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Guanidinium ionic liquid-controlled synthesis of zeolitic imidazolate framework for improving its adsorption property

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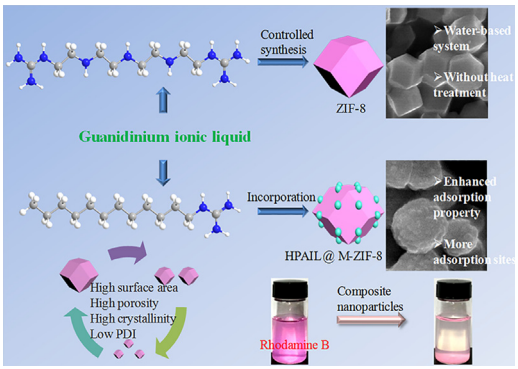
HIGHLIGHTS

- HPAIL@meso-ZIF-8 composite material as a rhodamine B adsorbent was successfully prepared at room temperature.
- The ZIF-8 and its composite showed improved adsorption capacity toward rhodamine B with high efficiency and selectivity.
- The great performance of obtained nanoparticles was attributed to the excellent structural properties.
- This work provided a promising and eco-friendly strategy to enhance adsorption property of ZIFs toward pollutants.

GRAPHICAL ABSTRACT



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ABSTRACT

The massive release of rhodamine B (RhB) to water system is an emerging problem, which dramatically threaten environment and human health. The development of an adsorbent with enhanced removal efficiency for RhB is urgently needed. Herein, we report an environment-friendly synthesis of high quality zeolitic imidazolate framework-8 (ZIF-8) and functional ionic liquid@ZIF-8 in water-based system without heat treatment for improving its adsorption property. Guanidinium ionic liquids (ILs) could not only act as greener agents instead of volatile bases and toxic surfactants to efficiently control the nucleation and growth rate of ZIF-8, but also were incorporated as shell material to add specific adsorption sites. The relationship between nanoparticle structure and adsorption performance for RhB was systematically investigated. Due to high surface area (1167 $m^2\ g^{-1}$), high porosity (0.79 $cm^3\ g^{-1}$), high crystallinity, nano size (about 100 nm) and monodispersity, the as-obtained ZIF-8 showed improved adsorption capacity toward RhB (80% removal efficiency). Heteropolyanion-based guanidinium IL@meso-ZIF-8 (HPAIL@meso-ZIF-8) exhibited the high RhB uptake capacity of 278 mg g^{-1} (higher than most of the reported adsorbents) and effectively removed 99% of RhB within 15 min. The results showed that the adsorption process of prepared materials fitted well with pseudo-second-order kinetics and Langmuir isotherm model. The existence of mesopores in ZIF-8 facilitated the diffusion of RhB and the incorporated guanidinium IL played a significant role in enhancing the adsorption affinity. Moreover, the reusability results revealed the HPAIL@meso-ZIF-8 as a highly efficient adsorbent for RhB removal with satisfactory performance and structural stability. Therefore, HPAIL@meso-ZIF-8 is one of the most promising adsorbents for organic dye removal from water.

