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REVIEW PAPER OPEN ACCESS

Biopolymer- Ceramics Nanocomposites for Humidity Sensors: A Review

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Abstract

The nanocomposites have many applications such as humidity sensors, solar cells, antibacterial,….etc. In this review, polymer- ceramics nanocomposites have been studied for humidity sensors with high sensitivity and low cost. The polyvinyl alcohol, oxides nanoparticles, carbide nanoparticles and other nanocomposites have been reviewed for humidity sensors.

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Introduction

Composite materials are widely available use this day for everyday life. Due to their low weight and capacity to suit their specific end using large flooring in high performance applications such as the aviation industry and the automotive industry.

The idea of connecting two or more different components in the material gives almost infinite possibilities for new creation engineering materials are characterized by a variety of different properties (Hashim and Hadi, 2017). Transition metal carbide (TMCs) appearance good chemical and mechanical immutability and resistance against attrition beneath reaction conditions (Ham and Lee, 2009).

The integration of MgO nanoparticles in a polymer such as polyvinyl alcohol (PVA) not only enhances the strength and also completely changes the physical properties of the polymer (Karthikeyan *et al.*, 2009). MgO and SiC are represent of oxide and non-oxide ceramics, and leading nominee materials for a lot of modern day engineering applications (Al-Nasrawy *et al.*, 2011). Polymers as a polyvinyl alcohol, mixed with water show higher sensitivity humidity sensing at room temperature. In presence of humidity it attract –OH group hence the resistance decreases (Joshi and Singh, 2009).

The nanocomposites have different applications in many fields such as: pressure sensors (Hamad and Hashim, 2018; Hashim and Hamad, 2018; Hashim and Hadi , 2017; Hashim and Hadi, 2018), antibacterial (Kadhim *et al.*, 2017; Kadhim *et al.*, 2016; Hashim *et al.*, 2018; Rashid *et al.*, 2018; Ahmed *et al.*, 2019), humidity sensors (Ahmed *et al.*, 2019; Agool *et al.*, 2017; Hadi and Hashim, 2017; Hashim and Hadi, 2018, Hashim and Hadi , 2018), radiation shielding (Hashim and Hadi , 2017; Agool *et al.*, 2017), ...etc.

Mechanism of humidity

Sensors are equipment that can notice external exciter and change them into consistent indication. Conservative sensors are typically stiff and cannot willingly distort, in dissimilarity, stretchy sensors can be simply committed to numerous surfaces and can be used in portable electronics and wearable. Stretchy sensors may permit applications inskin, electronic robot sensing and wearable health monitoring (Zhao *et al.,* 2017, Yang *et al.*, 2017). Humidity and temperature are critical factors for both living creatures and the environment. Temperature sensing has been understood out of many mechanisms such as the pyro electric result(Yang *et al.*, 2012), infrared radiation (Usamentiaga *et al.*, 2014) and the thermal resistance effect (Kong *et al.*, 2012). humidity sensing is chiefly perceive through the communication between sensing materials and moisture, such as polymers, electrolytes, semiconductor ceramics, *etc.*(Farahani *et al.*, 2014).

Amount of water vapor in the air is well-known humidity. At the upper of crystalline grains on triggered places of the surface ,interaction of a specific amount of water vapor molecules are chemically adsorbed (chemisorption), which is attended with a separation, mechanism of vapor molecules to forming hydroxyl groups, (two hydroxyl ions each water molecule). As a binding between the surface ions of grain neck and the adsorbed water, the hydroxyl group is absorbed from every water molecule on metal cations located in the grain surfaces and has great density for charge carriers and strong electrostatic fields, thus producing a movable protons.

The protons travel from spot to another on the surface and respond with the neighbor surface O^{-2} groups (oxygen) to forms a second hydroxyl (–OH) group, and when the resistor is exposed to humidity, the ionic functional groups will be dissociated to increase the electrical conductivity of the resistor, which results in the lessening of resistance (Farahani *et al.* 2014,Wang, 2013).

