HIGHLY TRANSPARENT ZNO-SNO$_2$/PMMA UVC SHIELDING COATINGS WITH EXCEPTIONAL MECHANICAL STABILITY

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Abstract

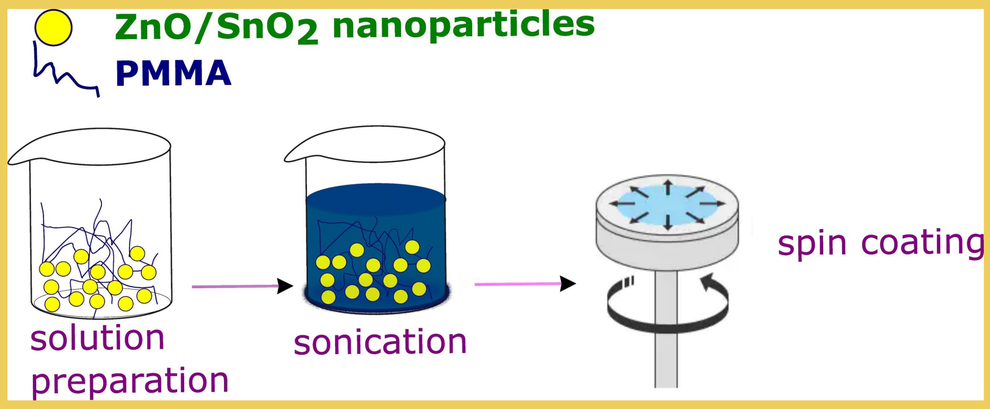
The thinning of the ozone layer has led to an increase in the amount of UV radiation reaching the Earth's surface in the last decades. The harmful effects of UV radiation on humans and the environment are numerous, while UVC irradiation in the range of 100-290 nm has the most harmful effect on health. Therefore, developing UV shielding materials is an important step in protecting ourselves and the environment from the harmful effects of UV radiation. Here we present a detailed study of ZnO-SnO$_2$/PMMA nanocomposite coatings, which completely block UVC radiation. Additionally, we study the effect of the addition of ZnO-SnO$_2$ nanoparticles on mechanical properties in the means of Vickers microhardness and find out that they positively affect the microhardness of the PMMA coatings up to a certain concentration. Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM) reveal the quite homogeneous distribution of nanoparticles for lower concentrations and the presence of nanoparticle aggregates for higher concentrations such as 1 wt.% and 5 wt.% of ZnO-SnO$_2$ nanoparticles.

Motivation

In the last decades, the thinning of the ozone layer has led to an increase in the amount of UV radiation reaching the Earth's surface, which can cause numerous health problems. It can also have a negative impact on plant and animal life, as well as on the Earth's climate. UV radiation can even damage different materials, such as fabrics, plastics, and other materials used in construction. The radiation in the UVC range (100-290 nm) is much more harmful than UVB (290-320 nm) and UVA (320-400 nm) radiation [1]. Therefore, there is a growing need for developing effective UV shielding materials for different applications, including contact lenses, flexible displays and optical filters [2]. One approach to preparing UV-shielding materials involves incorporating UV absorbing nanoparticles (NPs) or nanofillers into the polymer matrix [3].

We present the preparation and characterization of highly homogeneous ZnO-SnO2/PMMA nanocomposite coatings with high transparency in the visible range and blocking properties in the UVC region.

The preparation of nanocomposite films



Morphology of ZNO/SNO$_2$-PMMA nanocomposite coatings

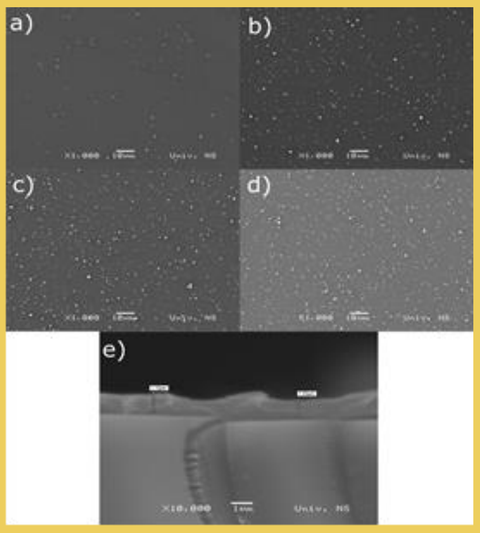


Fig. 1 - Surface morphology of ZnO-SnO$_2$/PMMA nanocomposite coating with a) 0.1 wt.% b) 0.5wt.% c) 1 wt.% d) 5 wt.% ZnO-SnO$_2$ NPs. e) The cross-section image of the coating on the glass substrate.

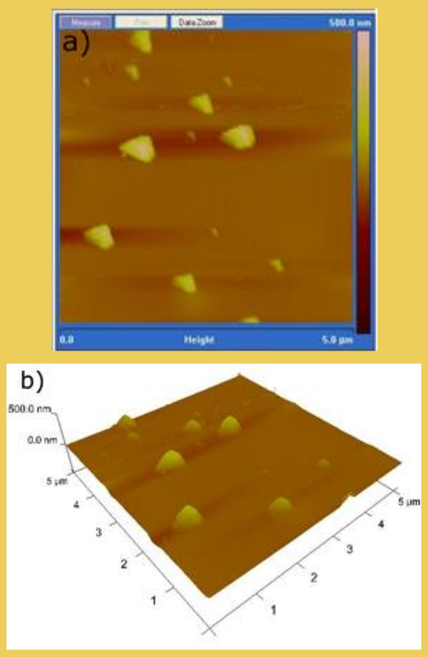


Fig. 2 - a) 2D and b) 3D AFM images of ZnO-SnO$_2$/PMMA nanocomposite coating with 5 wt.% of ZnO-SnO$_2$ NPs.

