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Synthesis and Characterization of Nanomaterial Based Polymeric Thin Films for Agriculture with Climatic Control

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Agriculture production is mainly dependent upon the climate and atmospheric condition variations. A small variation in atmospheric condition has large precursion on agriculture production. Whereas daily temperature variation upto 10 can be observed in several parts of India. This variation can affect crop production adversely. Hence, formation and optimization of polycarbonate based polyhouse is investigated in this work. Further, it was observed that the materials and properties of polysheet would affect temperature and other condition of polyhouse. In current work, the material optimization was investigated and observed that an introduction of UV active nanomaterials provides better climatic control of polycarbonate based polyhouse. Applications of ZnO or TiO_2 enhance the absorbance of UV rays from sunlight and resulted in large control on greenhouse environment. This helps to provide enhanced control on greenhouse conditions. The effect of presence of polycarbonate with 0.3% TiO_2 50 µ showed 13.8 ºC enhancement in temperature control, which makes it highly beneficial for agriculture applications.

Keywords: Agriculture production, Polycarbonate, Polysheet, TiO_2, ZnO.

INTRODUCTION

India is one of the agriculture-based economy with approx. 70% population depend upon agriculture for livelihood in. It makes almost around 20% of total GDP been added upon by directly or indirectly. The agriculture sector is facing major challenges today due to ever changing climatic conditions and global warming, which lead to the changing in the seasonal and monsoon cycles and thus affecting agriculture production [1-3]. The cultivation of crop is favoured by specific climatic conditions which enhances their quality and productivity [4].

Mango cultivation is one of the popular examples. Though it is exported all over world, it comes from small coastal zone during the period of March to May [5]. Present scenairos in the climatic conditions due to global warming has affected the production to a large extent. Crop cycles and quality has been affected to a greater extent, though the soil quality is same [6]. These situations have brought forward the importance of controlled environmental farming. It can be done by using polyhouses [7]. In this case, the polymeric enclosure can be used to regulate environmental factors, allowing for more efficient farming and higher yields [8]. This requires careful selection, modification and utilization of polymeric sheets as an enclosure which can suitably absorb, reflect or transmit sun radiations (UV, visible or IR) [9]. It would help to maintain the temperature profile along with providing a suitable irradiation of energy photons for photosynthesis. Further their light distribution can be controlled by addition of suitable nanoparticles [10-12].

Plants in greenhouses require the highest light diffusion possible for optimal development. If there isn't enough light dispersion in the greenhouse, it might lead to a harmful burning effect [13]. Polycarbonate sheets allow for an even distribution of light throughout the greenhouse. Additionally, these sheets can be used to get the best UV protection from the sun [14,15]. The nanoparticle being photoactive played a major role in absorbing and reflecting light photons thus enhancing temperature control, which polycarbonate polysheet would help to maintain mechanical stability avoid microbial contamination. Despite the fact that there are very few studies on nanoparticles' UV absorbance, few studies have shown that TiO_2 nanoparticles have outstanding UV absorption [10-12].

Atif *et al.* [16] studied quantum dot sensitized solar cells (QDSSCs) having screen-printed TiO_2 nanoparticles on cadmium sulphide (CdS) quantum dots (QDs). They observed wide absorption spectra in UV-Vis region. Popov *et al.* [17] studied the UV light protection properties of outer layer of human skin using TiO_2 nanoparticle. They performed the stimulation studies on different sizes of TiO_2 nanoparticle with two different wavelengths and found that wavelength of 310 nm has good absorption properties in size between 56-62 nm and for 400 nm wavelength, spheres with 122-170 nm size, respectively. Nayef *et al.* [18] synthesized TiO_2 nanoparticle deposited on porous silicon material and found that the spectra have strong absorption between 200-340 nm. Taunk *et al.* [19] reported that the PL spectra shows UV peak absorption in blue region around 407 nm and in blue region around 484 nm in the snythesized hexagonal crystalline structural zinc oxide nanoparticles. However, the structure stability, cohesive energy, surface energy, heat capacity, and photocatalytic efficacy for the elimination of water contaminants are all highly influenced by the size and shape of ZnO nanoparticles [20-23].

