

# SYNTHESIZE OF MWCNTs NANOFILLER ON GELATIN MIXED WITH ORANGE PEEL POWDER BASED BIO-POLYMER NANOCOMPOSITES

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## Abstract

Polymer nanoparticles have garnered increasing interest due to their diverse applications in biomedical and electronic fields. However, conventional synthetic polymers may pose biocompatibility concerns. This study explores a novel bio composite material composed of gelatin, orange peel powder, and multiwalled carbon nanotubes (MWCNTs), developed via polymer film formation. Four different MWCNT concentrations (0.02 wt%, 0.04 wt%, 0.06 wt%, and 0.08 wt%) were investigated. Characterization using Fourier Transform Infrared Spectroscopy (FTIR) revealed prominent absorption peaks at approximately 3300 cm<sup>-1</sup>, 1600 cm<sup>-1</sup>, and 1200 cm<sup>-1</sup>, indicating the presence of water molecules and C–H bonds in the 0.06 g molecular weight polymer gel. Electrochemical Impedance Spectroscopy (EIS) analysis of 0.06 wt% MWCNT sample showed low electrical impedance at low frequencies, with  $R_p$  for 1.10 T $\Omega$  and  $R_s$  for 1.76 k $\Omega$ , suggesting efficient electron transport across the sensor electrodes. The findings demonstrate the potential of this biodegradable nanocomposite for applications in flexible electronics and wearable biosensors, contributing to the advancement of natural polymer-based technologies.

**Keywords:** Biopolymers; Gelatin; Natural Polymers; Polymer

## Introduction

In recent years, the exploration of novel materials and their applications in various technological domains has garnered significant attention, particularly in the field of advanced electronics and bio-inspired materials. Nanocomposites, which incorporate nanoscale fillers into polymer matrices, have emerged as promising candidates for improving the mechanical, thermal, and electrical properties of materials. Among various nanofillers,

multi-walled carbon nanotubes (MWCNTs) have attracted special interest due to their exceptional structural integrity and superior electrical conductivity.

Polymer nanoparticles are also gaining momentum for their diverse industrial applications, especially in biomedical implants, electronic components, and energy systems (Sharma *et al.*, 2021). Functional polymer materials with high

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dielectric constants, low dielectric loss, and flexibility are particularly desirable for next-generation smart devices such as decoupling capacitors, photovoltaic systems, electric vehicles, and advanced sensors (Gupta *et al.*, 2022). These applications rely on efficient electrostatic capacitors, for which polymer-based nanocomposites present a viable alternative to traditional ceramic-based dielectric materials, due to their ease of fabrication, cost-effectiveness, and flexibility. However, the majority of polymers used in such applications are synthetic and may pose environmental and health hazards due to their toxicity and lack of biodegradability (Alam and Islam, 2022). A more sustainable alternative lies in the use of biopolymers, which are derived from renewable biological sources and are generally known for their biocompatibility and biodegradability. Examples include starch, gelatin, and polylactic acid (PLA), all of which occur naturally in various forms. Orange peel powder, a byproduct of agricultural waste, represents a low-cost, eco-friendly filler material with potential benefits such as biodegradability and sustainability (Aswathi *et al.*, 2023). The combination of gelatin, orange peel powder, and MWCNTs yields a synergistic bio-nanocomposite. Gelatin, recognized for its biocompatibility and sustainable sourcing, serves as a biopolymeric matrix, while the inclusion of orange peel powder introduces a natural additive that enhances both mechanical properties and environmental sustainability (Lizundia & Puglia, 2022). This study focuses on the development and characterization of gelatin-orange peel powder-MWCNT nanocomposites in the form of polymer films. The dielectric performance of these bio-based nanocomposites was investigated to evaluate the influence of MWCNT concentration on their electrical properties. Dielectric properties are crucial in determining the suitability of materials for use in capacitors and other energy storage devices.

The integration of MWCNTs is expected to significantly influence the dielectric behavior, providing insight into the relaxation mechanisms and conduction pathways within the bio composite system.

Preliminary results show that the fabricated gel/MWCNT nanocomposites with orange peel powder exhibit stable high dielectric permittivity and low loss tangent under ambient conditions. Their relaxation behavior and conduction mechanisms were also studied, revealing promising performance characteristics. With excellent dielectric properties and eco-friendly composition, these bio composites hold potential for application in flexible, bio-compatible, next-generation electronic devices (Hossan & Mainul, 2014).

