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Basic evaluation of typical nanoporous silica nanoparticles in being drug carrier: Structure, wettability and hemolysis

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ABSTRACT

Herein, the present work devoted to study the basic capacity of nanoporous silica nanoparticles in being drug carrier that covered structure, wettability and hemolysis so as to provide crucial evaluation. Typical nanoporous silica nanoparticles that consist of nanoporous silica nanoparticles (NSN), amino modified nanoporous silica nanoparticles (amino-NSN), carboxyl modified nanoporous silica nanoparticles (carboxyl-NSN) and hierachical nanoporous silica nanoparticles (hierachical-NSN) were studied. The results showed that their wettability and hemolysis were closely related to structure and surface modification. Basically, wettability became stronger as the amount of —OH on the surface of NSN was higher. Both large nanopores and surface modification can reduce the wettability of NSN. Furthermore, NSN series were safe to be used when they circulated into the blood in low concentration, while if high concentration can not be avoided during administration, high porosity or amino modification of NSN were safer to be considered. It is believed that the basic evaluation of NSN can make contribution in providing scientific instruction for designing drug loaded NSN systems.

1. Introduction

Nanoporous silica nanoparticles with nano pores (1–100 nm) possess common characteristics of being drug carriers, including nontoxic, good biocompatibility and degradability, and also unique advantages over other organic materials, such as tunable particle size, stable structure, double functionality of internal and external surface area, etc. [1–7] It is widely accepted that there are three types of nanoporous silica, including microporous, mesoporous, and macroporous silica. The term “microporous” refers to pore diameters of less than 2 nm, “mesoporous” is defined as diameters between 2 and 50 nm and “macroporous” refers to pore size range of greater than 50 nm [8]. They have been studied for considering as drug carriers in varying degrees, mainly covering immediate drug delivery systems, sustained drug delivery systems, stimuli-responsive controlled drug delivery systems and targeted drug delivery systems [9–15]. Though there is a massive of papers reported the application of nanoporous silica nanoparticles as drug carrier, the fundamental study on its ability in undertaking the mission of being drug carrier has rarely presented. Herein, our work focuses on the above exploration and makes efforts in establishing basic evaluation of typical nanoporous silica nanoparticles as drug carrier, which can significantly provide important instruction for designing drug loaded nanoporous silica nanoparticles systems. In the application of being drug carrier, the capacity of delivering drug molecules and its safety in physiological environment of nanoporous silica nanoparticles would be the most crucial points to be concerned. Therefore, the presented work mainly covers basic considerations regarding its uses in drug delivery systems, including structure, wettability and hemolysis. It is believed that the basic evaluation of nanoporous silica nanoparticles is of great scientific value in offering guidance for constructing drug loaded nanoporous silica nanoparticles systems.

Herein, typical nanoporous silica nanoparticles that consist of nanoporous silica nanoparticles (NSN), amino modified nanoporous silica nanoparticles (amino-NSN), carboxyl modified nanoporous silica nanoparticles (carboxyl-NSN) and hierachical nanoporous silica nanoparticles (hierachical-NSN) were studied for evaluating their capacities in being drug carrier.

2. Materials and methods

2.1. Materials

Tetraethoxysilane (TEOS) and 3-aminopropyltriethoxysilane (APTES) were purchased from Aladdin (Shanghai, China). All other chemicals were of reagent grade and were used without further purification. Ion exchange system was used for preparation of deionized water, which was used throughout the experimental work.

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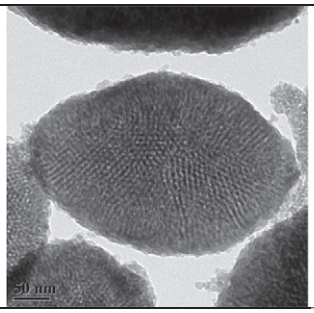
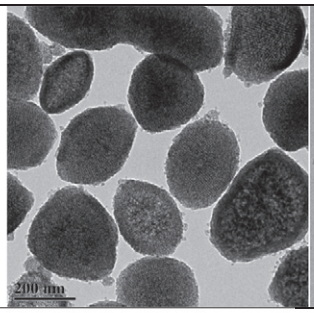
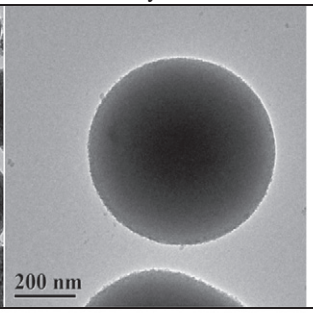
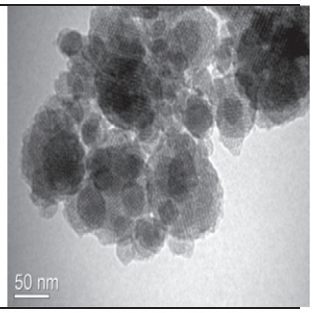
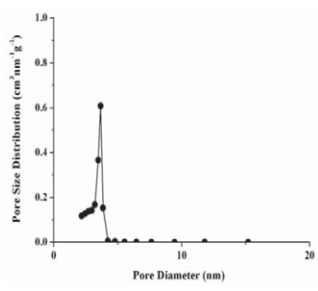
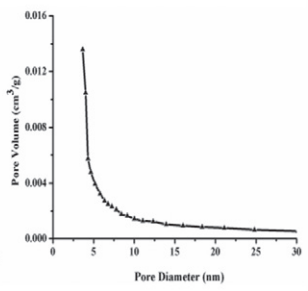
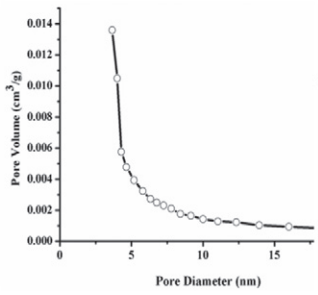
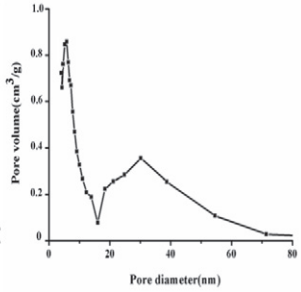
Table 1
The structure information of the four typical NSN.