In chemical, biological processes and physical, humidity is an important issue [Karthick. *et al.*, 2016]. Measurement of humidity in an industrial procedures is too critical because it may effect on the cost and quality of the product. Humidity sensors based on SnO_2, TiO_2, CuO and ZnO and cross linked with polymers have been developed in recent years (Zainelabdin *et al.,* 2012, Fei, T. *et al.,* 2014).

$$H^{+} + O_0 \leftrightarrow [OH]^{-}$$

where O_0 corresponds to oxygen at lattice sites. The (PVA-MgO-SiC) nanocomposites are absorbent in nature and has surface oxygen atoms, which fundamentally arise credited to the samples preparation technicality.Figure (1) shows the humidity-sensing mechanism of the PIM-based sensor.

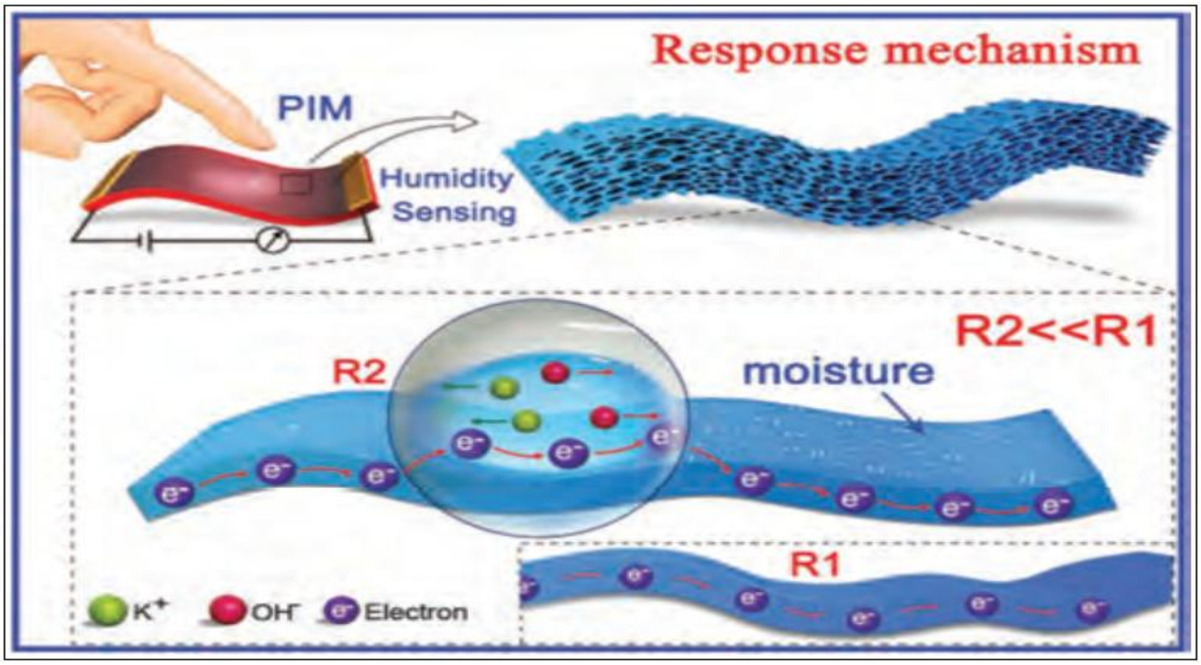

Fig. 1. Humidity-sensing mechanism of the PIM-based sensor (Li *et al.*, 2017).

Literature Survey

Semiconductor metal oxide based humidity sensors are used for environmental and emission monitoring, automotive, domestic, industrial and medical applications**.**

Sawai & Yoshikawa in (2004). Examined the Quantitative evaluation of antifungal activity of metallic oxide powders (MgO, CaO and ZnO) by an indirect conductimetric assay. The experimental results showed that the MgO and CaO were found to have good antifungal activities.