Polycarbonates (PC) are a class of thermoplastic polymers which are strong, durable and optically transparent in certain grades. They have a wide range of applications due to their easy to handle, mould and thermoform properties [24-28] as comparison to glass being a heavy and brittle material. In India major population depends on agriculture as a source of income. Due to increasing global temperature the yield of crop goes on decreasing hence it directly effects on economy of farmer and nation. Polycarbonate sheet in polyhouse is found to be superior to the currently utilized polyethylene sheet and by using polyhouse structures in agriculture, the temperature can be regulated. Moreover, the temperature and atmospheric properties can be controlled using selection of nanoparticle (TiO_2, ZnO), its concentration, membrane thickness, *etc*. Thus, in order to improve the thermal stability of polycarbonate, in this work, the authors optimized the polycarbonate based greenhouse sheets with enhanced temperature control properties by incorporation of ZnO and TiO_2 nanomaterials.

EXPERIMENTAL

All the chemical used *viz*. titanium isoproproxide(IV), $Ti(OCH(CH_3)_2)_4$, isopropanol, zinc oxide, polycarbonate granules and chloroform were purchased from Sigma-Aldrich with 99% purification.

Synthesis of TiO_2 nanoparticles: A modified co-precipitation technique was adopted to synthesize TiO_2 nanoparticles. This approach is a straightforward strategy which is simple to use and also appropriate for large-scale production [29]. In brief, a solution containing titanium(IV) isopropoxide (TTIP, 5 mL) and isopropanol (15 mL) was stirred for 30 min using magnetic stirrer followed by the addition of 50 mL deionized water added dropwise with continuous stirring, resulting in the formation of white precipitate of $Ti(OH)_4$. The precipitate was refluxed 2 h and stirred vigorously for 1 day. After that the precipitate was washed several times to remove impurities and then dried overnight. Finally, obtained precipitated $Ti(OH)_4$ was annealed at 700 ºC for 2 h.

Synthesis of polycarbonate coated TiO_2/ZnO nanomaterial films: The calculated amount of TiO_2/ZnO nanoparticle was mixed to 1 g polycarbonate granules dissolved in 25 mL chloroform and then stirred continuously for 18 h. The solution then poured into Petri dish and put into oven (not more than 50 ºC) to obtain the PC-TiO_2 or ZnO nanomaterial film.

RESULTS AND DISCUSSION

XRD studies: The XRD pattern of TiO_2 nanoparticle was recorded on X-ray diffractometer (Rigaku, MiniFlex) with Cu*K*α radiation (λ = 1.54059 Å). Fig. 1 shows XRD spectrum of TiO_2 nanoparticle prepared by chemical method. The peaks are matched with the reported data of TiO_2 nanoparticles. The synthesized sample consist of anatase (2θ = 25.35º, 37.75º, 48.00º, 53.83º, 55.15º, 62.66º, 68.73º, 70.40º and 75.05º) and rutile (2θ = 27.38º, 36.79º, 38.47º, 53.83º, 55.15º, 62.66º, 68.73º and 70.40º) mixture [30-34]. Peak broadening as observed in Fig. 1 also confirms the formation of nanocrystalline [35]. This shows bicrystalline structure of TiO_2 [36,37]. To determine the average crystalline size of nanoparticles, the Debey-Scherrer's formula was employed.

$$D = \frac{k\lambda}{\beta \cos\theta}$$

where D is the average grain size, k is the constant, λ is the wavelength of X-ray, β is the full width of half-maxima of the diffraction peak (FWHM) and θ is the Bragg's angle [D]. Here, value of k is 0.9 and wavelength of X-ray is 1.54059 Å. The full-width of half-maxima of the diffraction peak (FWHM) was observed by Gaussian fit and value of β is 0.005002 (radians). Thus, the mean crystal size was evaluated as 27.85 nm.