Structure	NSN	Amino-NSN	Carboxyl-NSN	Hierachical-NSN
TEM image				
S_{BET} (m^2/g)	525.36	190.74	460.46	376.93
V_t (cm^3/g)	0.45	0.3923	0.3009	1.06
W_{BJH} (nm)	4.9	<3.65	<3.65	35.08, 3.47
Pore size distribution				

2.2. Preparation of the four drug carriers

The synthesis process of NSN was referred to the reference reported [16] with some modification. In a typical run of preparing NSN, 1.1 mmol C_{16}-L-alanine was dissolved in 10 mL deionized water on 70 °C water bath, to which 10 g NaOH (0.1 M) was added under stirring. Then cooled down the temperature of water bath to 22 °C and this mixture was stirred on 22 °C water bath for 1 h. Afterwards, a mixed solution consisting of 0.24 mL 3-aminopropyltriethoxysilane (APTES) and 1.57 mL tetraethoxysilane (TEOS) was dropwise added to the mixture under stirring with the stirring rate of 800 rpm, and stirring was kept for 10 min after APTES and TEOS were added. Then the system was remained statically for 24 h, filtered, centrifuged, water washed and dried. Finally, the dried sample was calcined at 550 °C for 6 h to get

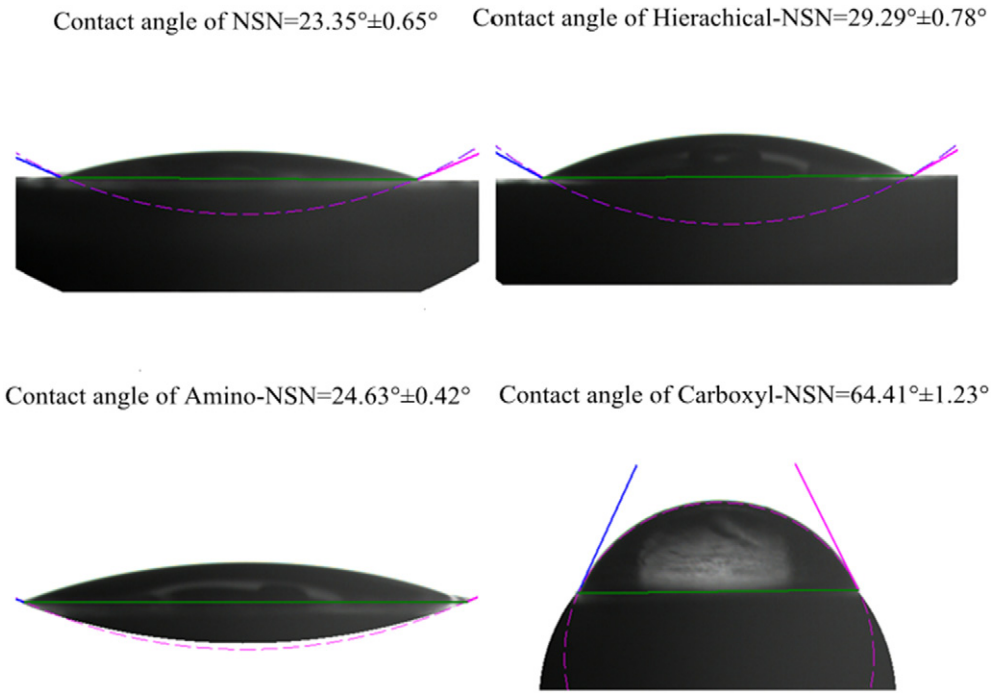


Fig. 1. Contact angles of the four typical NSN.