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Low cost and flexible biopolymers (polyvinyl alcohol-poly-acrylic acid)/niobium carbide new nanocomposites for sensors

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Key words: Niobium carbide, Electrical resistance, Nanocomposites, Pressure sensor.

Abstract

This paper aims to fabrication of (polyvinyl alcohol- poly-acrylic acid) blend and (polyvinyl alcohol- poly-acrylic acid) blend doped with niobium carbide nanoparticles have been investigated for pressure sensor with low weight, low cost and high sensitivity. The nanocomposites were prepared with concentration: 85 wt.% PVA and 15 wt.% PAA. The NbC nanoparticles were added to (PVA-PAA) blend with concentrations are (1.5, 3, 4.5 and 6) wt.%. The FTIR measurements have been examined. The pressure sensor application for (PVA-PAA-NbC) nanocomposites have been investigated in pressure range (80-160) bar. The experimental results showed that the electrical resistance of (PVA-PAA) blend decreases with increase in weight percentages of niobium carbide nanoparticles. The electrical resistance of (PVA-PAA-NbC) nanocomposites decreases with the increase of pressure.

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Introduction

Polymers can be prepared through various techniques such as radical, cationic and anionic polymerization. The mechanical, thermal and structural properties can be studied through different kinds of characterization methods to determination of structure–property relationships. Recently, polymers have been applied in various fields such as automotive, construction, electronic, cosmetic and pharmaceutical industries due to its advantageous material properties [Vetriselvi and Santhi, 2014]. Polymers have become the promising materials in various scientific and technological applications.

This is due to the fact that in addition to their excellent inherent characteristics, their properties can be customized for an appropriate use by various treatments e.g. chemical doping, gamma irradiation, ion or metal oxide implantation. Polymer systems are widely used due to their unique attributes: ease of production, light weight, and ductile properties which can often be found even at relatively low filler content. A composite is a heterogeneous substance consisting of two or more materials which does not lose the characteristic of each component. This combination of materials brings about new desirable properties [Abdel-Galil *et al.*, 2015].

The addition of inorganic nanoparticles to polymers allows the modification of the polymer physical properties as well as the implementation of new features in the polymer matrix. With decreasing particle size, the ratio of surface/ volume increases, so that surface properties become crucial. Smaller the particles are, more importantwill be the surface properties, thereby influencing interfacial properties, agglomeration behavior, and also the physical properties of the particles[Agool *et al.*, 2016]. PVA is a widely used biocompatible thermoplastic polymer. However, unlike most petroleum based polymers, it is fully biodegradable in the presence of suitable microorganisms. In addition, because of the hydroxyl (-OH) groups, PVA is strongly hydrophilic and soluble in water, which helps its degradation through hydrolysis. Due to its biodegradable nature, PVA nanocomposites and their crosslinked products have been widely investigated. Crosslinking of PVA can increase its useful life without compromising the biodegradability [Qiu and Netravali, 2015]. PVA polymer is soluble in water and other solvents and is widely used in synthetic fiber, paper, contact lens, textile, coating, and binder industries, due to its excellent chemical and physical properties, nontoxicity, processability, good chemical resistance, high dielectric strength, good charge storage capacity, wide range of crystallinity, good film formation capacity, complete biodegradability, and high crystal modulus dopant dependent electrical and optical properties [Kadhim *et al.* 2016].

Carbides have been broadly used in numerous fields, for instance composite ceramic materials, aerospace materials and wear resistance, because it has high melting temperature, high hardness, oxidation resistant, high thermal shock resistance and high abrasion resistance [Al-Ghaban, *et al.*, 2017].

Niobium carbide is type of transition metals carbides which has unique properties resembling with metal and ceramic constituents and used in many technological applications due to their high strength, durability [Al-Ghaban, *et al.*, 2017]. Recently polymer matrix-ceramic filler composites receive increased attention due to their interesting electrical and electronic properties, Integrated decoupling capacitors, angular acceleration accelerometers, acoustic emission sensors and electronic packaging are some potential applications [Al-Ramadhan *et al.*, 2011]. Composites and nanocomposites materials are characterized by their combination between the properties of the additive and matrix.

The new produced material has many applications in fields: antibacterial materials [Rashid *et al.*,2018, Al-Garah *et al.*,2018, Agool *et al.*,2015, Kadhim *et al.*,2016, Kadhim *et al.*, 2017], pressure sensors and piezoelectric [Hashim *et al.*,2017, Hashim and Hadi, 2017, Hashim and Hadi, 2018, Hashim and Hadi, 2017], humidity sensors [Hadi and Hashim, 2017, Hashim and Hadi, 2018, Hashim and Hadi, 2018, Hashim *et al.*,2017, Hashim and Hadi, 2017, Agool *et al.*,2017], thermal energy storage and release [Hashim *et al.*, 2018, Agool *et al.*,2017, Hashim and Hadi, 2017], radiation shielding [Hashim and Jassim, 2018, Hashim and Hadi, 2017, Hashim and Jassim, 2018, Habeeb *et al.*, 2017].