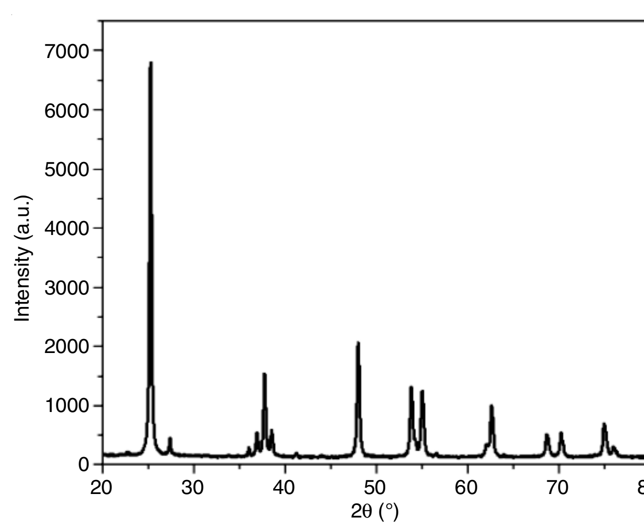

Fig. 1. XRD spectrum of TiO_2 nanoparticles

UV-vis studies: The absorption spectra of the material in the range of 200 to 800 nm were recorded using a UV-visible spectrometer (U-3010 Spectrophotometer LABINDIA Model: UV-3000). The UV-vis spectra of polycarbonate (PC), polycarbonate based TiO_2 nanomaterial (PC-TiO_2) and polycarbonate based ZnO nanomaterial (PC-ZnO) show the absorption at 277, 355 and 342 nm, respectively (Fig. 2), which clearly indicated that absorption increases when doping of TiO_2 was performed on polycarbonate. The reason is attributed due to fact that TiO_2 nanomaterial exhibit high refractive index and are better at absorbing and scattering UV light [38,39].

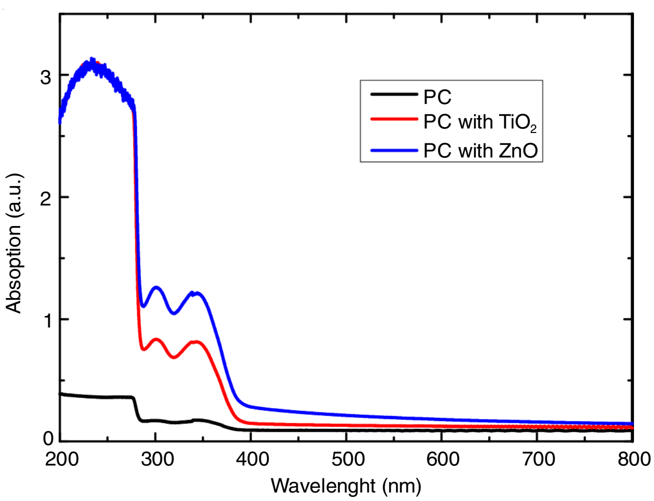

Fig. 2. UV-vis spectra of polycarbonate (PC) (a); PC coated 0.3% TiO_2 (b); and PC coated 0.3% ZnO (c) nanosheets

EDS studies: Using energy dispersive X-ray spectroscopy (EDS: Bruker Xflash 6I30), the compositions of the prepared polycarbonate coated TiO_2/ZnO nanomaterial films were analyzed. The EDS spectra display the peaks of titanium, zinc and oxygen along with carbon which sometimes acted as a capping agent to nanoparticles (Fig. 3). It can be clearly observed that the major element such as titanium, zinc which comprises more than 50% of total constituent along with oxygen and clearly confirms the formations of pure TiO_2 and ZnO nano-particles. This indicates that the nanoparticle synthesis of TiO_2 can be prepared by modified co-precipitation method [29]. The proper dispersion throughout the sheet along with its presence of on surface is highly important for current work. It would provide the surface activation and dispersion particles at different photonic energy conditions [40]. With higher dispersion and activation at given energy intensity it would provide better control on heat transfer across the sheet by light photons.

Effect of temperature on PC coated ZnO/TiO_2 (50 and 40 µ thickness): The effect of 50 and 40 µ thicknkess polycarbonate sheet and polycarbonate with 0.1%, 0.2%, 0.3% ZnO/TiO_2 doped sheets were investigated. In case of PC coated ZnO, for 50 µ thickness, as temperature decreases from 45 ºC to 34 ºC PC coated with 0.3% ZnO shows the maximum temperature difference ranging from 13.6 ºC to 4.8 ºC (Fig. 4), the reason is obviously due to the uniformly dispersion of ZnO nanoparticles, which have high refractive index [41].

In case of polycarbonate coated 0.1%, 0.2%, 0.3% TiO_2 films, the effect of temperature on 50 µ thickness films, it was found that as temperature decreases from 45 ºC to 34 ºC, the maximum differences ranges from 13.8 ºC to 5.1 ºC were observed with polycarbobate (PC) with 0.3% TiO_2 film (Fig. 5). In this case, the reason is similar as mentioned for PC coated ZnO doped sheets. The high reflectivity would result in higher enhanced control on heat transfer and energy intensity. It would lead to better control of polyhouse.

Conclusion

Temperature and temperature regulation is a primary focus during the construction of polyhouses. Hence, the work was undertaken to enhance temperature control using ZnO or TiO_2 nanoparticles in polycarbonate sheets. The nanocomposite ZnO/TiO_2 polycarbonate sheets were characterized with help of UV-vis and EDS analysis. The effect of temperature clearly shows the absorption increases when 0.3% TiO_2 doped polycarbonate sheets (50 µ thickness) as compared to ZnO and polycarbonate sheet. 0.3% PC TiO_2 50 µ shows maximum temperature difference of 13.8 ºC as compared to ZnO and polycarbonate sheet.

