Control of Dielectric Constant and Anti-Bacterial Activity of PVA-PEG/x-SnO$_2$ Nanofiber

M. Diantoro$^{1,2}$, L. A. Sari$^1$, T. Istirohah$^1$, A. D. Kusumawati$^1$, Nasikhudin$^{1,2}$, and Sunaryono$^{1,2}$

$^1$Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Jl. Semarang 5 Malang 65146, Indonesia
$^2$Central Laboratory of Minerals and Advanced Materials, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Jl. Semarang 5 Malang 65146, Indonesia

E-mail: markus.diantoro.fmipa@um.ac.id

Abstract. Research in the utilization of organic natural materials for electronic devices and for the biological application becoming extensively studied. We report a comprehensive review of the role of SnO$_2$ nanoparticle and the effect of light intensity on toxicity properties, antibacterial activity, microstructure and electrical properties of PVA-PEG nanofiber films. The PVA-PEG/SnO$_2$ nanofiber structure has been successfully fabricated on the ITO-glass substrate. Characterization was performed on samples using FTIR, XRD, SEM, toxicity and antibacterial tests, as well as LCR measurement. The presence of various light intensities has also measured the dielectric constant. The addition of SnO$_2$ nanoparticle influenced the structure of the PVA-PEG/SnO$_2$ nanofiber bonding functional group indicated by the appearance of Sn-O-Sn peaks at 648.08 cm$^{-1}$ and 958 cm$^{-1}$ wavenumbers. The addition of SnO$_2$ nanoparticles affects the grain size of SnO$_2$. Addition of SnO$_2$ nanoparticles increases the detected toxicity voltage but is still below the threshold. It means the compound is not toxic, or safe to use in the body. The film lacks the antibacterial power of S. Aurelius. The addition of nanoparticles SnO$_2$ increases the dielectric constant but decreases with increasing frequency of input voltage and the intensity of light employed to PVA-PEG/SnO$_2$ nanofiber. The application of the light intensity reduces the dielectric constant of the PVA-PEG/SnO$_2$ nanofiber in all nanoparticle doping ranges.

Keywords. Dielectric constant, light intensity, nanoparticles, PVA-PEG/SnO$_2$ nanofibers, SnO$_2$, and toxicity.

1. Introduction
Nanoparticle materials have shown a unique of physical, chemical, electrical properties, and magnetic properties [1]. Commonly, many researchers interest to nanoparticles materials especially on the metal oxide such as Fe$_3$O$_4$, organic material such as cellulose acetate, polyaniline and its composite [2, 3]. One of them is indicated by a well-known semiconductor of Tin (II) Oxide (SnO$_2$). SnO$_2$ is an n-type semiconductor that has a non-stoichiometric structure and wide band gap (E$_g$ = 3.6 eV to 3.8 eV) [4]. Also, SnO$_2$ has excellent optical and electrical properties. This oxide also relatively inexpensive, and not toxic [5]. In the previous research, SnO$_2$ is synthesized as powder, bulk, thin film. It also has kind
of surface morphology such as micro or nano spherical, fiber [6], rod [7], or wire [8]. SnO₂ nanofiber is applied as active material like anode of Li battery to enhance its specific capacitance [9–11]. On the other hand, SnO₂ as the primary precursor of synthesis nanofiber desire another material as a binder. Polymer regularly is used as binders such as PVDF [11] and PVA [11–13]. The function of the adhesive is giving elasticity on the nanofiber fabrication. Commonly, electrospinning method is used to fabricate fiber.

In the previous research, PVA-SnO₂ nanofiber has been synthesized well which obtain SnO₂ grain size about 100 nm to 300 nm and not homogeneous yield. Therefore, in this study will be done homogenization and reduce the size of a grain of PVA-SnO₂ nanofiber by adding PEG as a template.