This paper deals with fabrication of new kind of (PVA-PAA-NbC) nanocomposites for environmental applications with low cost, low weight and good quality.

Materials and methods

The nanocomposites films of polyvinyl alcohol- poly-acrylic acid and polyvinyl alcohol- poly-acrylic acid doped with niobium carbide nanoparticles have been prepared. The (PVA-PAA-NbC) nanocomposites were prepared by dissolving 1 gm of polyvinyl polyvinyl alcohol- poly-acrylic acid in 30 ml of distilled water with concentration is 85 wt.% PVA and 15 wt.% PAA by using magnetic stirrer to mix the polymers for 1 hour to obtain more homogeneous solution.

The NbC nanoparticles were added to polymers mixture with concentrations are (1.5, 3, 4.5 and 6) wt.%. The casting method was used to prepare the samples of nanocomposites. FTIR spectra for (PVA-PAA-NbC) nanocomposites were recorded by FTIR (Bruker company) in wave number range (400 – 4000)cm^{-1}.

The pressure sensor application of nanocomposites investigated by measuring the resistance between two electrodes on the top and bottom of the sample by using the Keithley electrometers type 2400 sources mater for different pressures range (80-160) bar.

Results and discussion

FTIR analysis of (PVA-PAA-NbC) nanocomposites is shown in Fig. 1. The FTIR studies of samples show the interactions in between (PVA-PAA) blend and NbC nanoparticles. It show broad bands at around 3200 cm^{-1} for all samples of (PVA-PAA-NbC) nanocomposites are observed due to OH groups in the polymers matrix chain. The bands at around 1200 cm^{-1} were attributed to the other bonds (C-O-C) [Mohammad *et al.*, 2013].

The band at around 2900 cm^{-1} was attributed to the C-H groups. The bands at around 1700 cm^{-1} are assigned to the C=C stretching mode.

The strong band at around 1060 cm^{-1} attributed to the stretching mode of C-O group [Karthikeyan *et al.*, 2009]. The NbC nanoparticles are caused changes in spectral of (PVA-PAA) blend which include shift in some bonds and change in the intensities.

These changes attributed to physical bonds of nanoparticles with polymers. The FTIR studies show that there is no interactions between (PVA-PAA) blend and NbC nanoparticles.

The transmittance in figures decreases slightly with the increase of NbC nanoparticles concentrations which attributed to increase the density of nanocomposites [Elmarzugi *et al.*, 2014].

These are consistent with the results of researchers [Arsalani, *et al.*, 2010, Kumar *et al.*, 2012].

Fig. 2. Shows the variation of electrical resistance for (PVA-PAA-NbC) nanocomposites with different concentrations of NbC nanopaticles at 80 bar. As shown in figure, the electrical resistance decreases with increase in NbC nanopaticles concentration, this behavior attributed to the increase in charge carriers number [Basha *et al.*, 2016].

Fig. 3. Shows the variation of electrical resistance for (PVA-PAA-NbC) nanocomposites with pressure for different concentrations of NbC nanopaticles. From figure, the electrical resistance decreases with increase in pressure, this behavior can be explained: the samples have a crystalline region that has an internal dipole moment.

