(PVP) /Pb Fibrous Membranes Fabricated via Electrospinning for Radiation Protection Application

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Abstract- Ionizing radiation like x-rays and gamma radiation have many applications in fields like medical diagnosis, cancer treatment, and radiation treatment of food (preservation). Therefore, shielding is necessary to protect users of such facilities from ionizing radiation, where exposure to ionizing radiation will cause a deterioration in the health of the user, depending on the absorbed radiation dose. Hence, using polymeric composites with different compositions as radiation shielding material is a current research interest. Furthermore, these polymeric materials can be dopped with high Z (atomic number) fillers for ionizing radiation shielding applications because of their unique properties; they are lightweight, cost-effective, mechanical, and less toxic. This paper will investigate the recent developments and methods in preparing polyvinylpyrrolidone (PVP/Pb) fibrous membranes as radiation shielding materials using the electrospinning technique to produce a protective fabric sheet. These fabric sheets can enhance the protection efficiency of protective users' suits. It has been found that a PVP/Pb nanofiber sheet of 0.3 cm thickness can approximately reduce the initial intensity (I_o) of 25 keV X-rays by 60 %.

<u>Keywords</u>: Electrospinning; PVP fibrous membranes; Pb particles; Radiation Shielding materials; Ionising radiation; Polymer composites; Lead shield; X-rays protection.

I. Introduction

The electrospinning is novel method in producing ultrafine fibers that has been used recently on a wide range of applications, electrospinning is adaptable, cost effective and versatile technique for producing nanofibers of polymer ranging from submicron to nanometer size. Also, they possess excellent properties so electrospinning is the perfect candidate for producing fibers used in nuclear radiation shielding. Electrospinning is a spinning technique with a unique approach using electrostatic forces to produce fine fibers from polymer solutions[1-4]. Electrospinning configuration usually consists of high-voltage supplier, metal needle connected to syringe and collector, a high voltage electric field is applied to the polymer in the syringe resulting in ejection of the polymer as a jet from the needle, by adjusting the applied electric field, the droplet of polymer ejected from the needle shape

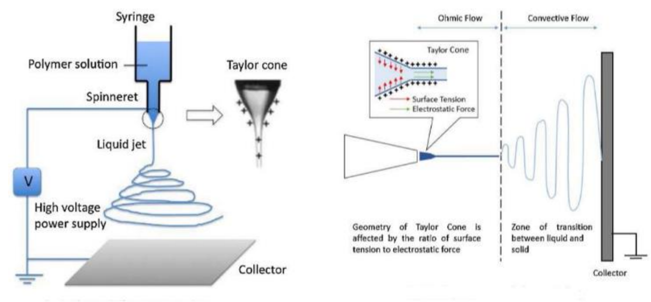

Fig. 1 Taylor cone.

changes from spherical shape to conical shape called "Taylor cone". At this moment, the electrical force overcome the surface tension of the droplet, then the jet will elongate, thins and solidifies as it moves towards the collector. There are several parameters must be considered when electrospinning is being conducted, these parameters are divided into three parts: solution parameters, process parameters and ambient parameters. Those parameters play a crucial rule not only in understanding the electrospinning but also in understanding how nanofibers are produced through electrospinning. PVP has an acceptable solubility in polar solvent and alcohols, also it is lightweight, cost-effective, mechanical and less toxic, so it was chosen as the polymer for electrospinning process [1][8][14].

II. Experimental

A. Material and preparation

High purity polyvinylpyrrolidone (PVP) with an average molecular weight of 40.000 g/mol was acquired form Alpha Chemika, India. Ethanol, methanol and isopropanol were obtained from Sigma-Aldrich, Germany, and has been used as solvents either individually or in mixtures. All these chemical products have been used in the experiment are obtained from their main source and no further purification process was made. It was important to find out which solvent would develop the required viscosity as it is very important factor, since PVP is polar solvent, a set of polar solvents were used, those solvent candidates were distilled water, ethanol, methanol and isopropanol, each was used individually to dissolve PVP particles. All these solvents were able to dissolve the PVP particles but none of them developed the required viscosity. Water, ethanol and methanol gave a low viscous solution, while isopropanol gave very viscous solution, so mixtures of water-ethanol, water methanol, ethanol methanol with 1:1 v/v ratio and ethanol-methanol-isopropanol mixture with a 1:1:1 v/v. then, the PVP particles were added to each solvent and the solutions were kept under continuous magnetic stirring for 6 hours followed by 15 minutes ultrasonication, the prepared mixtures were fed to 5-ml plastic syringe with a 0.8 mm stainless steel tip, then the voltage applied to the tip of the syringe and the electrospinning process started[4][7][9].

After the Polymer was prepared, lead particles were embedded to give the polymer the radiation protection properties that is required [10].

It was important to optimize the applied voltage and flow rate of the feed, hence, different voltage applied, which were as follow: 10, 13, 18 and 20 kV, while various flow rates were used as follow:2, 5, 10, 20, 40, 50 and 60 µl/min. The distance between the syringe and the collector was 14 cm, the collector rotating speed was 500 rpm, and the electrospinning session was 3 h, then the polymeric fiber was collected from the aluminum grounded collector as shown in fig. 2[9].

B. Results and discussion

After the electrospinning process was conducted, the produced nanofibers were extracted and made into 4 samples with different thickness. The samples then exposed to x-ray and gamma radiations.

The nanofibers were made into shielding sheets of dimensions 4*4 cm, each shielding sheets were placed at 2 cm from the detector. The thickness of each sheet was double its preceding.

First, the number of counts were calculated when only air was placed between the source of radiation and the detector, then each shielding sheet with different thickness was placed between the detector and the source.