Polyethylene Glycol (PEG) possesses indispensable unique properties in areas such as biological, chemical, biomedical, and pharmaceutical applications. PEG shows excellent features such as non-toxic, immunogenicity, biocompatible, and water-soluble [14]. SnO₂ nanoparticles composite with PVA-PEG polymer using electrospinning technique obtained PVA-PEG /SnO₂ nanofiber. Specific applications of the SnO₂ nanofiber in the health are diagnosing diabetes, and detecting lung cancer [14]. From our knowledge, it is still difficult to find a comprehensive study of the effects of SnO₂ nanoparticles and light intensity on dielectrics of PVA-PEG/SnO₂ nanofiber on which to open the possibility as a bio environmentally compatible and body bioactive sensors. Therefore, a series of studies on nanoparticle SnO₂ to nanoparticle especially PEG is needed. In this paper, we proposed the effect of nanoparticles SnO₂ and light intensity on the dielectric constant of PVA-PEG/SnO₂ nanofiber.

2. Materials and methods
The synthesis of nanoparticles SnO₂ was performed by using coprecipitation method from SnCl₂. The SnCl₂ powder as much as 8 g dissolved in ethanol (C₂H₅OH) as much as 25 mL at 60 °C and stirred about 30 min using magnetic stirrer. Acetyl Acetone was then added as much as five mL and inserted one mL of PEG 6000 then reflux at 80 °C for 5 h. Furthermore, the solution was allowed to stand for 72 h at 30 °C until the sole was formed, then dried at 100 °C for 3 h. After drying, it was then calcined at 400 °C for 1 h to create the nanoparticles. The next step was deposition of the nanofiber of PVA-PEG/SnO₂ using electrospinning technique.

The first step was to insert 4.3 mL of aquades into 10 mL beaker glass and stirred about 350 rpm at 90 °C for 15 min. Afterwards, introducing 3.5% SnO₂ nanoparticles of total volume, 111 μL of PEG 400, and 12.23 μL of TMAH. Subsequently, the mixtures were stirred at 350 rpm with a temperature of 90 °C for 60 min. When a homogeneous has reached, it followed by ultrasonic irradiation for 1 h using an ultrasonic bath. The obtained then incorporated a 0.5 g PVA and stirred 700 rpm at 120 °C for 60 min and sonicated again for 2 h. The solution then ready for electrospinning to fabricate a PVA-PEG/SnO₂ nanofiber

3. Results and discussion
The addition of the SnO₂ nanoparticles to the PVA-PEG nanofiber produces the PVA-PEG/SnO₂ nanofiber spectrum shown in Figure 1. The results of FTIR spectrophotometric characterization of nanoparticles SnO₂, PVA Gohsenol, PEG 400, and PVA-PEG/SnO₂ nanofiber are shown in Figure 1. SnO₂ nanoparticles show transmittance peaks at 3391 cm⁻¹, and 1568 cm⁻¹ which are associated to the vibration of stretching OH, while peaks at a wave number of 625, 930, and 1635 cm⁻¹, indicating the appearance of the stretching mode of Sn-O-Sn [14], [15]. The PVA-PEG/SnO₂ nanofiber in Figure 1 has a similar peak shape such as in PEG 400 and PVA compared to SnO₂ nanoparticles. The indistinguishable from the mixture may be caused the number of nanoparticles is less than the amount of PVA, so the transmittance of PVA is stronger appears in the PVA-PEG/SnO₂ nanofiber. The spectra of PEG-400 at (845 to 900) cm⁻¹ indicates the presence of O-O stretching [16], whereas the presence of 1109 cm⁻¹ peaks indicates symmetry C-O-C on aliphatic ether. Spectral peak at 1352 cm⁻¹ shows the presence of deformation of C-H alkyl while 2882 cm⁻¹ indicates the presence of str-C-H alkyl stretching.
3.1. Structure of PVA-PEG/SnO₂ Nanofiber Analyses

