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# Phosphate Adsorption Using Hierarchically Porous Functionalized Silica

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**Abstract:** Hierarchically porous functionalized silica material was synthesized with the use of P123 and polystyrene beads. Because of well-defined and interconnecting macro/mesoporous networks, the resulting adsorbent exhibited significantly better phosphate adsorption performance, including adsorption capacity and rate, as compared with the mesoporous adsorbent.

## 1 Introduction:

To date, the increasing discharge of contaminating nutrients, e.g. phosphate, into the aquatic system has resulted in serious environmental problems around the world. Therefore, there is a need to reduce the level of phosphate in wastewater before its release to environment. The adsorption processes have been recognized as effective ways. Among various phosphate adsorbents, there has been intensive interest on the development of mesoporous silica materials, due to their attractive features, *i.e.* a large surface area and ordered pore structure [1,2]. However, because of functional groups attaching on the silica surface, the decrease of pore sizes inside the functionalized mesoporous silicas limits diffusion [3]. In order to overcome this, more recently, research effort has been conducted on the synthesis of mesoporous materials with macropores. Herein, we reported our fabrication and use of hierarchically porous silica as a phosphate adsorbent. The presence of interconnected macroporous and mesoporous structures are expected to favour mass transfer and reduce transport limitation, thus higher phosphate adsorption capacity.

## 2 Experiments:

Macro/mesoporous silica was synthesized with 4:1 mass ratio of polystyrene to tetraethoxysilane [4]. The resultant silica was diamino-functionalized *via* a post-grafting method, followed by Al<sup>3+</sup> immobilization. The final adsorbent is denoted as MM-SBA. For comparison, the product fabricated without adding polystyrene was denoted as M-SBA. Both of the adsorbents were characterized by SEM (JSM-7401F) and XRD (Bruker D8 Advance diffractometer).

In the phosphate equilibrium tests [5], 0.025 g of adsorbent was added into 25.0 mL of phosphate solution with different concentrations. After 2 h, the solution was filtered and analyzed by Autoanalyzer 3. The adsorption capacities of adsorbents at the equilibrium were calculated and fitted to the well-known Langmuir and Freundlich isotherm models, respectively.

In the adsorption kinetic study, 0.10 g of adsorbent was added in 100.0 mL of 50 mg/L phosphate solution and shaken for 4 h. 2.0 mL of suspension was taken over a given period of time and analyzed.

## 3 Results and Discussion:

Fig. 1 shows the XRD patterns of M-SBA and MM-SBA, both of which have three SBA-15 characteristic diffraction peaks (100), (110) and (200) [6]. M-SBA exhibits a typical SBA-15 ropelike shape [6]; whilst MM-SBA exhibits a new morphology comprising macropores (Fig.2).

In Table 1, our experimental data are well fitted by both of Freundlich model and Langmuir model. As shown in Table 1, the quantitative Langmuir parameter ( $q_0$ )

Table 1. Langmuir and Freundlich isotherms parameters in the phosphate adsorption of M-SBA and MM-SBA.

| Sample | Langmuir        |                 |       | Freundlich |                 |       |
|--------|-----------------|-----------------|-------|------------|-----------------|-------|
|        | $q_0$<br>(mg/g) | $K_L$<br>(L/mg) | $R^2$ | $n$        | $K_F$<br>(mg/g) | $R^2$ |
| M-SBA  | 16.21           | 0.449           | 0.944 | 3.88       | 5.69            | 0.978 |
| MM-SBA | 23.59           | 0.498           | 0.941 | 3.73       | 7.99            | 0.977 |

for MM-SBA is 23.59 mg/g, which is significantly greater than that of M-SBA (16.21 mg/g). This is ascribed to the incorporation of macropores, which may promote the diffusion of phosphate to the active sites of MM-SBA.

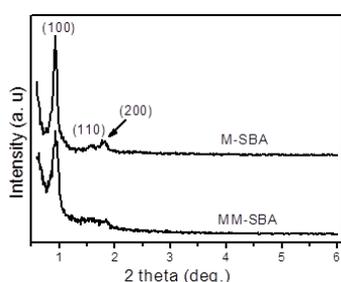


Fig. 1. XRD patterns of M-SBA and MM-SBA.

Fig. 3 shows the adsorption kinetic study with the use of M-SBA and MM-SBA. Over 95% of final adsorption capacity of MM-SBA is achieved in the first 1 min, as compared with only 79% for M-SBA, suggesting the faster phosphate diffusion within the macro/mesoporous structure.

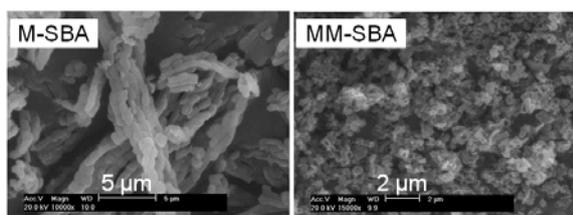


Fig. 2. SEM images of M-SBA and MM-SBA.

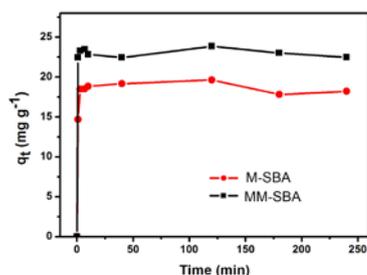


Fig. 3. Effect of contact time on phosphate adsorption of M-SBA and MM-SBA.

## 4 Conclusion:

MM-SBA with a macro/mesoporous network showed an enhanced phosphate adsorption capacity and faster adsorption rate.

## Acknowledgements

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