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Photophysical insights of highly transparent, flexible and re-emissive PVA @ WTR-CDs composite thin films: A next generation food packaging material for UV blocking applications

Akshay S. Patil[a,b], Ravindra D. Waghmare[b], Samadhan P. Pawar[a,b], Suresh T. Salunkhe[a], Govind B. Kolekar[b,c], Daewon Sohn[c], Anil H. Gore[a,b,d,*]

[a] Department of Chemistry, Rajarshi Chhatrapati Shahu College, Kolhapur, 416003, MS, India
[b] Fluorescence Spectroscopy Research Laboratory, Department of Chemistry, Shivaji University, Kolhapur 416004, MS, India
[c] Department of Chemistry, Hanyang University, Seoul Campus, Seoul 133-791, South Korea
[d] Department of Chemistry, Uka Tarsadia University, Maliba Campus, Tarsadi, 394350, GJ, India

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ABSTRACT

Herein, we have fabricated a highly transparent, flexible and re-emissive polyvinyl alcohol/waste tea residue carbon dots (PVA@WTR-CDs) composite thin films by simple solvent casting method. Incorporated WTR-CDs as a function of UV blocking (absorption of UV light and re-emission in the visible region) agent synthesized from waste tea residue powder as a sustainable material. The results revealed that, the WTR-CDs have the best compatibility with PVA. The incorporated fluorescent WTR-CDs impart fluorescence to the whole film and films are capable to not only block the UV region but also re-emit absorbed UV light into the visible region. The increased concentrations of WTR-CDs into PVA films enhances the UV blocking capability of the composite films. The composite, PVA@WTR-CDs-3 films were succeeded to block full (100%) of UV-C (230 – 280 nm) and UV-B (280 – 315 nm) region, while 20 – 60% of UV-A (315 – 400 nm). We achieved the maximum of UV blocking by PVA@WTR-CDs-5 composite films by controlling the transparency and thickness. By the successive addition of the UV blocking agent, there was no extreme changes observed in the intrinsic mechanical as well as tensile properties of PVA films. The thermal analysis study showed that, there was no adverse effect of WTR-CDs incorporation on the thermal stability and degradation profile of original PVA films. In detail, the possible mechanism of UV absorption and re-emission in the visible region by fabricated films is also discussed. Furthermore, practicability of the composite film was also investigated on a model (grape) fruit and thus can be used as a modern UV blocking material in packaging, pharmaceutical storage, wrapping, and coating etc.

1. Introduction

Since the last few decades, global warming is one of the big issues in front of all over the world. Increasing global warming results in the depletion of the ozone layer in the stratosphere and this is due to some human activities such as forest cutting, burning fossil fuels, etc. The UV rays coming from sunlight easily passes through the ozone layer, which is very harmful to living and non-living things. UV rays create many adverse effects such as degradation of organic and inorganic dyes and coloring pigments [1,2], loss of mechanical strength i.e. breaking and cracking of plastic and also dullness of plastics, yellowing papers [1] and consequently it reduces the efficiency and lifetime of materials. In addition to that monomers of degraded plastics and other synthetic packaging materials may be directly added into food and other products during packaging [3]. The direct exposure of UV radiation can cause skin cancer and skin burn [4]. However, the food products also need to be shielded from UV light because under the UV radiation there is a loss of many essential nutrients present in the milk [5]. Thus, to solve the aforementioned problems and dangerous effects of existing UV shielding agents, it is mandatory to pay time for the development of modern UV blocking agents, routes, and strategies.

All over the world, various scientists have been working in order to overcome such terrible problems and finding solutions [6]. From the last couple of years, more attentions have been paid to the use of less toxic nanomaterials [7], plant and animal extract [8–10], as a UV blocking agents for the designing of UV protective polymeric films from biodegradable, sustainable, green and natural sources [11,12]. Wang et al. used extract/ink of *Sepia Eumelanin* animal for simultaneous

* Corresponding author at: Department of Chemistry, Uka Tarsadia University, Maliba Campus, Tarsadi 394350, GJ, India.
E-mail address: anilanachem@gmail.com (A.H. Gore).

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