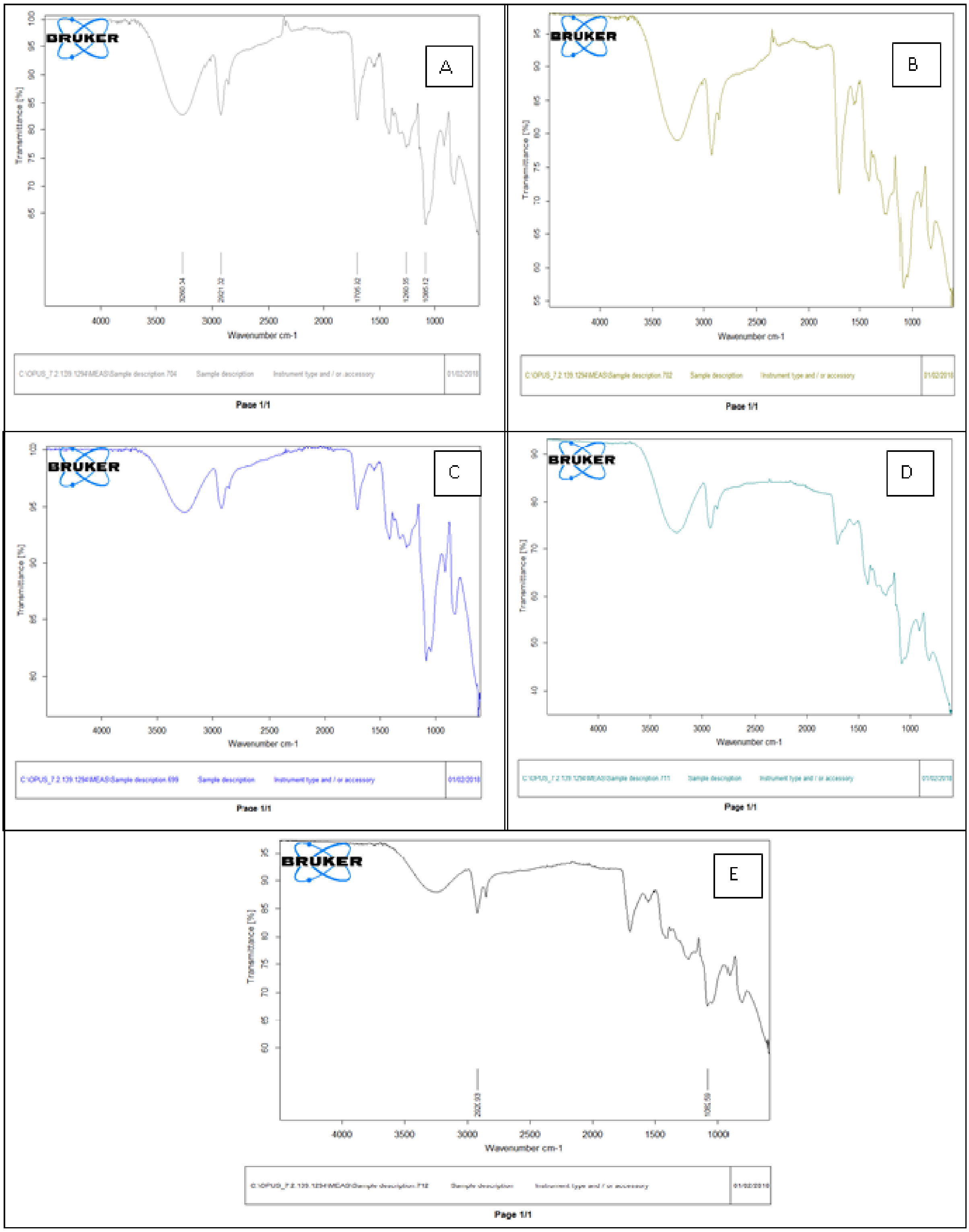

Fig. 1. FTIR spectra for (PVA-PAA-NbC) nanocomposites: A- Pure blend, B- 1.5 wt.% NbC nanoparticles, C- 3 wt. NbC nanoparticles D-4.5 wt.% NbC nanoparticles, E- 6 wt.% NbC nanoparticles.

These dipole moments are randomly oriented without any mechanical or electrical poling process, and the net dipole moment is zero in this condition. When stress is applied, it will change the local dipole distributions and induce an electric field. The induced electric field accumulates the charges at both the top and bottom of the sample [Kim, 2015].