First, the number of counts were calculated when only air was placed between the source of radiation and the detector, then each shielding sheet with different thickness was placed between the detector and the source. After that, the radiation shielding was exposed gamma ray source of different energies: 662 keV and 14 keV, each sheet of different thickness was used and the radiation intensity were calculated.

The procedures were repeated against x-ray tube which emits X-rays of energy 25 keV. As shown in the previous fig. 3,4 and 5, The shielding material has the highest attenuating effect against X-rays of energy 25 keV, comes after gamma rays of energy 14 keV, and come at last the gamma rays of energy of 662 keV.

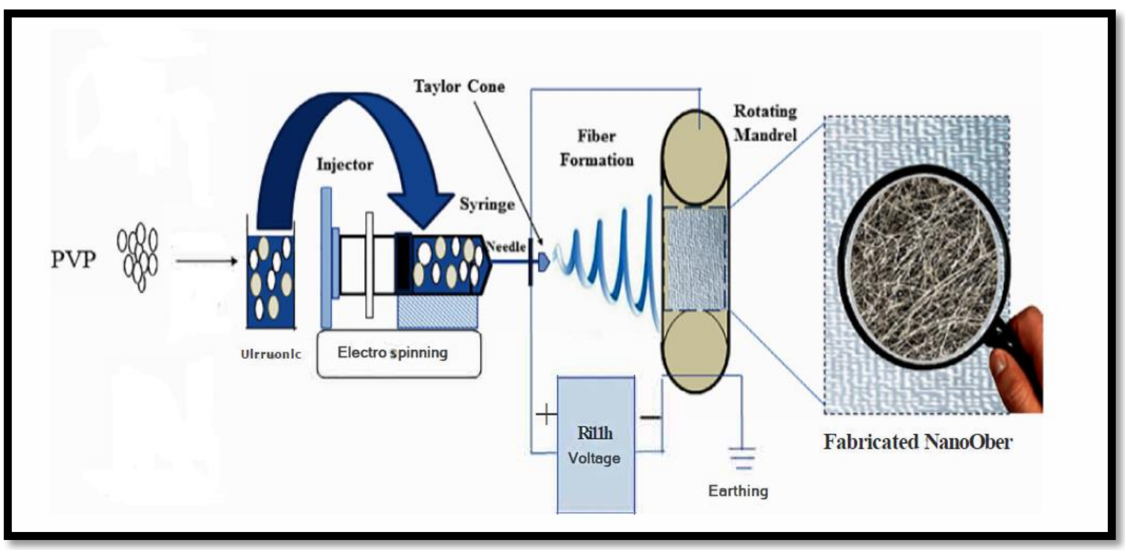

Fig.2 Schematic description of the in-situ fabrication of PVP composite fibrous film via electrospinning.

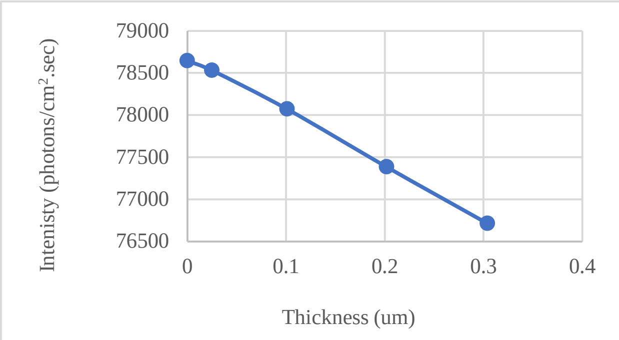

Fig.3 illustrating the effect of different thickness on the intensity of gamma radiation at energy 662 keV.

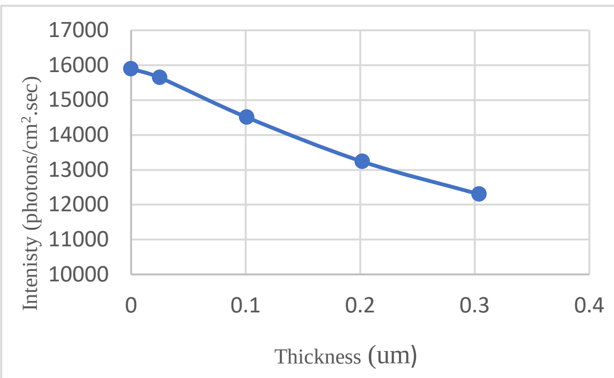

Fig.5 illustrating the effect of different thickness on the intensity of X-ray radiation at energy 25 keV.

III. Conclusion

By applying the optimum condition by mixing ethanol-methanol-isopropanol with a 1:1:1 volume ratio as solvent, also by optimizing the working parameters, it helped to successfully produce PVP nanofiber that was embedded with lead particles to achieve the required shielding properties, the produced PVP/Pb nanofiber sheets could be a high promising candidate in radiation shielding as it approximately reduced the initial intensity of X-ray of 25 keV by 60%.

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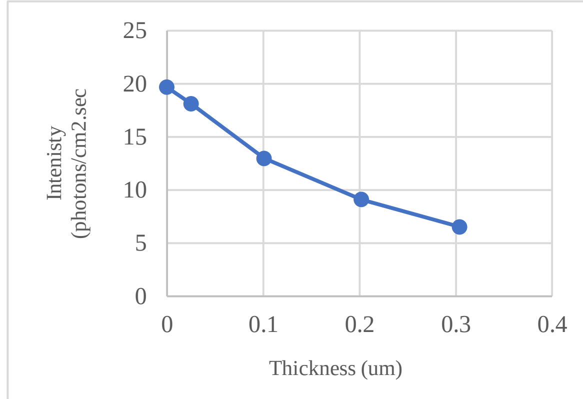

Fig.4 illustrating the effect of different thickness on the intensity of gamma radiation at energy 14 keV.

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