The diffraction patterns of PVA-PEG/SnO₂ nanofiber films are displayed in Figure 2. The X-ray diffraction pattern of nanoparticles synthesized by the sol-gel method is shown in Figure 2. X-ray diffraction pattern of nanoparticles of SnO₂ showed the result of crystalline according to the previous study [17]. The grain size of SnO₂ nanoparticles of 36.11 nm was obtained by diffusion using Origin program with PearsonVII function obtained FWHM value of 0.25182, then analyzed using Debye Scherer equation. Using the same method, the grain size of SnO₂ nanoparticles in PVA-PEG/SnO₂ nanofiber was 26.94 nm with the FWHM value of 0.33761. The SnO₂ nanoparticles were also analyzed using Rietica program with model data from AMCSD with code 2101853. We obtained that the lattice constant is \( a = b = 4.73735 \text{ Å} \) and \( c = 3.18640 \text{ Å} \). With these values indicating that the SnO₂ nanoparticles fit with a tetragonal crystal structure under \( P4_2/mnm \) space group. The diffraction peak of the SnO₂ nanoparticles is positioned at a diffraction angle of 26.58°, 33.85°, 37.94°, 51.76°, 54.74° and 65.94°.
3.2. Micro structure and morphology of PVA-PEG/SnO₂ nanofiber
A typical EDAX and SEM image of PVA-PEG/SnO₂ Nanofiber is shown in Figure 3. Information from EDAX in Table 3 shows the element of comparison between C, O, and Sn of 11.96 %, 29.46 %, and 03.53 %. Elements C and O are elements of the formation of PEG, while the Sn element comes from the doping given [18]. Based on the information, it shows the formation of PVA-PEG / SnO2 nanofiber in the presence of C, O, and Sn compositions.

![EDAX and SEM Image](image)

Figure 3. EDAX analyses (a) and SEM image (b) of PVA-PEG/SnO₂ nanofiber

3.3. Toxicity test of PVA-PEG/SnO₂ Nanofiber
All series of PVA-PEG/SnO₂ Nanofiber have been tested for their toxicity using animal intestinal muscle. An example of them is presented in Figure 4. Present a record of intestinal contractions in animals Mus musculus shows the intestine contracts indicated by the wave peaks. In Figure 4 is a record of regular intestinal contractions when compared with intestinal contractions when sampled in Figure 4, the contractions do not change significantly. Based on this, the composition of the PVA-PEG/SnO₂ nanofiber variation sample did not cause the rejection response to the organ.

![Intestinal Contraction Record](image)

Figure 4. Example of intestinal contraction record after inserting PVA-PEG/SnO₂ Nanofiber

3.4. Antibacterial activity of PVA-PEG/SnO₂ Nanofiber
An example of antibacterial activity for E. Coli of PVA-PEG/SnO₂ Nanofiber is shown in Figure 5. Based on an antibacterial test using S.Aureus bacteria from PVA-PEG/SnO₂ nanofiber did not show the antibacterial power of the material in the absence of clear zone in Figure 5. From the previous study, the antibacterial activity of nanoSnO₂ particles using E.Coli bacteria with different
concentration of solution indicated the clear presence zone [19, 20]. When compared with antibacterial trials using S. Aureus bacteria there is no clear zone; this suggests the antibacterial ability of SnO2 nanoparticles present in E. coli bacteria.

**Figure 5.** A typical pictogram of Antibacterial PVA-PEG/SnO2 Nanofiber for E.Coli

3.5. **Dielectricity**

The prepared samples have been characterized using LCR meter for various frequency. The real part of dielectric constant for all samples of PVA-PEG/SnO2 Nanofiber are presented compactly in Figure 6. Further analyses were performed for dielectric measurement using LCR meter at various light intensity is depicted in 7.

**Figure 6.** The dielectric constant as a function of Nano SnO and Frequency of PVA-PEG/SnO2 Nanofiber
Figure 7. Dielectric constant of different light intensity PVA-PEG/SnO$_2$ Nanofiber

The higher the intensity of light employed, the dielectric constant decreases. The influence of light on the dielectric constant shows the interaction between light and sample. The light impinges on the sample provides the energy give rise to the excitation of electrons in the atom. This situation produces an atomic swelling that occurs as the radius of the atom gets more prominent. As the ionic radius increases, the electron binding energy becomes weaker, allowing for the electrons to be more easily oriented by the electric screw. In other words, in the view of electronic polarization, to produce the same displacement required a smaller electric field. That is why the dielectric constant decreases.

4. Conclusions
Addition of nanoparticles SnO$_2$ increases IR spectra, increasing Sn-O-Sn peak in PVA-PEG/SnO$_2$ nanofiber. The addition of nanoparticles SnO$_2$ affects the stress of toxicity test in PVA-PEG/SnO$_2$ nanofiber, but not toxic when applied to the body. The addition of nanoparticles SnO$_2$ does not change the clear zone of antibacterial assays using S. Aureus microorganisms, so the PVA-PEG/SnO$_2$ nanofiber has non-antibacterial properties. The addition of nanoparticles SnO$_2$ the more significant the dielectric constant. The addition of light intensity given the PVA-PEG/SnO$_2$ nanofiber the smaller the dielectric constant.

