Monodispersed MCM-41 large particles by modified pseudomorphic transformation: diamine functionalization and application in bioseparation of proteins

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The research on organically functionalized mesoporous silicas has attracted extensive attention due to promising applications in diverse fields, such as electric devices, sensors, nanofluidic system, membranes, adsorption, and catalyst. Generally, three pathways are available for synthesizing inorganic-organic hybrid mesoporous organosilica materials: (1) post grafting, (2) co-condensation synthesis, (3) pseudomorphic transformation. By using post grafting, ordered meso-structure can be easily preserved; co-condensation approach can offer a better control of resultant materials in terms of a higher and more uniform surface coverage of organic; and it becomes readily to prepare uniform mesoporous spherical silica particles with desired sizes based on method (3). In this study, we try to combine the advantages of method (2) and (3).

Direct diamine functionalization of large spherical MCM-41 (15 micron in diameter) has been achieved via the co-condensation of pre-shaped spherical silica gel and [3-(2-aminoethyl aminopropyl)] triethoxysilane (ATMS) using a pseudomorphic transformation approach. The functionalized MCM-41 exhibits highly ordered hexagonal mesostructure, narrow pore size distribution, and high loadings of diamine group (1.785 mmol/g). The uniform particle size of pre-shaped silica gel has been well preserved during the simultaneous pseudomorphic transformation and functionalization, Various characterization techniques, e.g., thermogravimetric (TG), Fourier transform infrared spectroscopy (FTIR), ultra violet– visible-near infrared (UV-vis-NIR), and solid state $^{29}$Si
and $^{13}$C MAS NMR, demonstrate that the diamine groups incorporated in the spherical MCM-41 framework does not decompose. Benzaldehyde adsorption results strongly prove that the distribution of diamine groups is concentrated on the pore wall surface of MCM-41; they are active and accessible for further post treatment. The surface density of diamine groups can be easily controlled by changing the ATMS content in the initial synthesis mixture, while the order of mesoporous MCM-41 structure maintains. This preparation method provides a new synthesis protocol to modify large particle mesoporous materials with different functional groups. Furthermore, it is demonstrated that this diamine-functionalized MCM-41 large particle can be used to separate native proteins efficiently.