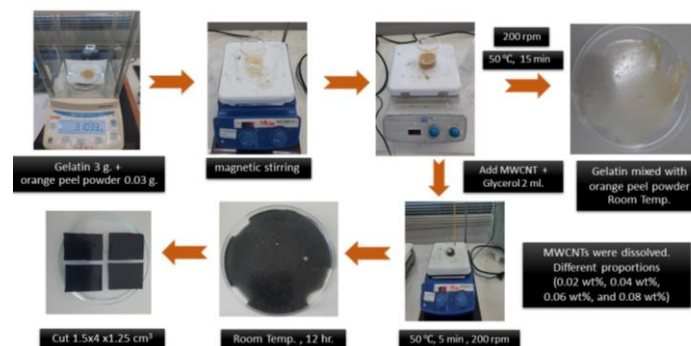
## Materials and Methods

### Materials

Mc Garrett brand gelatin powder, orange peel powder and glycerol (98% pure). multi-walled carbon nanotubes (MWCNT) to Sequence All materials are used as purchased without any further modification.

### Preparation of gel/MWCNT nanocomposite film

All aqueous solutions were prepared using DI water. A mixture of 3 g gelatin, 0.03 g orange peel powder, and DI water was heated to 50°C with continuous magnetic stirring at 200 rpm for 15 minutes until MWCNTs dissolved. Various MWCNT concentrations (0.02 wt%, 0.04 wt%, 0.06 wt%, and 0.08 wt%) were then added to the gelatin solution. Next, 2 ml of glycerol thickened. The mixture was poured onto a glass Petri dish and left at room temperature for 12 hours. Once set, the film was carefully peeled off, cut into  $1.5 \times 4 \times 1.25 \text{ cm}^3$  pieces as shown in Figure 1, and prepared for property analysis (Sharma *et al.*, 2021).

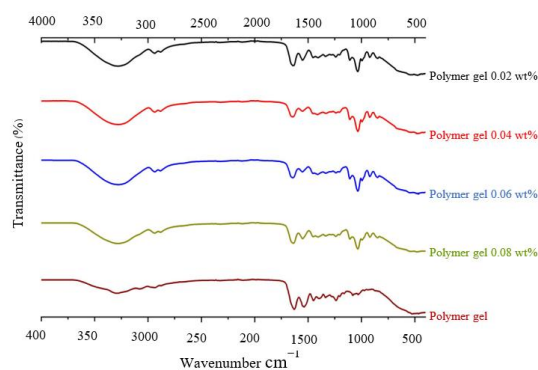


**Figure 1.** The synthesis procedure of gel/MWCNT with orange peel powder based nanocomposites by molding a polymer film is presented

## Results and Discussions

### Structural properties

Fourier transform infrared spectroscopy (FTIR) (Shimadzu IR Spirit, 500-4000  $\text{cm}^{-1}$ ) was used to analyze functional groups, chemical composition, and molecular interactions in the cross-linked gel/MWCNT nanocomposites. (Sharma *et al.*, 2021). and are shown in Figure 2. Here observed main functional groups of gelatins were located at 1036, 1110, 1549, 1636, 2883, and 2935  $\text{cm}^{-1}$  (Ma *et al.*, 2020) There is a broad peak around 3300  $\text{cm}^{-1}$ . This is a common peak that is due to O-H stretching in alcohols or phenols. There is a peak around 1600  $\text{cm}^{-1}$ . This peak is due to C=O stretching in carbonyl groups. Carbonyls are common functional groups in many organic molecules. There is a peak around 1400  $\text{cm}^{-1}$ . This peak is due to C-H bending in alkanes. Alkanes are hydrocarbons with only single bonds between the carbon atoms. There are peaks around 1100  $\text{cm}^{-1}$  and 1000  $\text{cm}^{-1}$ . These peaks could be due to C-O stretching in aliphatic alcohols or C-C stretching in aromatic groups. (Magar & Mulchandani, 2021).