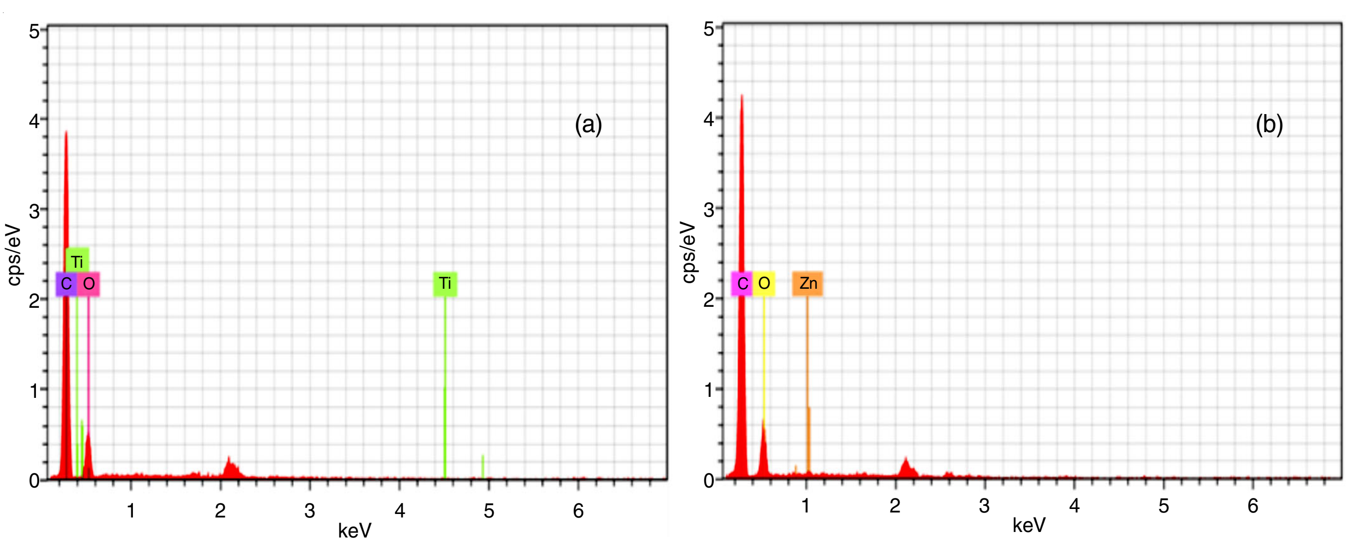

Fig. 3. EDS spectrum of polycarbonate (PC) coated 0.3% TiO_2 (a) and polycarbonate (PC) coated 0.3% ZnO (b) nanosheets