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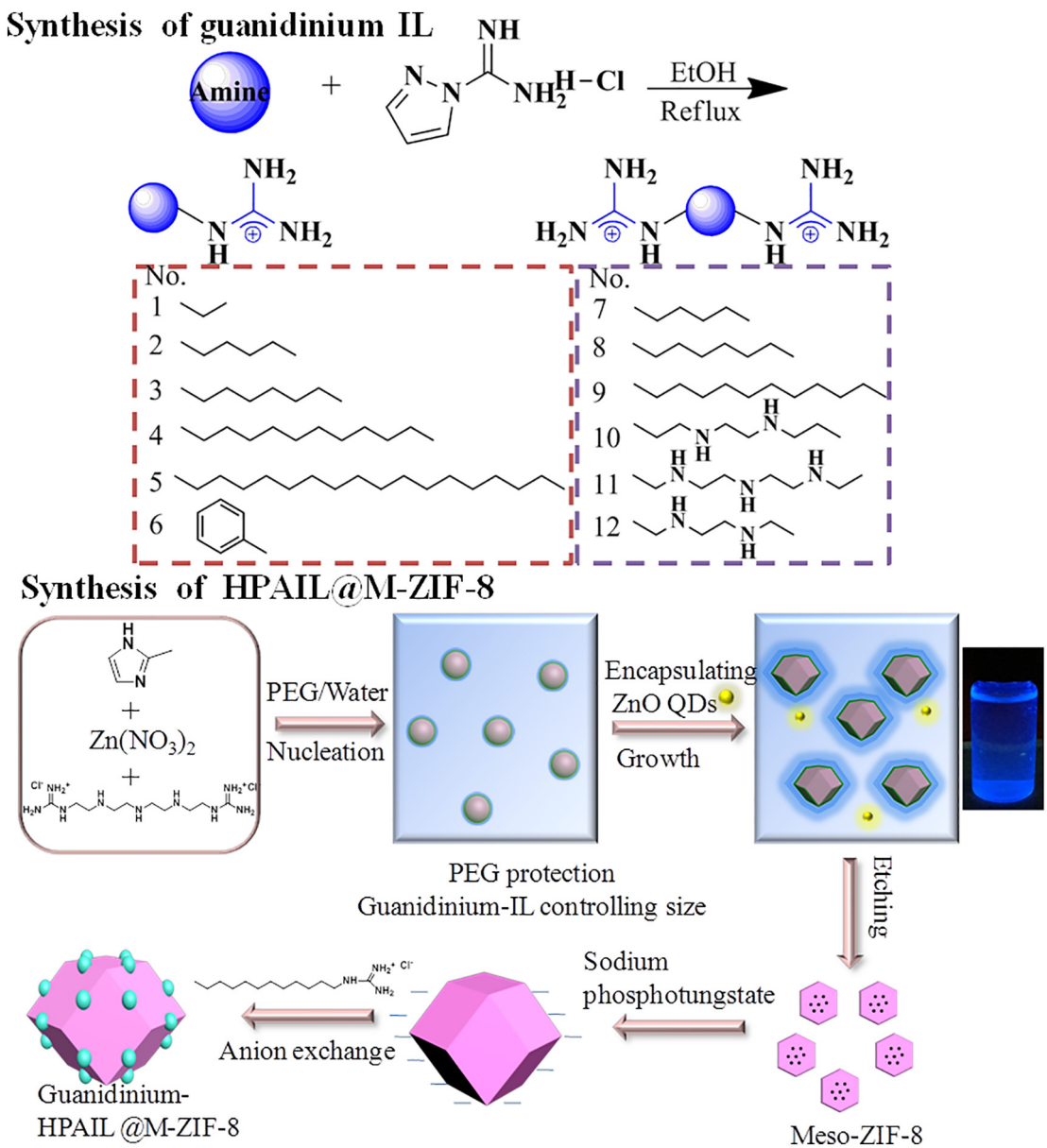
1. Introduction

Industrial toxic pollutants are worldwide problems which dramatically threaten environment and human health. Rhodamine B (RhB) has been listed as a priority pollutant by the European Environmental Agency and the US Environmental Protection Agency (EPA) because of its carcinogenic and neurotoxic characteristics, whereas it is still widely used in many fields (Jabli et al., 2018; Li et al., 2011). The discharge of RhB wastewater into hydrosphere without proper treatment has caused harm to the aquatic environment (Forgacs et al., 2004). Therefore, developing effective technologies of RhB removal is urgent for maintaining the quality and safety of water systems. Many efforts have been devoted to the removal of RhB from water including photocatalytic degradation, advanced oxidation, electrochemical technique, filtration and adsorption (Al-Hammadi et al., 2018; Pang et al., 2011; Saleh, 2018; Sun et al., 2018; Zhu et al., 2017). Compared with the other techniques, adsorption exhibits the advantages of high efficiency, simple operation, and lower risk of releasing decomposition products into the environment. Different types of adsorbents have been used for RhB removal such as red mud, activated-clay, porous carbon and metal-organic frameworks (MOFs) (Tuzen et al., 2018; Yagub et al., 2014). Among these adsorbents, MOFs have garnered tremendous attention in the last decade owing to their structural diversity, high porosity and tunable chemical functionalization (Easun et al., 2017; Li et al., 2016a, 2016b).

A large number of MOF structures have been designed and synthesized. One promising subclass of MOFs is zeolitic imidazolate frameworks (ZIFs) (Banerjee et al., 2008). In comparison to the other MOFs, ZIFs share many riches of zeolite chemistry and have high thermal and chemical stability, which make them attractive candidates for water treatment (Kaneti et al., 2017; Wang and Wang, 2016; Yao and Wang, 2014). In particular, ZIF-8 is one of the most studied prototypical ZIF (Venna et al., 2010). However, reported ZIF-8 particles showed low or negligible adsorption capacity toward RhB in water and adsorption affinity of ZIF-8 to RhB is relatively weak (Feng et al., 2016; Fan et al., 2014; Zhao et al., 2017). The particle size, crystallinity and dispersibility



Scheme 1. Schematic representation for the synthesis of guanidinium IL and HPAIL@M-ZIF-8.