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Study of the Radiation Shielding Properties of Some Polymer/Metal Oxide Nano-composites

THESIS

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By

Rehab Mansour Ebrahim Mohammed

M.Sc. in Chemistry (2013)

B.Sc. in Chemistry (2008)

Faculty of Science
Alexandria University
(2018)

SUMMARY

The present thesis is divided into five chapters.

Chapter One: Introduction

This chapter is focused on the definition of nanomaterials and polymer nanocomposites, classification and types of nanofillers, chemical synthesis of nanomaterials, naming and classification of nanocomposites, design and synthesis of polymer nanocomposites, characterization methods of nanocomposites, properties of nanocomposites, and a brief about waste plastics and plastic recycling. This chapter presents also definition of radiation, classification of radiation, properties of γ- rays, mechanism of attenuation, attenuation coefficients, types of detectors, and shielding of γ- rays. A review of attenuation and shielding by polymer composite materials and aim of the work are also included in this chapter.

Chapter Two: Experimental

This chapter presents the experimental part of this thesis. The chemicals, materials, solutions, and their resources are presented. The used instrumentations and techniques are also described. The procedure for synthesis lead monoxide bulk material (bulk PbO), lead oxide nanoparticles (PbO NPs), and composites from HDPE with different weight fraction of bulk PbO and PbO NPs are explained in this chapter. Instrumentations of radioactivity especially HPGe detector and instrumentation for measuring the mechanical and dielectric properties of the prepared composites are explained in details in this chapter.

Chapter Three: Results and Discussion

This chapter is divided into two main parts.

The first part describes the characterization methods, density evaluation of samples, the γ-ray shielding properties, heaviness calculations, the mechanical properties, and dielectric properties of pure HDPE and its composites as well as a comparative study to evaluate the behaviors of pure HDPE/PbO microcomposites versus pure HDPE/PbO nanocomposites as shielding materials for γ-radiation. The FT-IR spectra showed that there is an incorporation of PbO in the polymer matrix and there is no change in the chemical structure of pure HDPE during the synthesis of the composites.

The morphological structure of the bulk PbO, PbO NPs, pure HDPE and the composites were studied using SEM and TEM and confirmed that the prepared PbO NPs possessed spherical shape with fine size distribution between 6 and 11 nm, while bulk PbO showed morphologies between irregular and asymmetric flattened flakey shapes with average diameter about 0.4 μm and both materials dispersed uniformly in the pure HDPE matrix. The data of TGA confirmed the incorporation of PbO NPs and bulk PbO to pure HDPE and resulted in significant enhancement in the thermal stability of the polymer matrix. The XRD patterns of these materials were measured with respect to the identified 2θ-angle and revealed that, there is an

incorporation of PbO in the polymer matrix, and there is no crystalline structure change in pure HDPE during the synthesis of the composites. The experimental values of the apparent densities of pure HDPE and the assembled composites demonstrated that the density of the composites was observed to increase gradually with filler contents in the composites due to the large density of additive compound. In addition, the experimentally determined densities were found in good agreement with those of theoretical calculated densities.

The γ-ray shielding properties of pure HDPE and its corresponding composites were examined by measuring the linear and mass attenuation coefficients (μ and μ_m) using different disk thickness. Several conclusion points were identified from this study. First, the observed count rates (N) were found to decrease as the film thickness values of both micro and nanocomposite materials increase. Second, the relationship between the disk thickness and lnN was found to be linear. Third, the value of linear attenuation coefficient significantly increased with an increase in the content of bulk PbO and PbO NPs in the composite and for the same composition it decreased with the increase in γ-ray photon energy. Fourth, is the high superiority of pure HDPE/ PbO nanocomposites as an efficient absorbing and shielding material for γ-ray photon with different energies, compared to pure HDPE/bulk PbO composites with the same weight fraction. Also, it was found that, the proposed composites when compared to conventional shielding materials implement as strong rivals to barite, steel and concrete particularly at higher filler wt% and for low energy γ-ray.

The mechanical properties of pure HDPE, pure HDPE/bulk PbO composites, and pure HDPE/PbO nanocomposites were carried out. It was found that, the values of stiffness, ultimate tensile strength, and yield stress are increased by increasing either of bulk PbO or PbO NPs loading up to 40 wt% with respect to the host matrix. On the other hand, the values of ultimate tensile strain, tensile energy, and % elongation at break of the assembled composites were dramatically decreased with increasing fillers loading from 10 to 50 wt%. Besides, it is found that the composites with PbO NPs as a filler show higher mechanical properties than bulk PbO filler at the same wt%. The dielectric properties of pure HDPE and pure HDPE filled composites were performed to examine and characterize the structure of polymer composites. The values of relative permittivity, loss factor, and ac conductivities were measured as a function of frequency at room temperature and it was found that, incorporation of either bulk PbO or PbO NPs with different wt% to the polymer matrix resulted in enhanced dielectric properties.

The second part represents the characterization methods, γ-ray shielding properties, heaviness calculations, the mechanical properties, and dielectric properties of r-HDPE and its composites in addition to a comparative study to evaluate the behaviors of r-HDPE/bulk PbO composites versus r-HDPE/PbO nanocomposites as shielding materials for γ-radiation and another comparative study to evaluate the behaviors of pure HDPE/PbO composites versus r-HDPE/PbO composites as shielding materials for γ-radiation. The FTIR spectra, SEM, TEM, TGA data, the identified BET, and the XRD of r-HDPE, bulk PbO, PbO NPs, r-HDPE/bulk PbO composites, r-HDPE nanocomposites were investigated in the same manner as in part one and showed almost similar behavior.

The γ-ray shielding properties of r-HDPE and its corresponding composites were examined by the same way that discussed previously in part one and the same behaviors, trends, and effects were obtained in addition to superiority in the radiation shielding performance of r-HDPE as a matrix in the polymer composites under investigation with respect to pure HDPE matrix at the the determined energies and the same filler wt%. Also, the mechanical and dielectric properties of r-HDPE, r-HDPE/bulk PbO composites, and r-HDPE/PbO nanocomposites were studied by similar fashion to that described in part one and same behaviors, trends, and effects were found.

Chapter Four: General Conclusion

This chapter outlines our significant findings, conclusion and recommendations based on the collected results from this study.

Chapter Five: References

A number of 221 references were cited in this thesis.