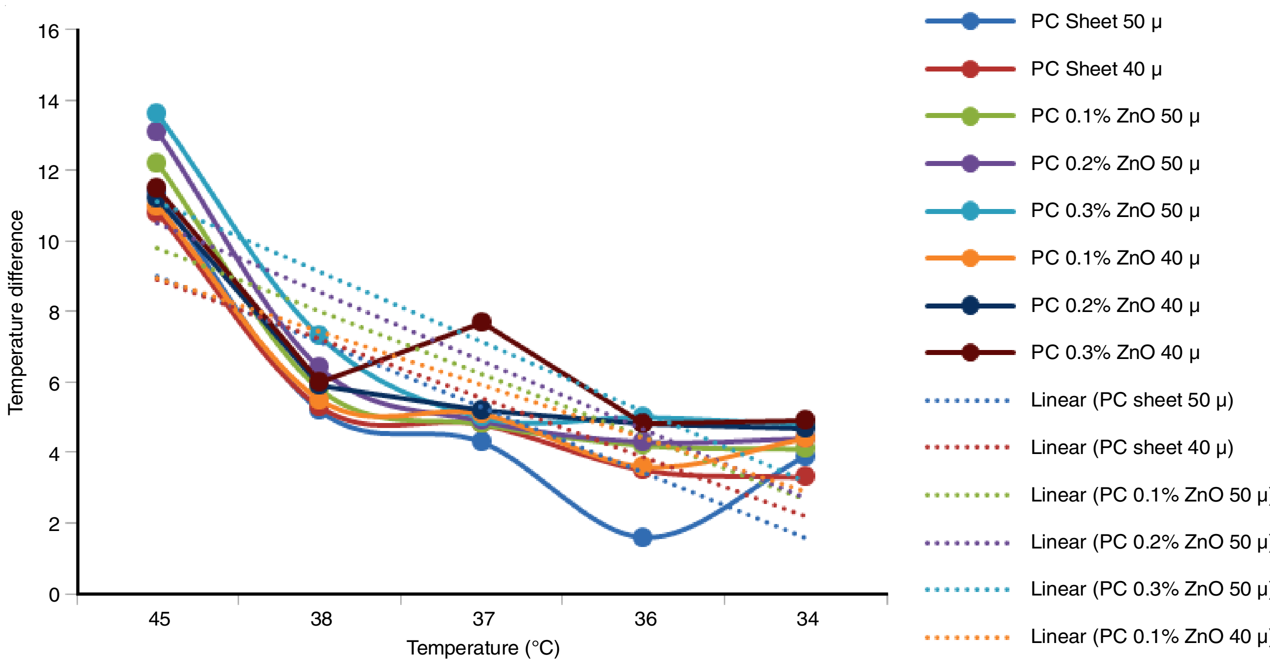

Fig. 4. Effect of temperatures on 50 & 40 µ thickness of polycarbonate (PC) coated ZnO sheets

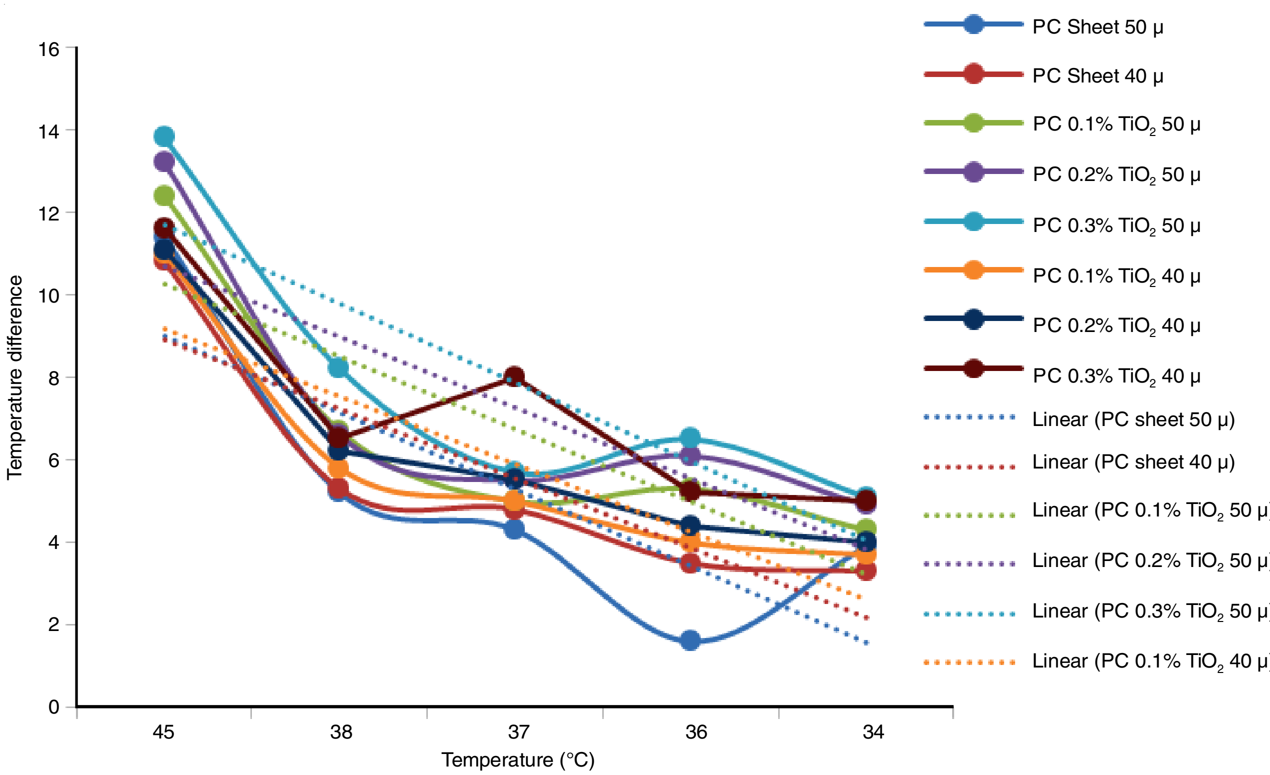

Fig. 5. Effect of temperatures on 50 and 40 µ thickness of polycarbonate (PC) coated TiO_2 sheets

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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