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APPLICATION OF ZINC/Cd-TITANATE NANO-PARTICLES AS UV- AND THERMAL STABILIZERS FOR RIGID PLASTICS

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ABSTRACT

Certain concentration of zinc-cadmium titanate nano-particles additives were added during processing of polystyrene as model of rigid plastics to raise thermal stability as well as resistivity to crakes resulted from sun exposure (UV). The nano-particles additives from zinc-cadmium titanate work as internal centers of energy compensation, which increaseS flexibility. Furthermore, zinc-cadmium titanate nano-particle acts as terminator for some of free radicals reactions, promoting its physical properties and consequently, increased area of applications. The synthesized plastic was monitored before and after nano-additive by spectral methods such as IR, spectrum and X-ray diffraction to evaluate internal structure. Furthermore, some of physical properties such as flexibility and role of grain size effect has been investigated via SEM and atomic force microscope (AFM).

Key words: Additives, Nano-particles, Thermal stability, Plastics flexibility crakes.

INTRODUCTION

Photocatalytic degradation reaction-based processes are becoming more attractive to industry because they provide an alternative avenue for the decomposition of environmental

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pollutants. Growth in industrial development can be directly linked to the emergence of toxic pollutants, which are deposited into aqueous streams[1,2]. Among the semiconductor catalysts, TiO_2 (titanium dioxide or titania) is close to the ideal benchmark in environmental photocatalytic applications because of its outstanding chemical and biological stability, abundance, high oxidative power, energy absorber compensator and, it is comparably less expensive[3-9]. Although the use of TiO_2 in suspension form is more feasible due to its large surface area, there are four major technical challenges that restrict large-scale application of titania. Firstly, it has a relatively wide band gap (~3.2 eV, which falls in the UV range of the solar spectrum) and therefore, it has minimal absorption of visible light and is unable to use harness visible light; hence, ruling out sunlight as the energy source of photo-activation[7,8,10-14]. Secondly, it has low quantum efficiency due to the low rate of electron transfer to oxygen resulting in a high recombination of the photogenerated electron-hole pairs[5,7,10-11]. Therefore, the effective utilization of visible light for photocatalytic processes has become the ultimate goal. Various methods like substitutional doping (N, C, F, etc.), dye sensitization, using narrow band-gap quantum dots, binary oxides, and noble and transition metal nano-particles have been developed to achieve this[12,13]. Also, the photoactivity of TiO_2 nanoparticles has been tailored by exposing the {001} facets, which are very active[14].

EXPERIMENTAL

Samples preparation

Polystyrene (PS), as model of rigid plastics, was synthesized by applying conventional bulk polymerization technique using styrene monomer. The photo-stabilizer nano-$(Cd_{0.5}/Zn_{0.5})TiO_3$ was prepared by conventional solution route using metal oxalate precursor and ethylene glycol as gel agent. The obtained gel precipitate was dried and followed by specific thermal treatment at 800^{o}C.

Application of $(Cd_{0.5}/Zn_{0.5})TiO_3$ to polystyrene

0.1 g of nano-$(Cd_{0.5}/Zn_{0.5})TiO_3$ was added to the monomers of polystyrene during the processing of PS via bulk polymerization technique.

UV-exposure

Pure styrene and promoted styrene (Styrene + nano-$(Cd_{0.5}/Zn_{0.5})TiO_3$) were exposed to three different doses of UV-lamp 6W) for 2, 4 and 6 hrs, respectively. The samples were investigated by some spectral and structural tools.

Phase identification

The X-ray diffraction (XRD) measurements were carried out at room temperature on the finely ground samples using Cu-K_α radiation source, Ni-filter and a computerized STOE diffractometer/Germany with two theta step scan. High-resolution atomic force microscopy (AFM) is used for testing morphological features and topological map (Veeco-di Innova Model-2009-AFM-USA).

FT-Infrared spectroscopy

The infrared spectra of the solid products obtained were recorded from KBr discs using a Shimadzu FT-IR Spectrophotometer in the range from 400 to 4000 cm^{-1}.

RESULTS AND DISCUSSION

Structure identification

Two samples of polystyrene as model of rigid plastics were synthesized using styrene monomer by applying conventional bulk polymerization technique. One of them was doped with 0.1 g/g of PS wt/wt percentage. The photo-thermal stabilizer nano-($Cd_{0.5}$/$Zn_{0.5}$) TiO_3 was added during bulk polymerization of selected samples. The prepared two samples were investigated carefully using UV, IR as well as XRD to prove structure of poly styrene doped with ($Cd_{0.5}$/$Zn_{0.5}$)TiO_3 and pure polystyrene symbolized with PS (Figs. 1, 2 and 3).