Li & Sun in (2010). Studied the poly(lactic acid) (PLA) nanocomposites were prepared by in situ melt polycondensation of L-lactic acid with different loading ratios of surface-hydroxylated magnesium oxide (MgO) nanocrystals. Molecular weight, structure, morphology, and thermal properties of the nanocomposites were characterized. PLA-grafted MgO (PLA-g-MgO) was isolated from free PLA for the nanocomposite with 3% MgO via repeated dispersion/centrifugation processes and characterized. The weight-average molecular weight of the PLA-0.01%MgO nanocomposite was 55500, which was 30% higher than that of pure PLA. Discoloration of PLA was obviously depressed in the presence of MgO nanocrystals. Formation of hydrogen bonding between PLA chains and surface -OH groups from MgO was detected by Fourier transform infrared spectroscopy. Morphological images showed uniform dispersion of MgOnanocrystals in the PLA matrix and demonstrated a strong interfacial interaction between the PLA matrix and MgOnanocrystals. PLA-MgOnanocomposites exhibited improved thermal stability compared with pure PLA *Sharma et al.* in (2015) . Studied the interphase structure of poly (vinyl alcohol)PVA–SiCnanofiber polymer nanocomposites. The interphase region in polymer nanocomposites extends from nanofillers' surface to bulk polymer matrix. PVA–SiC nanocomposite films with varying concentration of SiCnanofiber (0.1, 0.2, 0.5, and 1.0 wt %) were prepared using solvent casting method.

The crystallinity of the nanocomposite films have been determined using X-ray diffraction. The observed changes in the polymer nanocomposite structure are resultant of weak interaction between hydrophilic PVA and hydrophobic SiCnanofiber. The mechanical properties of the nanocomposites measured, using tensile testing method, have been explained in view of the changes in structure at interphase.

Jang &Jeong. in (2017) . Studied the wearable resistive-type humidity sensor is fabricated on a cylindrical organic substrate for the first time.

This sensor contained polyvinyl-alcohol (PVA) as the sensing material, which was applied by the dip-coating method at the middle, and copper (Cu) thin film was applied by RF magnetron sputtering for the side electrodes. The resistance was measured for 60–90%RH. Thus, the value was decreased by hydrogen bonds between the hydroxyl groups and water molecules in the highly humid condition.

Hashim and Hadi. in (2018). Studied the structural, optical and electrical properties of (PVA–CMC–NbC) nanocomposites for humidity sensors have been studied. The (PVA–CMC–NbC) nanocomposites were prepared with different concentrations of (polyvinyl alcohol and carboxyl methyl cellulose) and Niobium carbide nanoparticles.

The experimental results of optical properties for (PVA–CMC–NbC) nanocomposites showed that the absorbance, absorption coefficient, extinction coefficient, refractive index, real and imaginary dielectric constants and optical conductivity of (PVA–CMC) blend increase with increase in Niobium carbide nanoparticles concentrations.

The transmittance and energy band gap decrease with increase in Niobium carbide nanoparticles concentrations. The DC electrical properties of (PVA–CMC–NbC) nanocomposites showed that the electrical conductivity of the blend increases with increase in NbC nanoparticles concentrations. The experimental results of novel (PVA–CMC–NbC) nanocomposites applications showed that the (PVA–CMC–NbC) nanocomposites have high sensitivity for relative humidity.

Conclusion

Nanocomposites are very promising in many applications for environmental and biological fields. Polymer/ ceramics nanocomposites can be used for humidity sensors with high sensitivity and low cost.

The polyvinyl alcohol with oxide nanoparticles and carbide nanoparticles have been used for for humidity sensors with high sensitivity, low weight and low cost.

References

Agool IR, Kadhim KJ, Hashim A. 2017. Synthesis of (PVA-PEG-PVP-ZrO_2) Nanocomposites For Energy Release and Gamma Shielding Applications. International Journal of Plastics Technology **21(2).** https://doi.org/10.1007/s12588-017-9196-1.

Agool IR, Kadhim KJ, Hashim A. 2017. Fabrication of new nanocomposites: (PVA-PEG-PVP) blend-zirconium oxide nanoparticles) for humidity sensors. International Journal of Plastics Technology **21(2).** https://doi.org/10.1007/s12588-017-9192-5.

