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Studies on Ceramic Wastes based Composites for Capacitors Applications †

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Abstract: The ceramic industry is a bit new in Pakistan, and the wastes produced during industrial processes are not properly managed. No effective reusing and recycling schemes have been developed. These wastes are contributing greatly to environmental pollution. In this study, an effort has been made to recycle and use the ceramic wastes as reinforcement fillers in polymeric composites, helping an ecologically and economically possible alternative for the disposal of these wastes. PANI-based ceramic composite samples were prepared and characterized morphologically and electrically. Ceramic wastes were also investigated for purification purposes of municipal wastewater. It was observed that prepared materials are capable for capacitor production. Wastes were found to be 50% efficient in removing methyl orange from water in a specific time. This suggests that the prepared materials can be used in energy harvesting appliances (i.e., capacitors) while the ceramic waste can be applied for purifying polluted water coming out from industrial as well as municipal sewerages.

Keywords: waste ceramic material; polymer composite; SEM; dielectric properties; adsorption

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1. Introduction

Solid wastes produced due to human and industrial activities cause various types of environmental pollution. Industrial wastes result in water pollution, air contamination, soil effluence, and causing the rise in temperature globally. As water is considered an easy sink for dumping the effluents, so often these effluents are added into water that has threatened the aquatic life. It was found that various human health risks also occur due to industrial contamination in water.

There has been an increase in the utilization of natural resources, which ultimately caused the degradation of the environment [1]. A huge quantity of waste ceramics are generated inside the industrial unit that are badly affecting the surroundings. It was observed that one third of waste material is produced during ceramic processing [2]. Reusing these wastes is an economic, reduction in pollution and energy saving strategy for industries as well as academia. Ceramic wastes coming out from industries are dumped near the plants in vacant spaces and land. As a result, these wastes disperse in the air, water and soil while indulging the aesthetic scene all around. These wastes are hard and highly resistant to biological, chemical, and physical degradation forces. Recycled waste fly ash has been converted into porous ceramic membranes for adsorption processes [3]. Mud/polyaniline composites were investigated for their thermal and electrical properties [4]. Polymers reinforced with waste particles were proposed for possible high voltage outdoor applications [5]. Gypsum plaster-based composites have been investigated for physical and mechanical characteristics [6].

In Pakistan, apart from a large number of ceramic tile manufacturers, seven big ceramic industries are involved in the production of various ceramic products with a capacity of 22 million sqm with 18.7 million m^2 capacity [7]. In this work, ceramic powder waste materials were collected from a local industry. The materials were utilized for the preparation of composites with a PANI, which is a conducting polymer. The fabricated composites were then analyzed for different properties and application.

2. Experimental

2.1. Materials

Ceramic wastes were obtained from the locality of a National industry. Analytical grade (95–99%) aniline, HCl and $(NH_4)_2S_2O_8$ (Sharlu Spain), and deionized water (Laboratory based) were applied in experimental procedures.

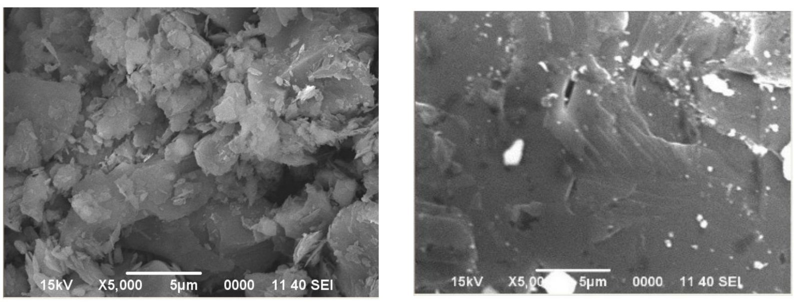
2.2. Synthesis of Composite Material

Standard polymerization methos was used for the fabrication of ceramic waste/PANI composite in already optimized conditions. About 250 mg of waste was added in about 100 ml distilled water and the solution was stirred properly. For the incorporation on aniline monomers in the waste ceramic matrix, about 25 mL of its solution was added into the waste ceramic solution slowly. Afterward, $(NH_4)_2S_2O_8$ solution was prepared in IM HCl and 25 mL of it was introduced to the ongoing mixture. The system was then stirred violently under low temperature conditions. Then, in the next step, various types of impurities were removed from the tis whole mixture using centrifugation process. Then, the synthesized material was passed through filtration and dried under elevated temperature. The resulted material was named PANI-WC.

3. Results and Discussion

3.1. SEM Analysis

Surface compactness of WC and PANI-WC was studied with SEM and the pictures are shown in Figure 1a for Wc and and Figure 1b for PANI-WC. WC is comprised of irregular pills and uneven particulates. About 1.75 μm mean particle size was observed for the WC powder. Certain pores and cracks were observed in WC and PANI-WC surfaces, which are assigned to be produced during heating process of samples in oven. PANI-WC shows even morphology which is referred to as the regular dispersal of wastes masses in the polymer medium. It means that there is a stable halt of WC particles on the PANI interchains.



