Chapter 16

Smart Mesoporous Nanomaterials With Improved Therapeutic Applications: Therapeutic Application of MSN

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ABSTRACT

Nanomaterials have revolutionized the drug delivery and therapeutic industry due to their unique physical characteristics, which render them extremely manipulative at nano-scale. One such category of nanomaterials is mesoporous silica nanoparticles. Due to their small size and rigid honeycomb-like structure, they are highly conducive for packaging of drugs, dyes, antibodies, etc. In addition, they show excellent biocompatibility. These new generation nanomaterials can be further functionalized by incorporating surface modifications, thus increasing their acceptability as carriers for drugs and molecules. In this chapter, a brief and comprehensive review covering various aspects of the recent advancements in synthesis of mesoporous nanomaterials and post-synthesis strategies for functionalization has been presented. Further, it also sheds light on how efficiently these smart nano-carriers are involved in transport and site-specific delivery of highly toxic drugs, like chemotherapeutic agents for cancer treatment, and their biocompatibility evaluation from a biosafety point of view.

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BACKGROUND

Nanomaterials have revolutionized the drug delivery and therapeutic industry due to their unique physical characteristics which render them extremely manipulative at nano-scale. One such category of nanomaterials is mesoporous silica nanoparticles. Due to their small size and rigid honeycomb-like structure, they are highly conducive for packaging of drugs, dyes, antibodies etc. Besides, they show excellent biocompatibility. These new generation nanomaterials can be further functionalized by incorporating surface modifications, thus increasing their acceptability as carriers for drugs and molecules. In this chapter, a brief and comprehensive review covering various aspects of the recent advancements in synthesis of mesoporous nanomaterials and post-synthesis strategies for functionalization has been presented. Further, it also throws light on how efficiently these smart nano-carriers are involved in transport and site-specific delivery of highly toxic drugs, like chemotherapeutic agents for cancer treatment, and also, their cytocompatibility/biocompatibility evaluation from biosafety point of view.

INTRODUCTION

In recent era, nanomaterials have got immense applications in healthcare, electronics, cosmetics and other areas (Xia, Yang, Sun, Wu, Mayers, Gates, Yin, Kim, & Yan, 2003; Sanchez, Belleville, Popall, & Nicole, 2011; Vallet-Regí & Arcos, 2015). They are widely used in nanomedicine which opens new range of solutions for different problems (Lanone, & Boczkowski, 2006; Shi, Votrub, Farokhzad, & Langer, 2010; Fernandez-Fernandez, Manchanda, & McGregor, 2011; Albanese, Tang, & Chan, 2012). Till date, more than 250 nanomedicine products have been developed that have been either accepted for use or are at different stages of clinical study (Etheridge, Campbell, Erdman, Haynes, Wolf, & McCullough, 2013). Besides, nanomaterials have also been employed in development of target-specific drug therapies and methods for early diagnosis of pathologies. Consequently, powerful new nano-devices for early diagnosis, prediction, prevention and personalized treatment of cancer tumors have been developed (Barreto, O’Malley, Kubeil, Graham, Stephan, & Spiccia, 2011; Xie, Liu, Eden, Ai, & Chen, 2011; Baeza, 2014). Use of nanoparticles (NPs) has allowed more effective and patient friendly treatment regimens by reducing drug concentration and dosing frequency, easy administrations and improved safety. Inorganic nanomaterials are highly advantageous as compared to the organic ones in terms of high thermal, chemical and mechanical stability under physiological conditions and biocompatibility. Among inorganic nanomaterials, mesoporous silica nanoparticles (MSNs) are one of the most promising drug carriers, and have attracted increasing attention in fields such as drug delivery, diagnostics, medical imaging and engineering due their unique properties (Figure 1) that include: large surface area (~1000 m²·g⁻¹ for MCM-41 type particles) and large pore volumes (~1 cm³·g⁻¹) providing high loading capacity, high degree of tunability, morphology and pore diameter, biocompatibility, bio distribution, biodegradation and excretion (Vallet-Regí, Balas, & Arcos, 2007; Manzano, Colilla, & Vallet-Regí, 2009; Gai, Yang, Li, Wang, Niu, & Lin, 2010; Yang, Gai, & Lin, 2012; Argyo, Weiss, Braeuchle, & Bein, 2014; Tang, Hu, Zhang, Song, Nie, Wang, Niu, Huang, Lu, & Chen, 2012; Li, Barnes, Bosoy, Stoddart, & Zink, 2012; Colilla, Baeza, & Vallet-Regí, 2015; Vallet-Regí, Manzano, & Colilla, 2012; Martínez, Fuentes-Paniagua, Baeza, Sánchez-Nieves, Cucuñá, Gómez, de la Mata, González, & Vallet-Regí, 2015). Besides, the ease with which MSNs can be synthesized and that too with a range of