Materials Chemistry and Physics 215 (2018) 242–250

Contents lists available at ScienceDirect

Materials Chemistry and Physics

journal homepage: www.elsevier.com/locate/matchemphys

A TiO_2 nanocomposite hydrogel for Hydroponic plants in efficient water improvement

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HIGHLIGHTS

- Antifouling AM and AA were applied to construct a support for TiO_2 NPs to form a functional hydrogel.
- Hydrogel showed integrated photocatalytic, antibacterial, and self-healing functions.
- Hydrogel was applied for improving water quality of hydroponic plant with solar light.

ARTICLE INFO

Keywords:
Titanium dioxide nanoparticles
Hydrogel
Hydroponic plant
TOC
Water treatment

ABSTRACT

The increasing use of titanium dioxide nanoparticles (TiO_2 NPs) in a wide range of fields raises concerns about their potential environmental impact. In this work, the antifouling materials acrylamide (AM) and acrylic acid (AA) were selected to construct a support for TiO_2 NPs to form a functional nanocomposite hydrogel through simple one-pot UV-induced free-radical polymerisation. The constructed mechanically strong nanocomposite hydrogel showed integrated photocatalytic, antibacterial, and self-healing functions. Finally, pothos (*Epipremnumaureum*) was used as a model hydroponic plant to investigate the effect of the nanocomposite gels on the water quality after irradiation with solar light (indoor, no direct sunlight). In contrast to the rapid deterioration of the reference sample system, the lower TOC concentration in the photocatalytically treated system shows that the efficient oxidation of TiO_2 photocatalysis, which lowers the environmental impact of soil-less system. The high strength hydrogel with integrated functions is expected to be applied readily as a water treatment strategy under solar light irradiation.

1. Introduction

Hydroponics is a method of growing plants without soil, instead using an aqueous mineral nutrient solution. The use of hydroponics is increasing because of its advantages such as ease of controlling crop growth, low chance of infection by soil pathogens, and reduced risk of replanting failure [1–3]. Hydroponics has been accepted by both government and private citizens. In recent decades, NASA carried out extensive hydroponic research for its Controlled Ecological Life Support System (CELSS) [4]. In 2017, Canada encouraged the development of large-scale commercial hydroponic greenhouses, producing *Tomatoes*, *Peppers*, and *Cucumbers* [5]. Although hydroponics can reduce pollution significantly compared to traditional soil planting, a large quantity of water is required, and the emission of waste water is inevitable. For example, the nutrient solution contains NO_3^-, PO_4^{3-}, K^+, and other nutrients required by the plants for photosynthesis and growth. However, the plants are generally supplied with more nutrients than they can use in photosynthesis, and 10–30% of the supplied solution is not absorbed by the plant roots and is released into the environment as a waste product [6]. Furthermore, in addition to man-made pollutants, plants also release a variety of organic chemicals into the environment, including organic acids and alcohols. Furthermore, some plants even release phytotoxins, inhibiting the growth and germination of other plants [7,8]. Therefore, the purification of the container and the timely exchange of water (filtration for water improvement in large scale planting system) is necessary, especially in summer. Concerning cost savings and environmental protection, the efficient improvement of water quality in hydroponics remains a challenge.

Titanium dioxide (TiO_2) is one of the most promising and widely used semiconductor nanomaterials for environmental remediation and energy applications because of its biological and chemical inertness, strong oxidizing power, nontoxicity, and long-term stability against