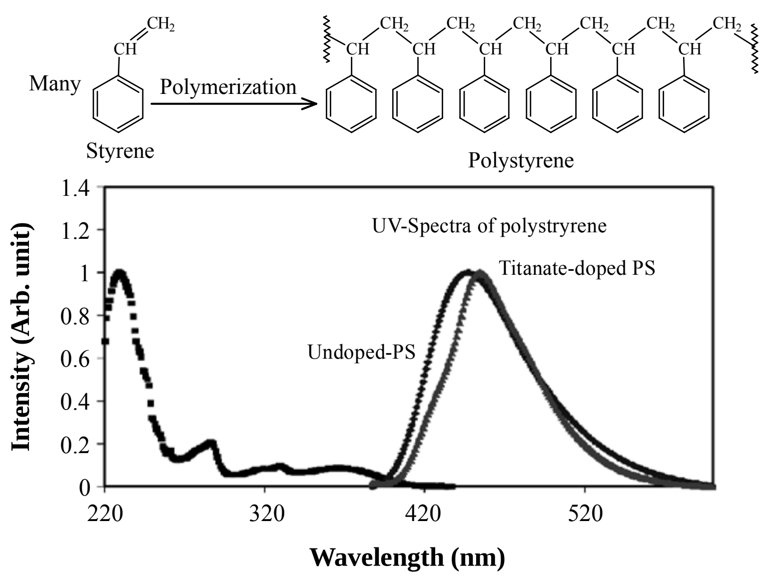

Fig. 1: UV-vis spectral curve for solid polystyrene (PS) at 25°C

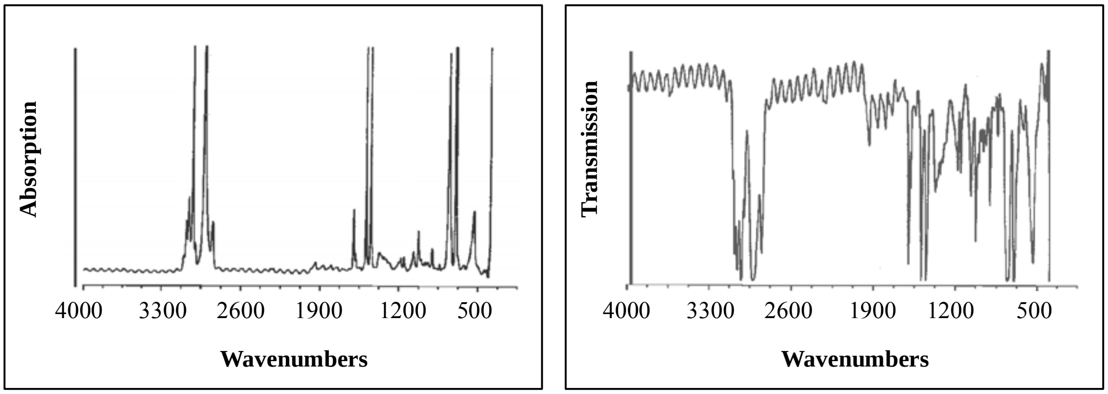

Fig. 2: IR absorption spectra for solid polystyrene (PS) at 25°C

It is clear from Figs. 1 and 2 that the characteristic wavelength of PS as well as peaks in IR spectra are present, which confirm that PS doped with zinc-cadmium titanate has the structural lattice without any change from parent pure PS.

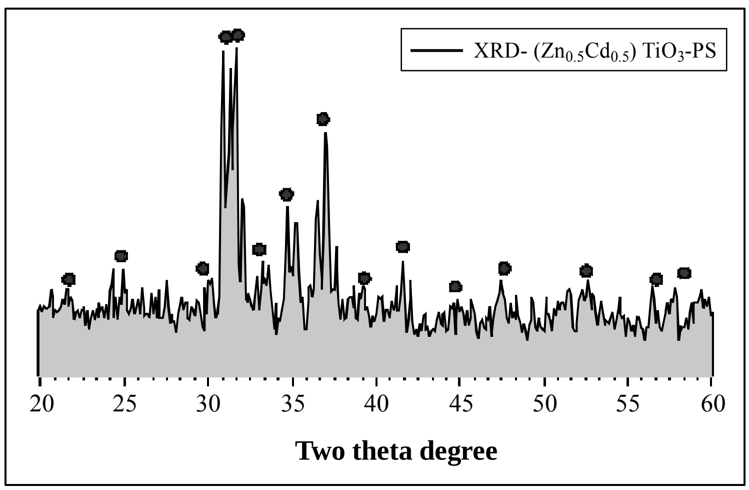

Fig. 3: XRD pattern recorded for promoted polystyrene (PS)

One can observe from Fig. 3 that addition of 0.1 g/g PS of $(Cd_{0.5}/Zn_{0.5})TiO_3$ as thermal stabilizer does not effect the main crystal form of PS and raise ratio of crystallinity of PS since PS, as polymeric matter has certain ratios of crystallinity as well as amorphous phase and these ratios are additive dependent[11,12].

