HIGH ENERGY RADIATION EMITTED FROM NANIFIBRES

Petr MIKEŠ[1], Pavel POKORNÝ[1], Tomáš TROJEK[2], T. ČECHÁK[2] and David LUKÁŠ[1]
[1] *Technical University of Liberec, Faculty of Textile Engineering-NanoScience Centre, Department of Nonwovens, Liberec, Czech Republic*
[2] *Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Prague, Czech Republic*
E-mail :david.lukas@tul.cz

Abstract
Nanofibrous materials, e.g. electrospun jets, consist of midget cylindrical structural features with diameters ranging from several nanometers up to several tenths of a micrometer. Tiny nanofibres and electrospinning jets can serve as unusually fine electrodes to create extremely high electric field intensity in their vicinity. However, this ability and a potential for application of tiny electrodes are only scarcely investigated, and the interactions of this kind of electric fields with ambient gasses are nearly unknown. Here we report on the discovery that electrically charged polymeric jets and highly charged gold-coated nanofibrous layers in contact with ambient atmospheric air generate X-ray beams up to energies of hard X-rays. Here we hypothesize how gigantic field strength values are created and how they accelerate ions under atmospheric conditions. Experimental set-ups designed by us for the generation of high energy electromagnetic radiation are extremely simple consisting of unsymmetrical capacitors with at least one electrode made by nanofibrous jets. We anticipate our essay to be a starting point for more sophisticated investigation of the radiation phenomena occurring in proximity to nanofibre electrodes and for designing new devices for harvesting various products of these instrumentations.
Key words: electrospinning, X-rays, polymeric jets,

1. Introduction

The classic way to obtain X-rays, founded by W.K. Röentgen more than a century ago, is to accelerate thermally emitted electrons from a hot filament in a vacuum discharge tube onto a metallic target. X-ray tubes are typically run at 20 kV and a vacuum of 10^{-5} Torr having the distance between the hot filament and the target about 100 mm. The incident electrons experience either continuous energy losses giving rise to bremsstrahlung or to discrete energy losses providing characteristic radiation both resulting in X-ray emission. The excitation of colliding particles may be caused also by a bombardment of charged particles other than electrons. An alternative X-ray source has been described recently by Putterman *et. al.* [1]. They reported that peeling a roll of common adhesive tape in a moderate vacuum of 10^{-3} Torr produces X-ray emission with an observed peak of 15 keV and spectrum spanning even up to more than 80 keV. Surprisingly, also lightning generate X-rays with energies of about 10 keV [2,3].

We carried out experiments and designed unusual devices capable of producing X-ray electromagnetic radiation under atmospheric pressure. Instead of water droplets we worked either with liquid electrospinning polymeric jets [4], created from aqueous solutions of Polyvinyl-alcohol (PVA), or with solid electrically charged gold coated PVA electrospun nanofibrous layers. Electrospinning is a recent fibre forming nanotechnology, which enables us to create submicron fibres drawn from a polymer solution by electrical forces. Electrospinners, devices for production of fibrous electrospun materials, likewise Röentgen tubes, run at voltages above 10 kV. The immense diminution of the radius of a charged electrospinning jet to radii about 100 nm leads, according to our hypothesis and experimental observation, to the creation of a gigantic field strength in the jet vicinity that is strong enough to accelerate charged particles, e.g. ions, to kinetic energies that can be transferred to X-rays. To learn more about the irradiation processes occurring in electrospinning we used an efficient X-Ray SLP Detector.

Electrospinning was carried out with a needle electrospinner equipped with a hypodermic needle pointing downwards at the circular metallic electrode called the ‘collector’. The needle emitted a jet of PVA solution at voltages of 7.5 kV, 15 kV and 30 kV against the collector while distances between the needle and the collector were kept, respectively, at 25 mm, 50 mm and 110 mm. The collector was grounded while the needle was connected to the positive pole of the high voltage source. The needle was supplied with the solution at volume rate of **3** ml/hour using a syringe. The Beryllium window of the SLP Detector was positioned just behind a grounded screen collector.

The continuous spectrum of X-ray photons emitted from the end of the electrispinning jets, as recorded by the unshielded SLP Detector is shown in Fig. 1a,b. Surprisingly, this type of radiation can reach energy levels of 10 keV.

