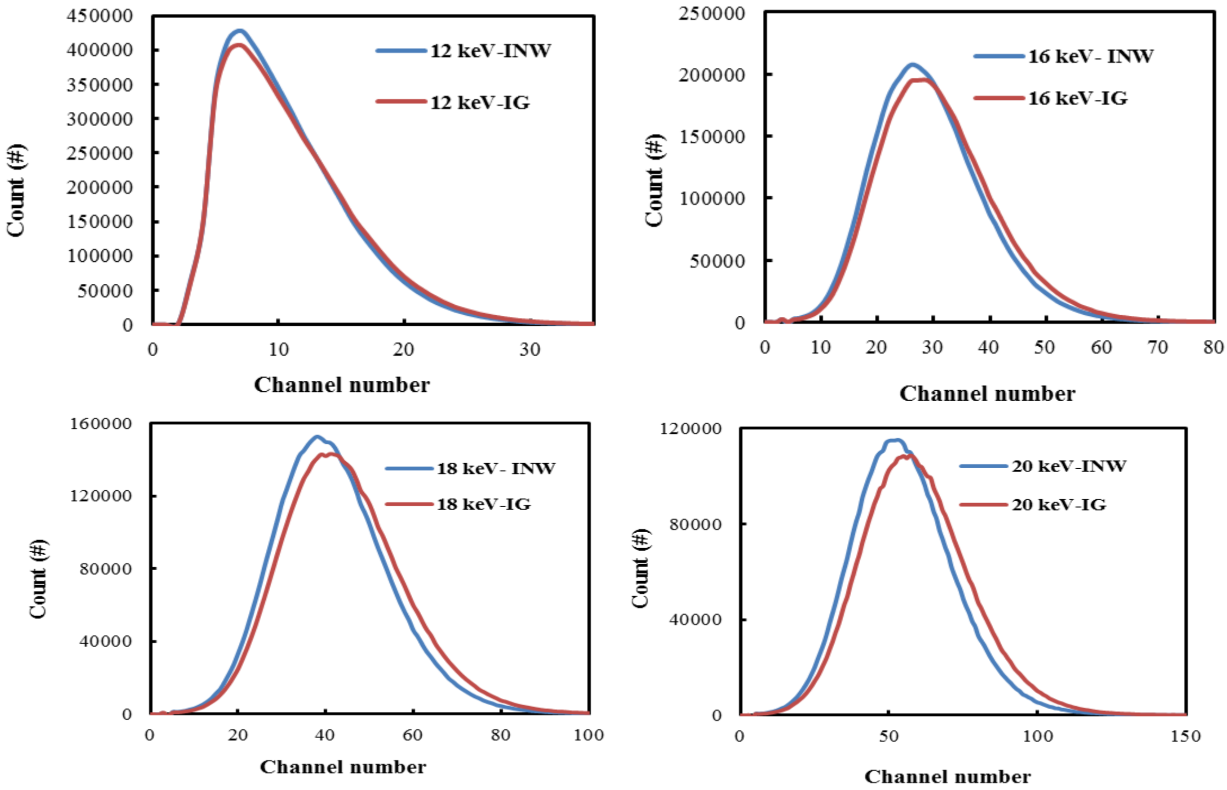

Fig. 2 – Recorded spectrum in the 256 channels MCA for both side of NCTF in four different X-ray energies by plastic scintillator during 90 s; INW (blue line) and IG (red line) indicating X-ray is incident from the Cu NWs and glass side, respectively.

REFERENCES

1. Y.S. Zhou, K. Wang, W. Han, S.C. Rai, Y. Zhang, Y. Ding, C. Pan, F. Zhang, W. Zhou, Z.L. Wang, *ACS Nano* **6**, 6478 (2012).
2. F. Qian, S. Gradecak, Y. Li, C.-Y. Wen, C.M. Lieber, *Nano Lett.* **5**, 2287 (2005).
3. S. Liu, J. Yue, A. Gedanken, *Adv. Mater.* **13**, 65 (2001).
4. J. Hu, T. W. Odom, C.M. Liber, *Acc. Chem. Res.* **32**, 435 (1999).
5. E. Edalatkhah, S. Saramad, S. Sheibani, *Adv. Mat. Res.* **829**, 227 (2014).
6. W. Wang, C. Lan, Y. Li, K. Hong, G. Wang, *Chem. Phys. Lett.* **366**, 220 (2002).