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Multi-walled carbon nanotubes improve the physicochemical properties of mesostructured silica nanoparticles for efficient adsorption of methylene blue

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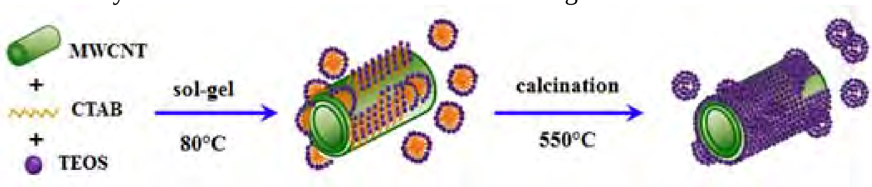
Carbon nanotubes (CNTs) have attracted great attention in nanoscale science and technology due to their unique optical, electronic and mechanical properties[1]. Besides, mesostructured silica nanoparticles (MSN) have become effective adsorbents owe to its high surface area and pore size which is essential to adsorb wide range of organic pollutant[2-4]. Modification of CNT with MSN may enhance the dispersion properties and adsorption capacities from their singles. In this study, a series of carbon nanotubes–mesostructured silica nanoparticles (CNT–MSN) composites were prepared by a simple sol-gel method with 1, 3 and 5 wt.% loading of CNT. The composites then calcined to remove surfactants (Scheme 1). Their surface properties were characterized by XRD, N_2 physisorption, TEM and FTIR, while the adsorption performance of the CNT–MSN composites were evaluated on the adsorption of methylene blue (MB) under varying pH (2–11), adsorbent dosage (0.05–0.5 g L^{-1}), initial MB concentration (5–100 mg L^{-1}) and temperature (303-323 K). The increasing CNT loading into MSN were found to improve the physicochemical properties of the material and led to an enhanced adsorptivity for MB. N_2 physisorption measurements revealed the development of a bimodal pore structure that increased the pore size, pore volume and surface area. The best conditions were achieved at pH 8, 0.05 g L^{-1} CNT–MSN dosage, 100 mg L^{-1} MB concentration and 303 K. The maximum adsorption capacity reached for 5 wt.% CNT-MSN was 524 mg g^{-1}. The equilibrium data were evaluated using the Langmuir and Freundlich isotherm models, with the Langmuir model affording the best fit to the adsorption data. The adsorption kinetics was best described by the pseudo-first order model. Thermodynamic studies showed that the adsorption process was spontaneous, exothermic and occur through physisorption mechanism. Therefore, CNT-MSN is believed to be a promising adsorbent for dye removal as well as removal of wide range wastewater.



Scheme 1 Schematic diagram for the preparation of MWCNT-MSN composites

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