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Low-Cost and Light-Weight Pressure Sensors Fabricated from $BaTiO_3$-NPs-Doped PVA/PEG Blend

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This work aims to fabricate the new PVA/PEG/$BaTiO_3$ nanocomposites for pressure sensors having high sensitivity, flexibility and low cost. The structural properties and pressure sensor applications are investigated. The structural properties are studied by means of microscopic images and FTIR analysis. The pressure-sensors' tests based on the PVA/PEG/$BaTiO_3$ nanocomposites are examined at pressures within the range from 80 bar to 160 bar. The experimental results show that the PVA/PEG/$BaTiO_3$ nanocomposites have good pressure sensitivity.

Цю роботу спрямовано на виготовлення нових нанокомпозитів ПВС/ПЕГ/$BaTiO_3$ для давачів тиску з високою чутливістю, гнучкістю та низькою вартістю. Досліджено структурні властивості та застосування давача тиску. Структурні властивості вивчаються за допомогою мікроскопічних зображень і аналізи інфрачервоної спектроскопії на основі Фур'є-перетвору. Тести давачів тиску на основі нанокомпозитів ПВС/ПЕГ/$BaTiO_3$ досліджуються за тисків у межах від 80 бар до 160 бар. Експериментальні результати показують, що нанокомпозити ПВС/ПЕГ/$BaTiO_3$ мають хорошу чутливість до тиску.

Key words: pressure sensor, Fourier-transform infrared spectroscopy, polyvinyl alcohol, polyethylene glycol, $BaTiO_3$, nanocomposite.

Ключові слова: давач тиску, інфрачервона спектроскопія на основі Фур'є-перетвору, полівініловий спирт, поліетиленгліколь, $BaTiO_3$, нанокомпозит.

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1. INTRODUCTION

Blending of polymer products is the latest technique for optimizing

different polymer matrices and is a valuable method for producing substances with an extensive diversity of characteristics. Polymer characteristics may be improved by combining two or more polymers and/or adding organic/inorganic fillers for use in various applications. The melt blending and solvent casting routes are the most common ways for the manufacturing of polymer blends or composites [1].

Polyvinyl alcohol (PVA) is a synthetic thermoplastic polymer having water solubility. It is represented as $[CH_2CH(OH)]n$. It is a low cost and easily processable polymer. Commercial production of PVA is usually attained *via* vinyl acetate monomer. PVA is susceptible to partial or complete hydrolysis that may affect the final polymer properties. Hydrogen bonding between PVA chains is often responsible for the semi-crystalline nature of this polymer. PVA has good water solubility, thermal stability, corrosion resistance, and optical transmission. Different morphologies of PVA have also proven useful manifestation for pharmaceutical and biomedical characteristics. PVA has found applications in number of fields including membranes, coatings, adhesives, sensors, batteries, fuel cells, textiles, papermaking, and biomedical frameworks.

Attempts have been made to form PVA nanocomposites to increase their span in technical arenas. Different types of nanofillers have been incorporated into PVA matrix to enhance the structural, optical, electrical, and mechanical properties of this versatile polymer [2].

Polyethylene glycol (PEG) is a hydrophilic and non-toxic polymer having tremendous properties like electron-acceptor nature, biocompatibility, chain flexibility and a wide range of molecular weight. PEG is widely used to increase the ductility and flexibility of rigid polymers. However, PEG is having a lower melting point than PVA that preserves the highly strengthened carbon chain backbone in PVA as compared with the C–O–C backbone in PEG [3].

Ferroelectrics such as barium titanate ($BaTiO_3$), lead titanate ($PbTiO_3$) and lead zirconium titanate (PZT) with the perovskite crystal structure have gained considerable interest in industrial sectors. Ferroelectric ceramics exhibit excellent dielectric properties but poor mechanical performances. On the other hand, polymers possess good flexibility, but low dielectric permittivity. Thus, combination ferroelectric fillers and polymer can overcome these deficiencies [4].

There are many studies on the optical and electrical properties of composites and nanocomposites [5–35], which were studied and applied for different types of sensors [36–39]. This paper aims to fabrication of low cost and lightweight pressure sensors using PVA/PEG/$BaTiO_3$ nanostructures.