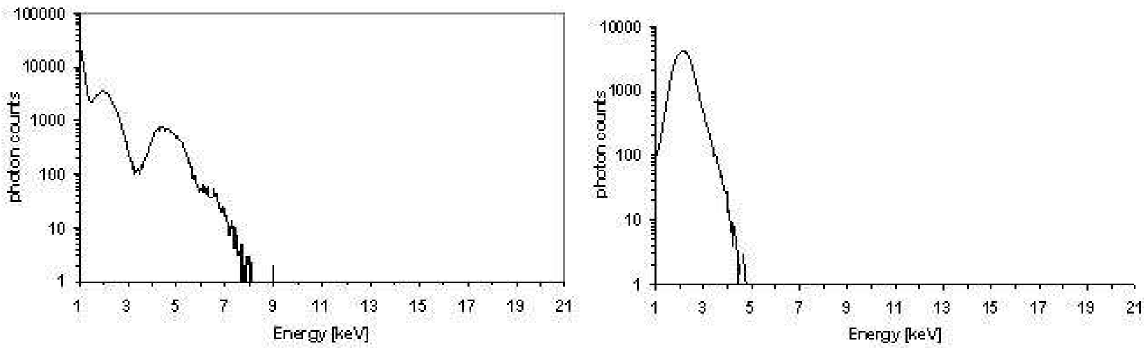

Figure 1. (a) Continuous energy spectra of X-ray total photon count accumulated during 150 s emitted from the end of PVA electrispinning jets recorded by the unshielded SLP X-Ray Detector. The distance between the needle and the collector was adjusted on 50 mm and the voltage was 15 kV.

2. Experimental

The asymmetric capacitor is composed of a piece of thin gold coated electrospun nanofibrous layer having a width **40** mm, length **50** mm **and thickness comparable with a nanofibre diameter**. The rod-like electrode supporting the scrap and radiographic material has the radius 32.8 mm and length 73.7 mm. The counterpart disk electrode is of the diameter 149.9 ± 0.1 mm. The radiographic film INDUX R7 is made by FOMA, Czech Republic. The radiographic material, positioned on the nanofibrous layer, is shielded and wrapped by a black paper having the thickness of 0.2 mm and area density 161 gm^{-2}, and is exposed for **5** minutes. The hypodermic needle in the electrospinning experiments is of the length L = 32 mm, outer diameter R = 8.5 mm and inner diameter 0.55 mm. Polyvinyl-alcohol, Sloviol-R, purchased from Novacke chemicke zavody, Novaky, Slovakia, with a predominant molecular weight of 60,000 g/mol, has the viscosity of 10.4 mPas for 4% aqueous solution. A fresh 12% solution is prepared by dissolving the PVA in distilled water. The circular metallic collector for radiographic detection from electrospun materials is the same as the one used for the asymmetric capacitor. The radiographic material, positioned on the collector, is shielded by black paper and also by Aluminum foil having the thickness of 0.01 mm and area density 25 gm^{-2}. The screen collector for spectral measurements has an area of 50 x 50 mm and is made by the copper wire of the diameter 0.23mm with inner mesh element having the area 1.07 x 1.05 mm. The employed voltage source is: 300 Watt High Voltage DC Power Supply with regulators; model number PS/ER50N06.0-22; manufactured by Glassman High Voltage, INC.; output parameters 0-50 kV, 6mA. The electrospinning process is run for 2 minutes to obtain the resultant spectra. Spectroscopy of X-rays is carried out using ORTEC SLP-10180P Lithium-Drifted Silicon X-Ray Detector having its energy range from 30 keV down to 1 keV and is equipped with an ultra-thin, 25 μm, Beryllium window providing with the energy resolution about 35 eV. The Beryllium window of SLP Detector is positioned just behind a grounded screen collector.

4. Conclusion

We have shown that electrospinning jets and gold coated motionless electrospun nanofibrous layers in the asymmetric capacitor can produce X-ray beams of a top energy close to 15 keV. The 'nanoscopic' physical process of electrospinning spontaneously organises enormously high field strength, high chemical potential difference and supposed gas ionization, hence it will be worthwhile to investigate these aspects in a more intensive manner. The predicted charge density (0.12 Cm^{-2}) estimated in these experiments on fibre surfaces is even higher than the effective charge that accumulates on the surface of the pyroelectric crystal (0.0037 Cm^{-2}) used to generate table-top nuclear fusion [5].

5. References

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