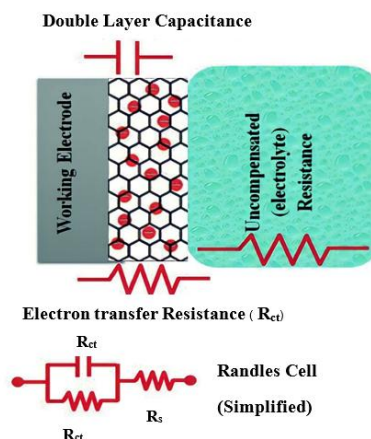
**Figure 2. Fourier transform infrared spectroscopy (FTIR) of gel/MWCNT with orange peel powder-based nanocomposites for various amounts of MWCNTs filler content**

It was found that the graph has an absorption peak at a wavelength of approximately 3300  $\text{cm}^{-1}$ . This absorption peak is caused by the vibration of water molecules. A water molecule consists of two hydrogen atoms and one oxygen atom. the bond between hydrogen and oxygen is a polar covalent bond. this bond can vibrate in many directions. Each direction causes the absorption of light at a specific wavelength. In addition, there are absorption peaks at wavelengths around 1600 and 1200  $\text{cm}^{-1}$ . these absorption peaks are caused by the molecular vibrations of the C-H bond, a nonpolar covalent bond.

In summary, this FTIR graph shows that the absorption peaks at wavelengths are approximately 3300  $\text{cm}^{-1}$ , 1600 and 1200  $\text{cm}^{-1}$ . Therefore, it indicates that the polymer gel with a molecular weight of 0.06 g contains water molecules and C-H bond molecules.

### Electrochemical Impedance Spectroscopy (EIS)

Electrochemical Impedance Spectroscopy (EIS) measurements provide information about the dielectric constant, loss tangent, and impedance of the nanocomposites. These parameters influence how the material stores and dissipates electrical energy, making them crucial for applications like capacitors and energy storage devices. In a simple electrochemical cell, electrode interactions with redox species involve electroactive species concentration, charge transfer, and mass transfer from the bulk solution to the electrode surface. Along with electrolyte resistance, these characteristics can be represented by an equivalent electrical circuit comprising resistors, capacitors, or constant phase elements in parallel or series (Figure 3) (Magar and Mulchandani, 2021).



**Figure 3. Schematic representations of the mechanism of CNTs creating a capacitive layer in the nanocomposites. scheme to describe the EIS circuit and the redox reaction takes place a polymer film.  $R_{ct}$  is the charge transfer resistance,  $R_s$  is electrolyte resistance, and  $C_{dl}$  is the capacitance double layer**

Electrochemical impedance spectroscopy (EIS) enables the analysis of mass transfer, charge transfer, and diffusion processes, helping to investigate material properties or specific factors affecting conductivity, resistance, and capacitance. Unlike DC resistance, which follows Ohm's law, impedance is measured using a small signal

excitation expressed as a time-dependent function (Equation 1).

$$E_t = E_0 \cdot \sin(\omega t) \quad (1)$$

Where  $E_t$  is the potential at time  $t$ ,  $E_0$  is the amplitude of the signal, and  $\omega$  is the radial frequency.

Figure 4 shows the electrochemical impedance results. Electrochemical Impedance Spectroscopy (EIS) of polymer gels with 4 different molecular weights: MWCNT 0.02 wt%, 0.04 wt%, 0.06 wt% and 0.08 wt%. The graph shows the relationship between the electrical impedance ( $Re$ ) and the capacitance ( $-Im$ ) and frequency of the electrical signal fed into the sample. From the graph, it is found that low molecular weight polymer gels have

low electrical resistance and low frequencies because electrons can move through the polymer gel more easily than high molecular weight polymer gels.

Curvature of a polymer gel with a molecular weight of 0.06 wt % This circuit shows  $R_p$ : a resistor with a value of 1.10 T $\Omega$  and  $R_s$ : a resistor with a value of 1.76 k $\Omega$ . It may represent various resistances within the system, e.g. Charge transfer or resistance of a solution and the polymer gel curve with a molecular weight of 0.06 wt % is suitable for making sensors. because this curve has a low electrical impedance, low frequency, low electrical resistance allows electrons to flow quickly through the sensor's electrodes. This allows the sensor to respond quickly to changes in electrical signals as well.

