Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2017.21358

90 (2017) 299–310
September

Comparative analysis of adsorption and light decomposition of methylene blue by ordered mesoporous C-Nb-TiO_2 nanocomposites prepared via self-assembly and sol–gel methods

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Received 16 March 2017; Accepted 22 August 2017

ABSTRACT

Highly ordered mesoporous carbon–niobium doped TiO_2 nanocomposites with nanocrystal frameworks have been synthesized via the self-assembly and sol–gel methods from organic–inorganic–amphiphilic co-assembly followed by the in situ crystallization technology. A soluble resol polymer was used as a carbon precursor, TiO_2 as an inorganic precursor, and triblock copolymer F127 as a template. The soluble resol–niobium doped TiO_2 nanocomposites with controllable texture properties and composition can be obtained in a wide range from 0.0 to 20.0 wt% TiO_2 by adjusting the initial mass ratios. A detailed characterization of the nanocomposites shows that films contain nanoparticles with the anatase modification with pentavalent Nb chloride dissolved into the anatase and mesoporous carbon structure. The nanocomposites have high surface area (424–613 $m^2\ g^{-1}$) and ordered pore size (~3.9 nm). Both energy-dispersive X-ray and X-ray fluorescence data detected the presence of Nb and TiO_2 in composite mesoporous materials. The scanning electron and transmission electron microscopic images of C-niobium doped TiO_2 nanocomposites exhibit highly ordered two dimensional hexagonal mesostructure. The Nb-doped films displayed an enhanced visible light absorption with a red-shift of the optical absorption edge and X-ray diffraction data showed that the films consisted of the anatase polymorph of TiO_2. Ultraviolet–visible spectrophotometry data showed that the optical indirect band gap of the films decreased significantly, from 3.13 eV (undoped) to 3.04 eV (0.2 mol% Nb). X-ray photoelectron spectroscopic results of materials show that the characteristic peaks at C1s, Ti2p, O1s and Nb3d exhibit the existence of C, Ti, O, Nb in nanocomposites. Additionally, the nanocomposites show good performance in the degradation of methylene blue due to the photocatalytic activity of the Nb-doped TiO_2 nanocrystals and the strong adsorptive capacity of the mesoporous carbon.

Keywords: Mesoporous carbon; Titanium dioxide; Nb-doping; Adsorption; Light decomposition

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