Ahmed H, Abduljalil HM, Hashim A. 2019. Analysis of Structural, Optical and Electronic Properties of Polymeric Nanocomposites/Silicon Carbide for Humidity Sensors. Transactions on Electrical and Electronic Materials, https://doi.org/10.1007/s42341-019-00100-2

Ahmed H, Hashim A, Abduljalil H. 2019.

Analysis of Structural, Electrical and Electronic Properties of (Polymer Nanocomposites/ Silicon Carbide) For Antibacterial Application. Egyptian Journal of Chemistry. https://doi.org/10.21608/EJCHEM.2019.6241.1522.

Al-Nasrawy DK, Abdulmajeed IM, Noori FT, Abaid AH, Thajeel KM. 2011. The effect of SiC–particles– reinforced MgO composites. Journal of Kufa-physics **3(1).**

Farahani H, Wagiran R, Hamidon MN. 2014. Humidity sensors principle, mechanism, and fabrication technologies: a comprehensive review. Sensors **14(5).**

Fei T, Jiang K, Liu S, Zhang T. 2014. Humidity sensor based on a cross-linked porous polymer with unexpectedly good properties. Rsc Advances **4(41).**

Hadi A, Hashim A. 2017. Development of a new humidity sensor based on (carboxymethyl cellulose–starch) blend with copper oxide nanoparticles. Ukrainian Journal of Physics **62(12).** https://doi.org/10.15407/ujpe62.12.1044.

Ham D, Lee J. 2009. Transition metal carbides and nitrides as electrode materials for low temperature fuel cells. Energies **2(4).**

Hamad Z S, Hashim A. 2018. Biopolymer blend or titanium nitride nanoparticles: synthesis and pressure sensor characterization for environmental application. Journal of Biodiversity and Environmental Sciences **13(6).**

Hashim A, Hadi A. 2017. Novel lead oxide polymer nanocomposites for nuclear radiation shielding applications. Ukrainian Journal of Physics **62(11),** https://doi.org/10.15407/ujpe62.11.0978.

Hashim A, Hadi A. 2018. Novel Pressure Sensors Made From Nanocomposites (Biodegradable Polymers–Metal Oxide Nanoparticles): Fabrication and Characterization. Ukrainian Journal of Physics **63(8).** https://doi.org/10.15407/ujpe63.8.754

Hashim A, Hadi A. 2017. Synthesis and Characterization of ($MgO–Y_2O_3–CuO$) Nanocomposites for Novel Humidity Sensor Application. Sensor Letters **15(10).**

Hashim A, Hadi A. 2017. Synthesis and characterization of novel piezoelectric and energy storage nanocomposites: biodegradable materials–magnesium oxide nanoparticles. Ukrainian Journal of Physics **62(12).** https://doi.org/10.15407/ujpe62.12.1050.

Hashim A, Hadi Q. 2018. Structural, electrical and optical properties of (biopolymer blend/ titanium carbide) nanocomposites for low cost humidity sensors. Journal of Materials Science: Materials in Electronics **29,** 11598–11604, https://doi.org/10.1007/s10854-018-9257-z

Hashim A, Hadi Q. 2018. Synthesis of Novel (Polymer Blend-Ceramics) Nanocomposites: Structural, Optical and Electrical Properties for Humidity Sensors. Journal of Inorganic and Organometallic Polymers and Materials **28(4).** https://doi.org/10.1007/s10904-018-0837-4.

Hashim A, Agool IR, Kadhim KJ. 2018. Novel of (Polymer Blend-Fe_3O_4) Magnetic Nanocomposites: Preparation and Characterization For Thermal Energy Storage and Release, Gamma Ray Shielding, Antibacterial Activity and Humidity Sensors Applications. Journal of Materials Science: Materials in Electronics **29(12).** https://doi.org/10.1007/s10854-018-9095-z

Hashim A, Hamad ZS. 2018. Low cost and flexible biopolymers (polyvinyl alcohol-poly-acrylic acid)/niobium carbide new nanocomposites for sensors. Journal of Biodiversity and Environmental Sciences **13(6).**

Jang JH, Han JI. 2017. Cylindrical relative humidity sensor based on poly-vinyl alcohol (PVA) for wearable computing devices with enhanced sensitivity. Sensors and Actuators A: Physical **261,** 268-273.