(**a**) (**b**)

Figure 1. Scanned images of (**a**) WC and (**b**) PANI-WC.

3.2. Dielectric Characteristics

3.2.1. Dielectric Permeability (ε′)

ε′ of both the materials was determined with the given equation;

$$\varepsilon' = cd/\varepsilon_0 A \tag{1}$$

where C is for capacitance of the material, d (pellet thickness), ε_0 is free space permittivity and A is the pellet cross-sectional area. Figure 2 shows ε' for both WC and PANI-WC. It is evident that ε' declines and then obtain a persistent value of about 1.6–1.8 GHz. Above this value resonance occurs when the frequencies of applied and inner fields match with each other. High ε' value at low frequency is ascribed to the space charge effects. Metallic electrodes accumulate ions at PANI-WC boundary resulting in the rises of ε' at low range of frequency [8]. Polar regions in the material cannot alter to respond quickly to the applied field. Consequently, dielectric reduction and hence ε' decreases. At high frequency, dielectric reduction harvests alternation of elastic and electric performance [8].

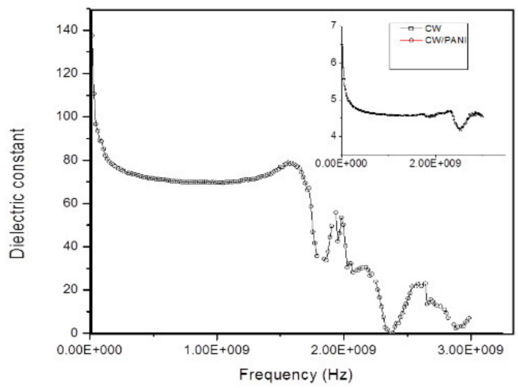


Figure 2. Frequency dependent dielectric constant at 300 K for WC and PANI-WC.

3.2.2. Tanδ (Dielectric Loss)

In ideal capacitors, *tanδ magnitude* is much too important. *tanδ* was determined with the given equation b;

$$Tan\delta = \frac{1}{2\pi f R_p C_p} \quad (2)$$

Here, f is the frequency, C_p Capacitance and R_p is resistance.

Figure 3a,b represent the results of this study.

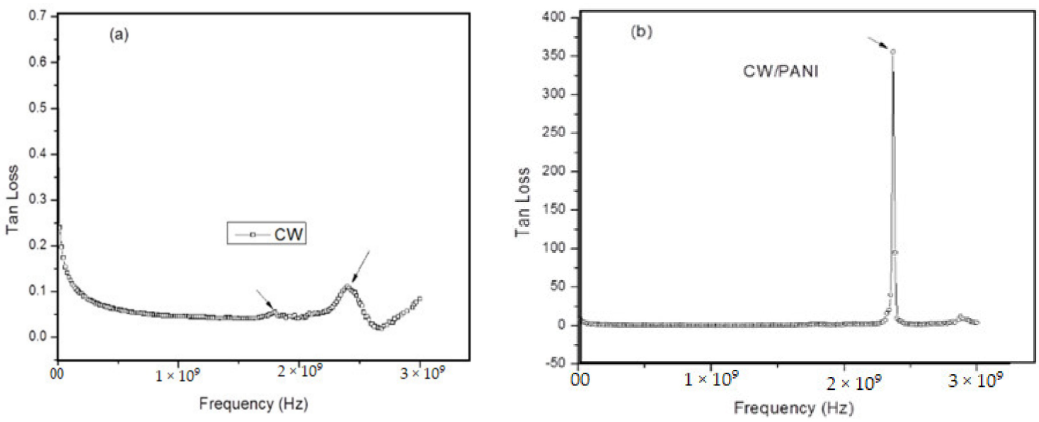


Figure 3. Variation of *tanδ* at 300 K (**a**) WC and (**b**) PANI-WC.

It is obvious that *tanδ* for WC is declining directly with frequency, which shows insulation behavior in waste ceramics. A little rise at about 1.7–1.8 and 2.4–2.5 GHz is due to loss in polarization in WC. Rapid increase in *tanδ* (~2.37 GHz) of PANI-WC indicates WC influence in the composite [8]. Dipole reduction at high frequency range also causes a rise in *tanδ*.

4. Conclusions

Wastes produced from ceramic tiles were introduced into polymer medium by standard polymerization method, and composite materials (PANI-WC) were obtained. Surface compactness and structure of WC and PANI-WC composites were obtained with SEM analysis. The dielectric properties for composite were observed, and it was found that, based on these characteristics, the prepared materials are supposed to be used as capacitor materials for energy harvesting purposes.

Author Contributions: M.S. presented the concept of the paper, discussed the results and wrote the paper. M.O. and A. designed the methodolgy of the work. M.G.S. and A.S. worked on the experiments and analysis. I.U. and A.A. contributed in the characterization of the samples. All authors have read and agreed to the published version of the manuscript.

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