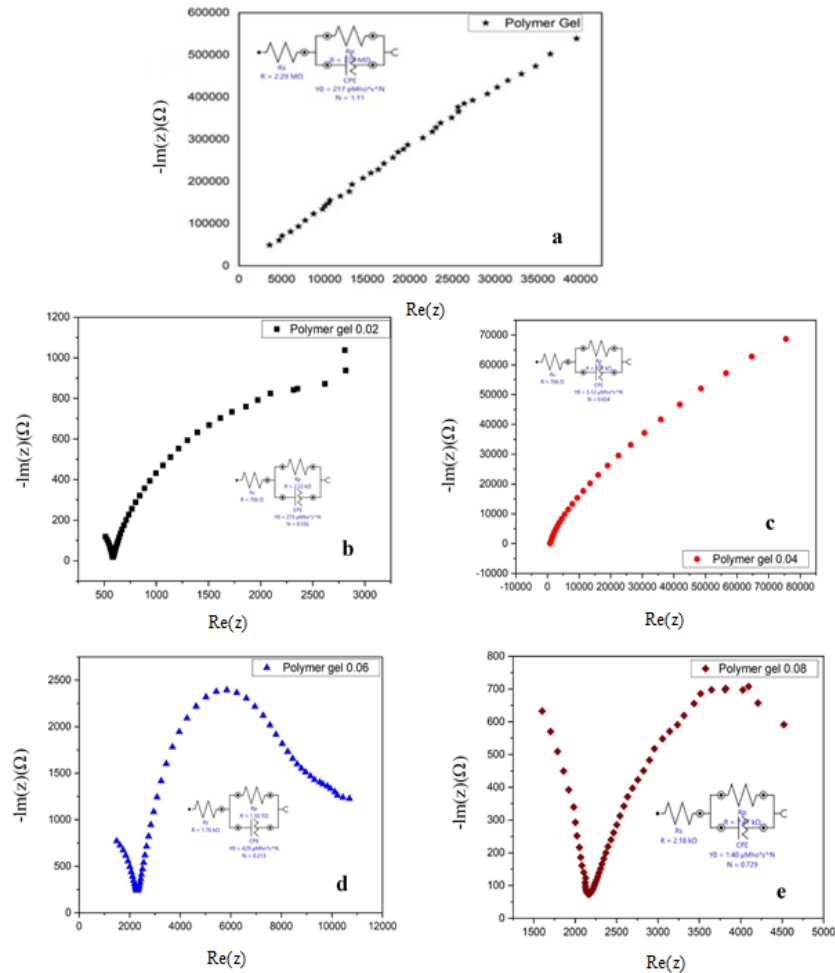


Figure 4. EIS shows the resistivity curve and sample circuit (a) polymer gel (b) polymer gel 0.02 wt% (c) polymer gel 0.04 wt% (d) polymer gel 0.06 wt% (e) polymer gel 0.08 wt%

## Conclusions

Biodegradable gel/MWCNT nanocomposites with different concentrations of MWCNT were successfully prepared using a polymer film molding technique. Fourier Transform Infrared Spectroscopy (FTIR) analysis revealed that the main functional groups of gelatin were located at 1036, 1110, 1549, 1636, 2883, and 2935  $\text{cm}^{-1}$ . The peak at 3300  $\text{cm}^{-1}$  is commonly attributed to O–H stretching in alcohols or phenols. A peak observed around 1600  $\text{cm}^{-1}$  corresponds to C=O stretching in carbonyl groups, which are typical functional groups in many organic molecules. Another peak around 1400  $\text{cm}^{-1}$  is due to C–H bending in alkanes, which are hydrocarbons containing only single bonds between carbon atoms. Additionally, peaks near 1100  $\text{cm}^{-1}$  and 1000  $\text{cm}^{-1}$  may be attributed to C–O stretching in aliphatic alcohols or C–C stretching in aromatic compounds. These findings indicate that the polymer gel with a molecular weight of 0.06 g contains water molecules and C–H bond-containing groups. Moreover, Electrochemical Impedance Spectroscopy (EIS) was performed on polymer gels with four different MWCNT concentrations: 0.02 wt%, 0.04 wt%, 0.06 wt%, and 0.08 wt%. The resulting graph illustrates the relationship between electrical resistance (Re) and capacitance. It was found that the polymer gel containing 0.06 wt% MWCNT exhibited the lowest electrical resistance at low frequency. These findings suggest potential applications in flexible electronics and sensing devices intended for use on the human body. This breakthrough paves the way for the future utilization of natural polymers.

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