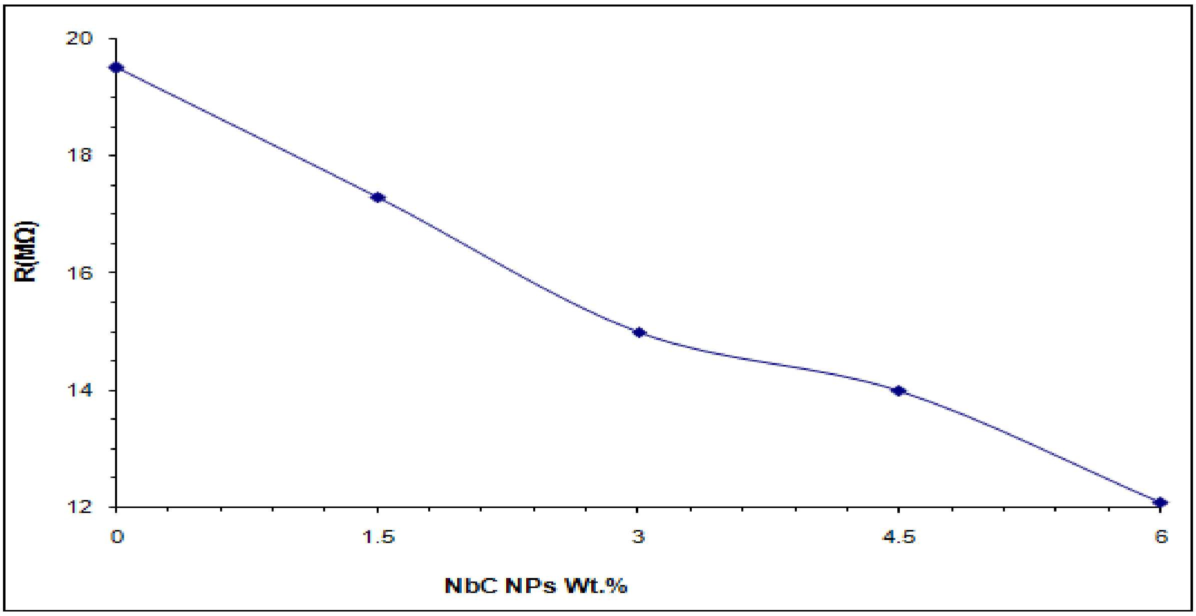

Fig. 2. Variation of electrical resistance for (PVA-PAA-NbC) nanocomposites with different concentrations of NbC nanopaticles at 80 bar.

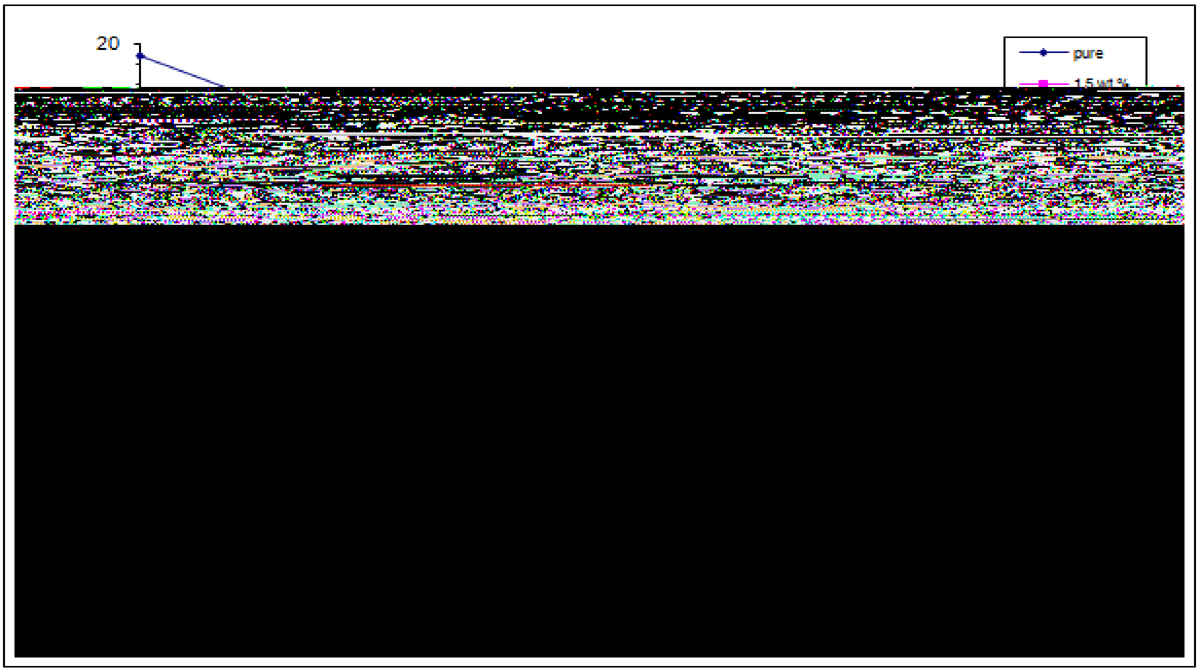

Fig. 3. Variation of electrical resistance for (PVA-PAA-NbC) nanocomposites with pressure for different concentrations of NbC nanopaticles.

Conclusions

The electrical resistance of (PVA-PAA) decreases with increase in niobium carbide nanoparticles concentration. The electrical resistance of (PVA-PAA-NbC) nanocomposites decreases with increase in stress. The (PVA-PAA-NbC) nanocomposites have high sensitivity for pressure which may be used for piezoelectric or pressure sensors with low cost, high sensitivity, flexible, high corrosion resistance, good electrical and thermal properties and high mechanical Properties.

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