2. MATERIALS AND METHODS

The materials, which used in this work, are polymers of polyvinyl alcohol and polyethylene glycol with ratio 88 wt.% PVA to 12 wt.% PEG. Then, the $BaTiO_3$ nanoparticles (NPs) are added to polymeric solution with concentrations of 0, 1.4, 2.8, 4.2 and 5.6 wt.%. The (PVA/PEG/$BaTiO_3$) nanocomposites are prepared by using casting method. The film of (PVA/PEG/$BaTiO_3$) nanocomposites was placed between copper plate and under applied load on two plates where film was between them. The capacitance for various applied load range 80–160 bar was measured by using LCR meter type (HIOKI 3532-50 LCR HI TESTER) at 100 Hz, which is locally manufactured.

3. RESULTS AND DISCUSSION

Figure 1 represents microscopic images of (PVA/PEG/$BaTiO_3$) nanocomposites. In Figure 1, *a*, *b*, *c*, *d* and *e*, it can be seen the distribu-

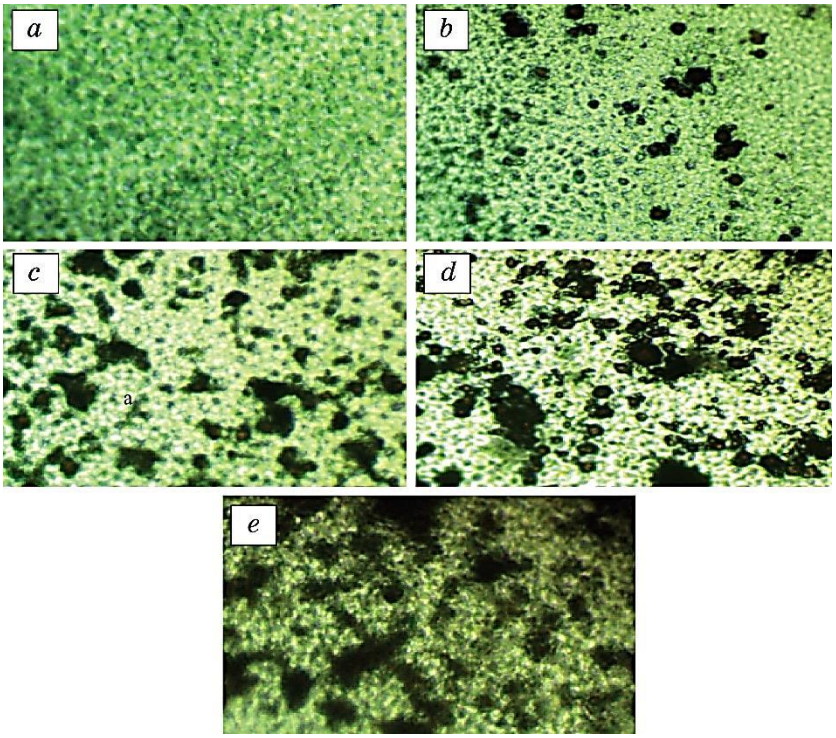

Fig. 1. Microscope images (×10): (*a*) blend, (*b*) 1.4 wt.% $BaTiO_3$ NPs, (*c*) 2.8 wt.% $BaTiO_3$ NPs, (*d*) 4.2 wt.% $BaTiO_3$ NPs, (*e*) 5.6 wt.% $BaTiO_3$ NPs.