Kadhim KJ, Agool IR, Hashim A. 2016. Synthesis of (PVA-PEG-PVP-TiO2) Nanocomposites for Antibacterial Application. Materials Focus **5(5),** https://doi.org/10.1166/mat.2016.1371

Kadhim KJ, Agool IR, Hashim AA. 2017. Effect of Zirconium Oxide Nanoparticles on Dielectric Properties of (PVA-PEG-PVP) Blend for Medical Application. Journal of Advanced Physics **6(2).** https://doi.org/10.1166/jap.2017.1313.

Karthick S, Lee HS, Kwon SJ, Natarajan R, Saraswathy V. 2016. Standardization, calibration, and evaluation of tantalum-nano rGO-SnO_2 composite as a possible candidate material in humidity sensors. Sensors **16(12).**

Karthikeyan K, Poornaprakash N, Selvakumar N, Jeyasubrmanian K. 2009. Thermal properties and morphology of MgO-PVA nanocomposite film. J Nanostruct Polym. Nanocompos **5(4),** 83-88.

Kong D, Le L T, Li Y, Zunino JL, Lee W. 2012. Temperature-dependent electrical properties of graphene inkjet-printed on flexible materials. Langmuir **28(37),** 13467-13472.

Li T, Li L, Sun H, Xu Y, Wang X, Luo H & Zhang T. 2017. Porous ionic membrane based flexible humidity sensor and its multifunctional applications. Advanced Science **4(5).**

Rashid F L, Hadi A, Al-Garah N H, Hashim A. 2018. Novel Phase Change Materials, MgO Nanoparticles, and Water Based Nanofluids for Thermal Energy Storage and Biomedical Applications. International Journal of Pharmaceutical and Phytopharmacological Research **8(1).**

Sawai J, Yoshikawa T. 2004. Quantitative evaluation of antifungal activity of metallic oxide powders (MgO, CaO and ZnO) by an indirect conductimetric assay. Journal of applied microbiology **96(4),** 803-809.

Sharma SK, Prakash J, Sudarshan K, Sen D, Mazumder S, Pujari PK. 2015. Structure at Interphase of Poly (vinyl alcohol)–SiC Nanofiber Composite and Its Impact on Mechanical Properties: Positron Annihilation and Small-Angle X-ray Scattering Studies. Macromolecules 48(16).

Usamentiaga R, Venegas P, Guerediaga J, Vega L, Molleda J, Bulnes FG. 2014. Infrared thermography for temperature measurement and non-destructive testing. Sensors **14(7),** 12305-12348.

Wang Y. 2013. Fabrication of Relative Humidity Sensors based on Polyimide Nanoparticles (Doctoral dissertation, Applied Sciences: School of Engineering Science).

Yang T, Xie D, Li Z, Zhu H. 2017. Recent advances in wearable tactile sensors: Materials, sensing mechanisms, and device performance. Materials Science and Engineering: R: Reports **115,** 1-37.

Yang Y, Zhou Y, Wu J M, Wang ZL. 2012. Single micro/nanowire pyroelectric nanogenerators as self-powered temperature sensors. ACS nano **6(9).**

Zainelabdin A, Amin G, Zaman S, Nur O, Lu J, Hultman L, Willander M. 2012. CuO/ ZnO nanocorals synthesis via hydrothermal technique: growth mechanism and their application as humidity sensor. Journal of Materials Chemistry **22(23),** 11583-11590.

Zhao X, Long Y, Yang T, Li J, Zhu H. 2017. Simultaneous High Sensitivity Sensing of Temperature and Humidity with Graphene Woven Fabrics. ACS applied materials & interfaces **9(35),** 30171-30176.