Nonlinear optical nanocomposite:Electrospun PVA nanofibers embedded with PCBS

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ABSTRACT

This work presents a new electrospun nanocomposite of PVA nanofibers with embedded nonlinear optical nanostructure of poly {1-[p-(3'-carboxy-4'-hydroxyphenylazo) benzenesulfonamido]-1, 2-ethandiyl} (PCBS). PVA polymer has been synthesized and converted into nanofibers via electrospinning process. Moreover, PCBS of different amounts are added to be embedded with the generated nanofibers. These nanofibers are optically active due to the second order nonlinear optical behavior of PCBS. The formed nanocomposite shows promising generated second harmonic intensity. In addition, the optimum added amount of PCBS to generate maximum intensity is investigated and was found to be ~ 1mL. The applied wavelength is 1550 nm, while the generated one is 775 nm. The synthesized optical nanocomposite can be useful for further biomedical applications.

Keywords: electrospinning, nanofibers, nonlinear optics, PCBS.

1 INTRODUCTION

Second harmonic generation (SHG) is a process in which a pump wave with certain wavelength can generate another wave with half wavelength. Thisphenomenon has been applied in many applications such as optical communications and biomedical area [1, 2]. Optical nonlinear organic nanomaterials such as PCBS have proved its ability to generate thermally stable second harmonic signal with fair conversion efficiency when added as a coating layer for tapered fibers [3-5]. In this work, we fabricate optical biodegradable nanocomposite applicable for SHG. This biodegradable nanocomposites is composed of PVA nanofibers, embedded with an optical nonlinear PCBS nanomaterial. This nanocomposite is fabricated using electrospinning process, which is considered as a simple, quick, and feasible technique to produce nanofibers matts [6]. The proposed design of the electrospun nanofibers with an embedded optically nonlinear PCBS can have many applications such as solar cells, bioimaging, and biomedical applications. The aimed optical nanaomaterial (PCBS) can lead to the optical conversion from 1330-1550 nm to red or near IR regions [7,8].

In this paper, we experimentally proved that PCBS remains an efficient optical conversion nanomaterial after being embedded inside an electrospun nanofibers material such as PVA. We also determined best PCBS amount to be added to PVA solution in order to obtain the highest emission. The formed electrospun nanofibers were characterized optically through a simple setup to detect the emission under IR excitation.

2 EXPERIMENTALWORK

For this experimental study PCBS was purchased from (Sigma-Aldrich, St. Louis, MO, USA). The concentrations and the pH values are 3.7 mg/mL, and pH ~7 for PCBS solution, respectively. Then the solution is stirred for about 24 hour to be homogenous. The PCBS is added to the PVA solution before the electrospining process.

Typical electrospinning setup consists of a high voltage power supply ranges up to 30 kV (Voltage Electronics Corporation model CZE1000R, Hauppauge, New York, NY, USA), a syringepump (NE1000-Single Syringe Pump, New Era, Farmingdale, New York, NY, USA)that is used to regulate the feed rate of polymer solution, and a syringe to hold the polymer solution. The collector plate is covered with aluminum foil to be used as a target where nanofibers can be deposited. The distance between the needle's tip and the target is ~ 15 cm. The electrospinning system is shown in Fig. 1.Regarding the used chemicals, a concentration of 10wt. % Poly (vinyl alcohol) PVA (Sigma-Aldrich, St. Louis, MO, USA) solution was prepared by mixing 10 g PVA pellets with 90 mL of distilled water. The solution was heated to 100 °C for 30 min, and then it was stirred overnight. Then, PCBS (Sigma-Aldrich, St. Louis, MO, USA) solution has been added to PVA solution at different amounts.

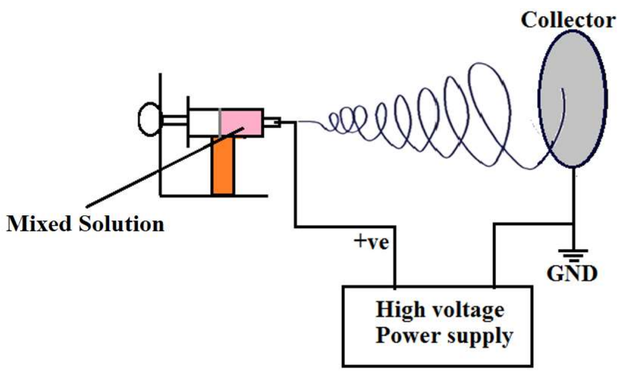


Figure 1: The electrospinning system.

To detect the emitted light, the experimental setup is shown in Fig.2 [9]. In this setup an IR laser module of central wavelength of 1550 nm is applied to the PVA electrospun nanofiber sample with an embedded optically nonlinear PCBS. The second harmonic signal is collected using the monochromator (Newport cornerstone 130) which was set to obtain emission at wavelength from 700 to 900 nm.The monochromator is followed by photomultiplier tube (PMT) (from Oriel Instruments) to amplify the received intensity. Finally, the PMT is connected to a power meter (Newport) to show the amplified signal as a function of wavelength. The emissionwas measured by positioning nanofibers solid sample holder inclined by 45^o between the laser source and the input port of the Monochromator, so that the input optical signal to the monochromator is perpendicular to the initiallaser excitation signal for minimum scattering effect [10]

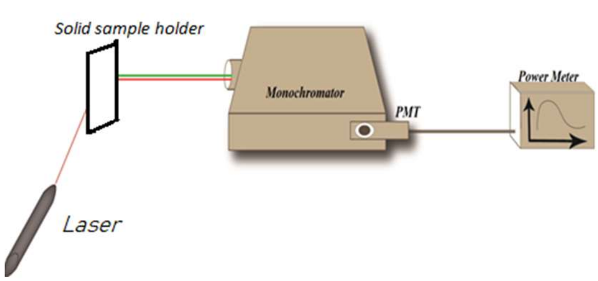


Figure 2:Setup for intensity measurement.