Optical properties of ZnO-SnO$_2$-PMMA nanocomposite coatings

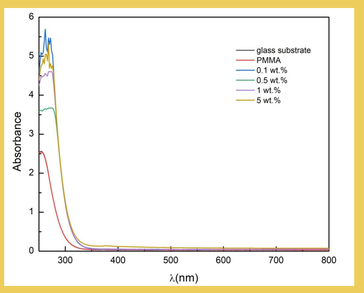


Fig. 3 - Absorption spectra of pure the glass substrate, pure PMMA and ZnO-SnO$_2$/PMMA nanocomposite coatings with different concentrations of ZnO-SnO$_2$ NPs.

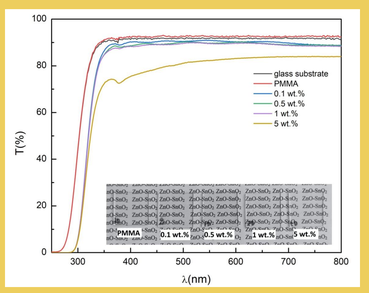


Fig. 4 - Transmittance spectra of pure the glass substrate, pure PMMA and ZnO-SnO$_2$/PMMA nanocomposite coatings with different concentrations of ZnO-SnO$_2$ NPs.

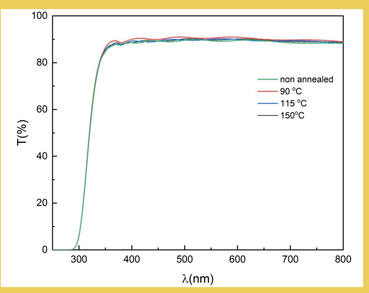


Fig. 5 - Transmittance spectra of ZnO-SnO$_2$/PMMA nanocomposite coatings with 0.5 wt.% of ZnO-SnO$_2$ NPs annealed at different temperatures.

The nanocomposite films containing only small concentrations of ZnO-SnO$_2$ NPs such as 0.1 wt.% show high UV blocking efficiency.

Optical properties of ZnO-SnO$_2$-PMMA nanocomposite coatings

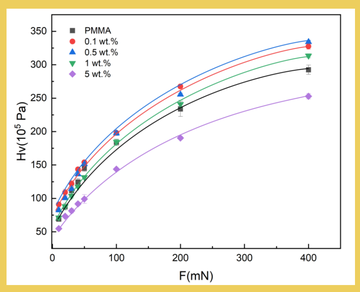


Fig. 6 - Variation of Vickers microhardness with applied load for pure PMMA and ZnO-SnO$_2$/PMMA nanocomposite coatings annealed at 150 ^{o}C with different concentrations of ZnO-SnO$_2$ NPs.

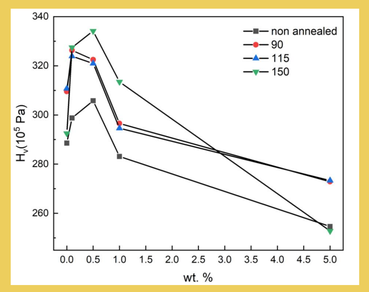


Fig. 7 - Variation of Vickers microhardness of of ZnO-SnO$_2$/PMMA nanocomposite coatings with concentration of ZnO-SnO$_2$ NPs for load of 400 mN.

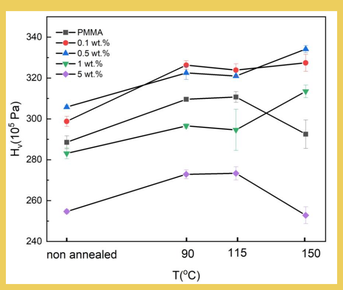


Fig. 8 - Variation of Vickers microhardness of of ZnO-SnO$_2$/PMMA nanocomposite coatings annealing temperature for load of 400 mN.

The nanocomposite coating with 0.5 wt.% ZnO-SnO$_2$/PMMA annealed at 150^{o}C showed the highest value of Vickers microhardness over all samples including the pure PMMA.

Conclusions

- ZnO-SnO$_2$/PMMA nanocomposite coatings which completely block UVC radiation and start to block in the UVB region with high transparency in the visible region.
- Reinforcing the PMMA matrix with ZnO-SnO$_2$ NPs not only improves optical properties, but also improves mechanical properties.
- Morphology and topography investigations confirm the presence of aggregates at higher NP concentrations, which probably deteriorate mechanical properties of the coatings.
- The examinations of the influence of annealing temperature on Vickers microhardness have shown that annealing has a positive effect on microhardness, meaning that it increases with annealing temperature.
- ZnO-SnO$_2$/PMMA coatings have the ability to completely absorb UV radiation of wavelengths smaller than 322 nm and have high mechanical resistance, which makes them perspective material for UV shielding applications.

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Aknowlegment

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