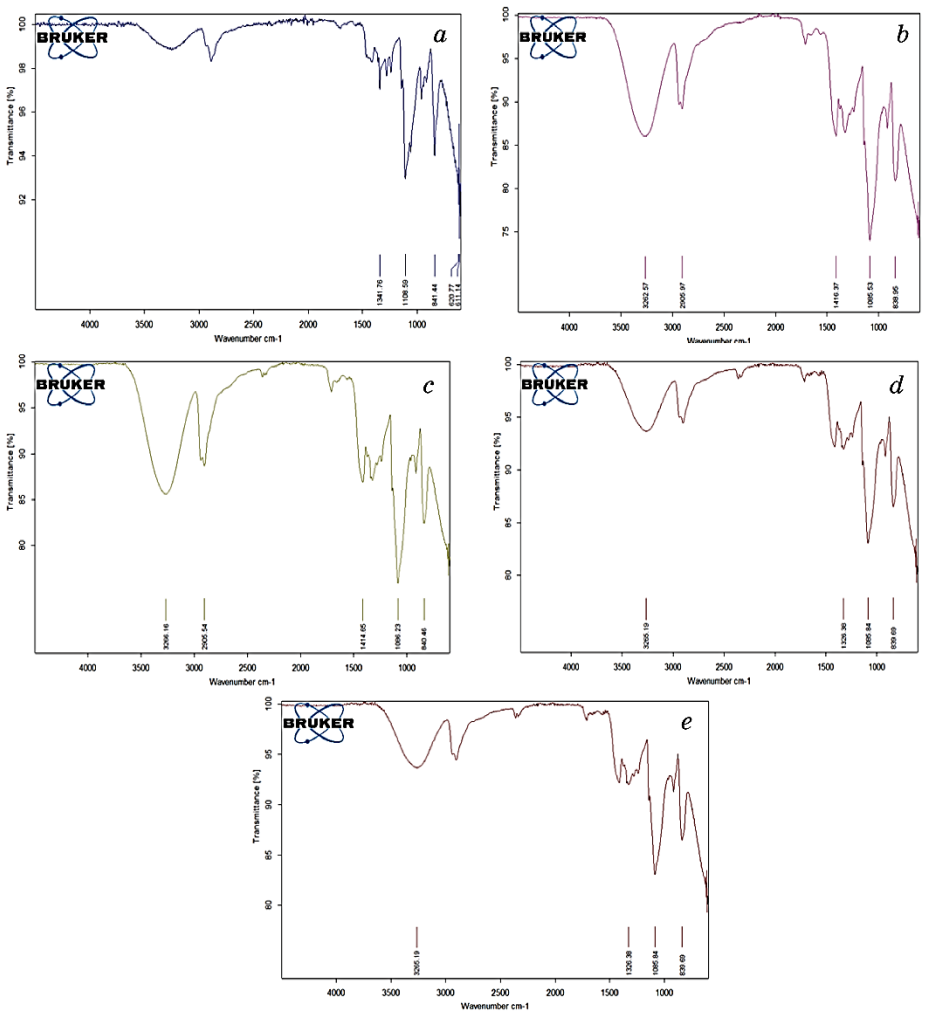

Fig. 2. FTIR analysis of PVA/PEG/$BaTiO_3$ nanocomposites: (*a*) blend, (*b*) 1.4 wt.% $BaTiO_3$ NPs, (*c*) 2.8 wt.% $BaTiO_3$ NPs, (*d*) 4.2 wt.% $BaTiO_3$ NPs, (*e*) 5.6 wt.% $BaTiO_3$ NPs.

tion and homogeneity of $BaTiO_3$ NPs within the (PVA–PEG) matrix.

FTIR analysis of (PVA/PEG/$BaTiO_3$) nanocomposites' samples is shown in Fig. 2. FTIR manifests the nanocomposites' interactions. The band around 3262 cm^{-1} is related to OH group. The strong band around 1085 cm^{-1} is attributed to the stretching mode of C–O group. The two strong bands observed around wave numbers of 1416 cm^{-1} and 840 cm^{-1} are attributed to the bending and stretching modes of CH_2 group, respectively [40].

Figure 3 shows the variation of electrical capacitance of

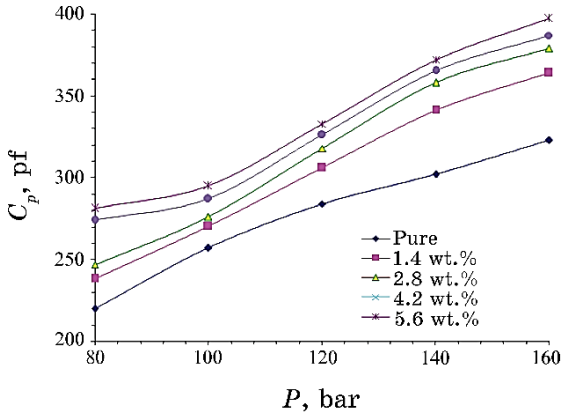

Fig. 3. Variation of the electrical capacitance for PVA/PEG/$BaTiO_3$ nanocomposites with pressure.

(PVA/PEG/$BaTiO_3$) nanocomposites with pressure (compression). As shown in Figure 3, the electrical capacitance increases with increasing of the pressure. The crystal consists of multiple interlocking domains, which have positive and negative charges. These domains are symmetrical within the crystal, with the result that the crystal has a net charge of zero. When a stress is applied to the crystal, this symmetry is broken, and, in order to restore the symmetry, these domains realign themselves and, through the realignment, generate a current, and the capacitance will be increased [41–45].

4. CONCLUSIONS

The (PVA/PEG/$BaTiO_3$) nanocomposites have been prepared by using casting method. The studied characteristics in this work included: microscopic images, FTIR analysis, and pressure-sensor application. The results indicated that the capacitance of (PVA/PEG/$BaTiO_3$) samples increases with the increase in pressure. This behaviour makes it possible the (PVA/PEG/$BaTiO_3$) nanocomposites be used for pressure-sensor applications.

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