Acknowledgements
This research was partially supported by PDUPT Grand of Ministry of Research Technology and Higher Education.

References
[1] Koole R et al 2014 Size effects on semiconductor nanoparticles In Nanoparticles (Berlin Heidelberg :Springer) pp 13–51
[2] Diantoro M et al 2017 Microstructure and dielectric properties of cellulose acetate-ZnO/ITO composite films based on water hyacinth J. Phys. Conf. Ser. 853 p 12047
[3] Diantoro M et al 2017 Effect of Fe$_3$O$_4$ on the Electro-Optic and Magneto-Electric Characteristics of ( PANI / Fe$_3$O$_4$ ) -Ag Film IOP Conf. Ser. Mater. Sci. Eng. 12062

[4] Batal M A, Nashed G and Ineed F H 2014 Conductivity and thermoelectric properties of nanostructure tin oxide thin films Journal of the Association of Arab Universities for Basic and Applied Sciences 15 pp 15–20

[5] Sahm T et al 2007 Sensing of CH4, CO and ethanol with in situ nanoparticle aerosol-fabricated multilayer sensors Sensors and Actuators B: Chemical 127 pp 63–68

[6] Shukla G P and Bhatnagar M C 2015 SnO$_2$: Fiber: Morphology, Optical Property Journal of Materials Science and Engineering A 5 pp 377–380

[7] Khuc Q T 2010 The influence of hydrothermal temperature on SnO$_2$ nanorod formation Advances in Natural Sciences: Nanoscience and Nanotechnology 1 p 025010

[8] Lu F C and Wang C Y 2016 April The SnO$_2$ nanowires Synthesis and Characterization Meeting Abstracts (The Electrochemical Society) 24 pp 1259–1259

[9] Fang D et al 2014 Hollow SnO$_2$-ZnO hybrid nanofibers as anode materials for lithium-ion battery Mater. Res. Express 1 p 25012

[10] Zhao Y et al 2015 Electrospun SnO$_2$–ZnO nanofibers with improved electrochemical performance as anode materials for lithium-ion batteries International Journal of Hydrogen Energy 40 pp 14338–14344

[11] Wei Y et al 2017 A Stable Cross-Linked Binder Network for SnO$_2$ Anode with Enhanced Sodium-Ion Storage Performance Chemistry Select 2 pp 11365–11369

[12] Prosanov I Y et al 2013 Hybrid material polyvinyl alcohol-stannic acid/stannic oxide Physics of the Solid State 55 pp 1519–1524

[13] Hatamie S et al 2009 Polymer-embedded stannic oxide nanoparticles as humidity sensors Materials Science and Engineering: C 29 pp 847–850

[14] Mostafaei A and Nasirpour F 2014 Epoxy/polyaniline–ZnO nanorods hybrid nanocomposite coatings: Synthesis, characterization and corrosion protection performance of conducting paints Progress in Organic coatings 77 pp 146–159

[15] Thanasanvorakun S et al 2008 Characterization of SnO$_2$ nanowires synthesized from SnO by carbothermal reduction process Ceramics International 34 pp 1127–1130

[16] Wang W et al 2015 Electrochemistry of myoglobin on graphene–SnO$_2$ nanocomposite modified electrode and its electrocatalysis Arabian Journal of Chemistry

[17] Blessi S et al 2014 Preparation and characterization of SnO$_2$ nanoparticles by hydrothermal method ChemTech Research 6 pp 2153–2155

[18] Liu Y et al 2008 Improved molten salt synthesis (MSS) for SnO$_2$ nanorods and nanotwins Materials Chemistry and Physics 112 pp 381–386

[19] Bouarroudj T et al 2016 Cytotoxic effect of sno2 nanoparticles on alternative cellular model: paramecium tetraurelia Studia Universitatis Vasile Goldis Seria Stiintele Vietii (Life Sciences Series 26

[20] Kumari M M and Philip D 2015 Synthesis of biogenic SnO$_2$ nanoparticles and evaluation of thermal, rheological, antibacterial and antioxidant activities Powder Technology 270 pp 312–319