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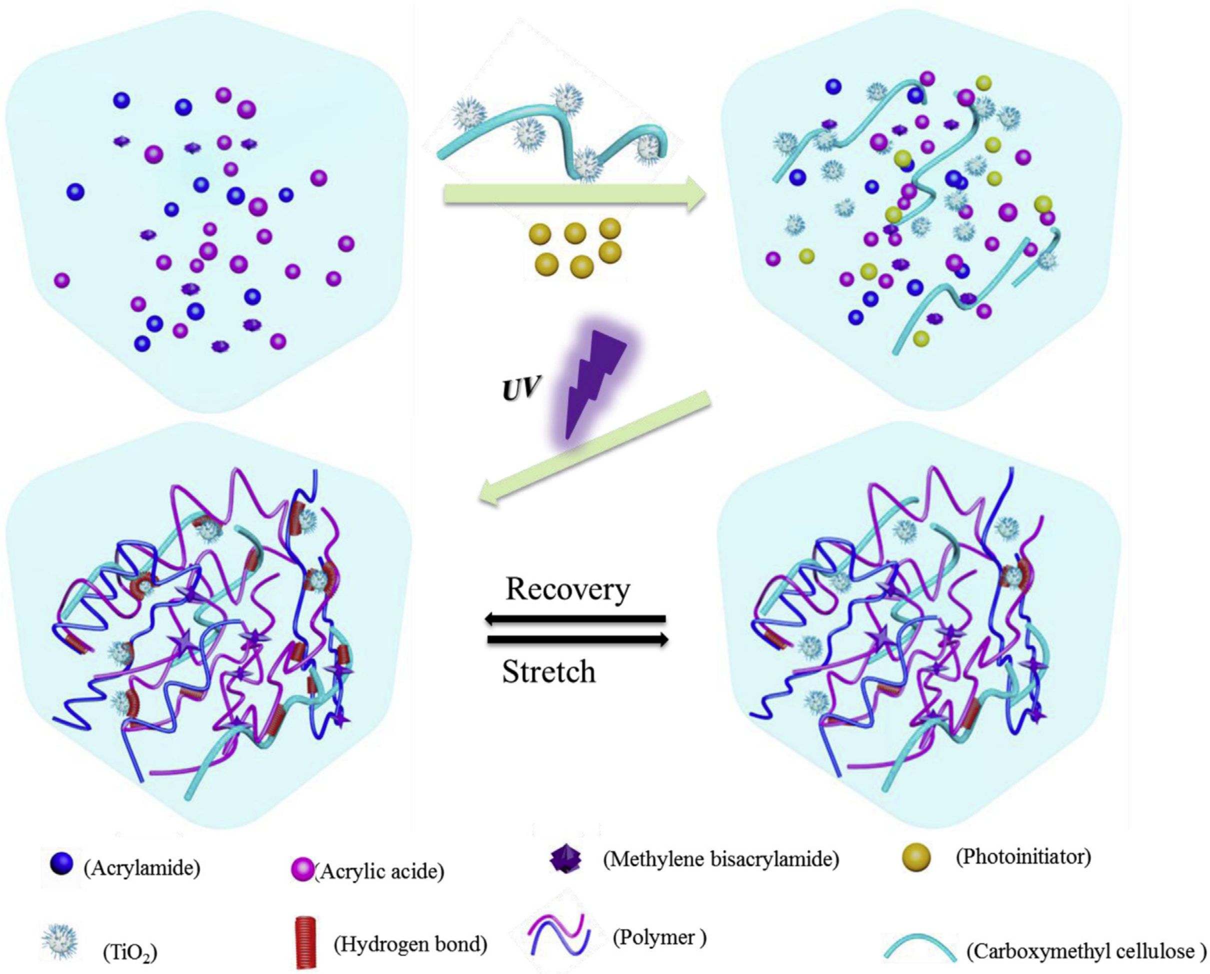
https://doi.org/10.1016/j.matchemphys.2018.05.042
Received 11 February 2018; Received in revised form 17 May 2018; Accepted 19 May 2018
Available online 19 May 2018
0254-0584/



Scheme 1. Schematic diagram representation of the preparation and a possible network structure of the (PAA-*co*-PAM-CMC)/TiO_2 nanocomposite hydrogel.

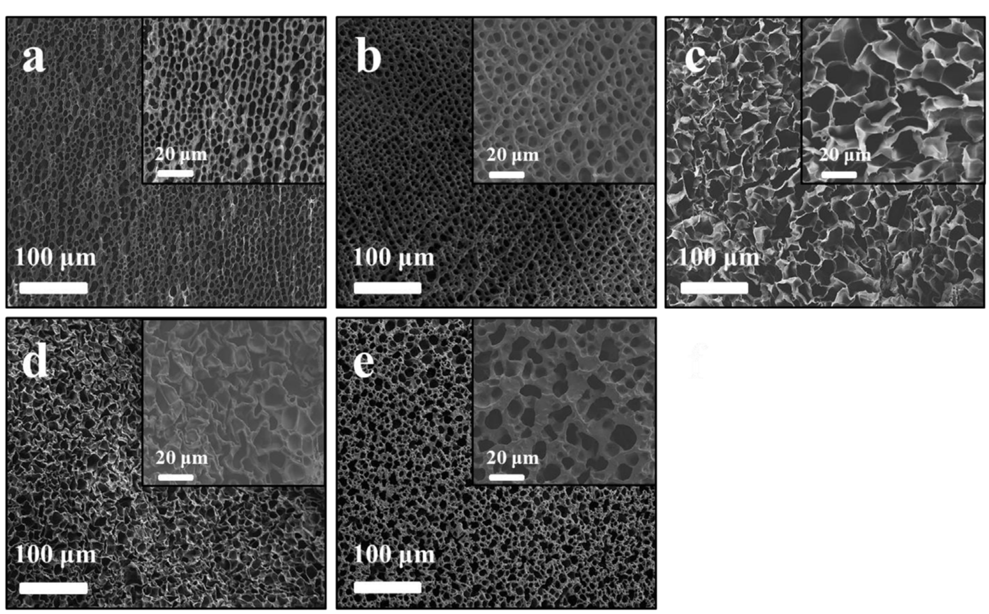


Fig. 1. Cross-sectional SEM images of freeze-dried (a) pristine PAA-*co*-PAM, (b) PAA-*co*-PAM-CMC, and (PAA-*co*-PAM-CMC)/TiO_2 nanocomposite hydrogels with different TiO_2 contents: (c) 0.4, (d) 0.6, and (e) 0.8 wt%. The inset shows the enlarged image of the pore structure.