3 RESULTS AND DISCUSSION

The intensity of emission was obtained for different amounts of PCBS nanomaterial which were embedded in PVA nanofibers. Studied amounts of PCBS nanomaterial were from 0 (pure PVA) to 6 mL with step 0.2 mL. As shown in Fig.3. The peak of the emission is appeared for all measurements at wavelength 775 nm as expected. In case of pure PVA nanofibers, no considerable emission is observed.

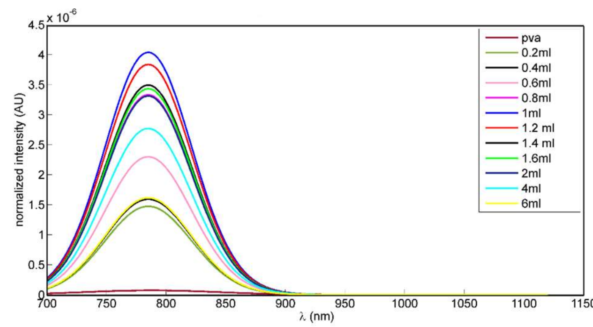


Figure 3: Emission intensity of PVA nanofibers withembedded different amounts of PCBS nanomaterial.

From Fig.4, it can be noticed that, there is an optimum amount of PCBS solution which is about 1 mL. At this amount, the emission is maximum and nanofibers formulation is still feasible.

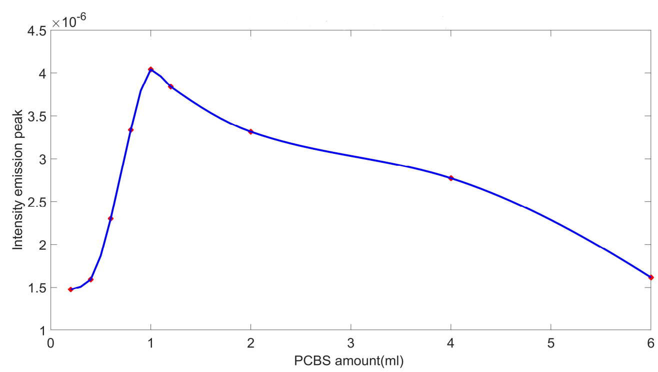
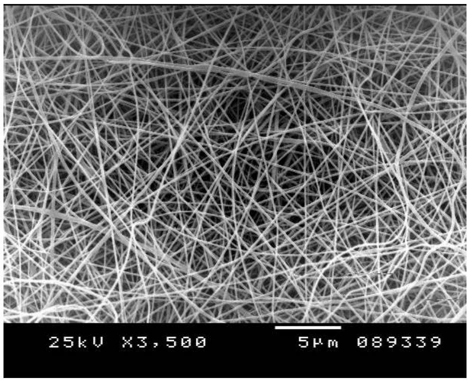
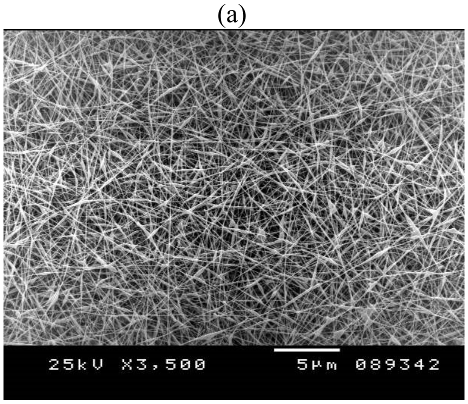


Figure 4: The maximum intensity dependency on PCBS amount.The red points are the measured intensities, while the blue is the fitting curve.

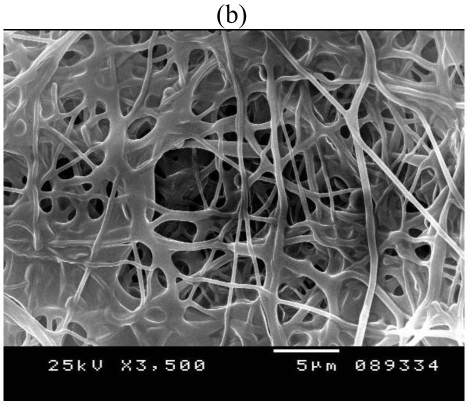
It is worthy to mention that, when the amount of PCBS nanomterial increases, the electrospinning become more difficult and the resulted fibers thickness increase severely as illustrated in the SEM images shown in Fig.5. Also, it was very easy to have electrospun nanofibers with PCBS amount less than 1 mL. They were formed after ~ 10 minutes on the targeted aluminum foil, while nanofibers withamounts higher than 1mL, needed more time to be formed (~ 45 minutes).



(a)



(b)



(c)

Figure 5: SEM images of PVA nanofibers with embedded PCBS nonmaterial : (a) Pure PVA, (b) Low amount of PCBS, and (c) High amount of PCBS.

4 CONCLUSION

In this paper, we studied the implications of adding PCBS nanomaterial with different amounts inside electrospun PVA nanofibers. It was found that, the emission at second harmonic frequency is increasing by adding more PCBS up to certain limit. The maximum emission occurs when ~ 1 mL of PCBS is added to the PVAsolution. Then, the emission is decreasing as the amount of PCBS becomes greater than 1 mL. Also, SEM images show that the formulation of nanofibers mat was significantly difficult and a huge distortion occurred in the nanofibers shape after increasing PCBS amount above the aforementioned amount (1mL). Nanofibers of PCBS nonlinear nanomaterial and PVA can be useful for further biomedical applications.

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