Some of ground powder was carefully investigated for nano-structural features of $(Cd_{0.5}/Zn_{0.5})TiO_3$ thermal stabilizer via high resolution AFM applying non-contact tapping mode (Fig. 4). The grain size ranged in between 200-233 nm and average particle size was found to be 37.8 nm, which confirms that synthesis of $(Cd_{0.5}/Zn_{0.5})TiO_3$ by solution oxalate precursor yields nano-products[4,5].

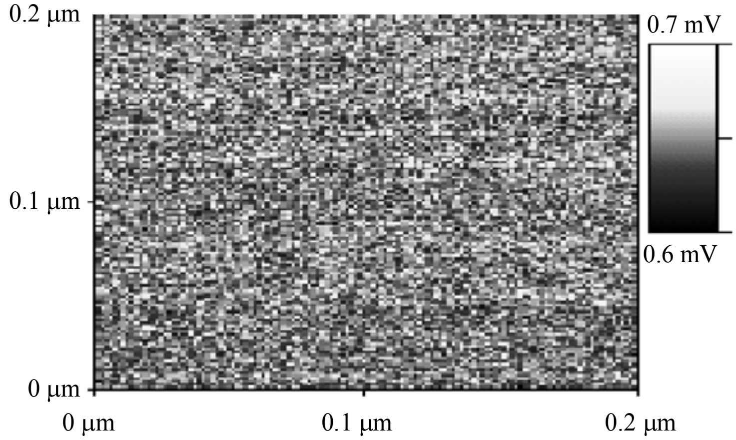

Fig. 4: 2D-AFM- image for $(Cd_{0.5}/Zn_{0.5})TiO_3$ added polystyrene

Testing photo-stability of doped PS

The two synthesized samples, PS and titanate doped PS with dimensions 0.5 x 05 x 0.3 cm were exposed to the UV-light lamp with 6 W power for 2,4 and 6 hrs, respectively.

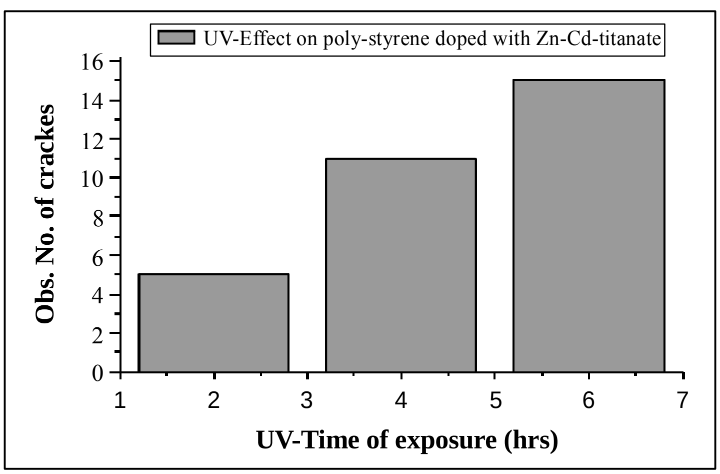

Fig. 5

Numbers of crakes per radiation of UV-light dose were monitored by ordinary optical microscope through two different sectors in the investigated samples. Undoped polystyrene recorded 7, 13 and 19 crakes per UV-radiation dose 2, 4 and 6 hrs, respectively while $(Cd_{0.5}/Zn_{0.5})\ TiO_3$ added polystyrene recorded lower crakes 5, 11 and 15 crakes, repectively (Fig. 5). It confirmed that nano-cadmium-zinc titanate $(Cd_{0.5}/Zn_{0.5})\ TiO_3$ acts as energy absorber (or thermal stabilizer); thus, raising possibilities of energy compensation over entire lattice of PS indicated by results.

CONCLUSION

Addition of nano-cadmium-zinc titanate $(Cd_{0.5}/Zn_{0.5})TiO_3$ (10% wt/wt) to polystyrene by enhances the thermal stability of PS by acting as energy absorber centers.

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