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Fluorine free superhydrophobic surface textured silica particles and its dynamics–Transition from impalement to impingement

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ABSTRACT

We report a facile method towards synthesis of fluorine free superhydrophobic mesoporous silica particles. Silica particles were prepared from rice husk (RH) as the silica source and CTAB as the structure directing agent. The as-prepared hydrophilic silica particles were converted to superhydrophobic structures by silane treatments. Silane treatment enhanced the wetting nature of the silica material from 60° to <150° and resulted in superhydrophobicity.

1. Introduction

Surfaces having an apparent water contact angle (WCA) greater than 150° with a low contact angle hysteresis (CAH) are called superhydrophobic surfaces. WCA of solid surfaces depends on chemical composition and physical topology of the surfaces [1]. The chemical composition determines the surface energy of the material whereas geometrical microstructure determines the roughness parameter (Scheme 1). Both should be balanced in a golden ratio to acquire superhydrophobicity. Recently, a large momentum has been gained in superhydrophobic surfaces because of the associated properties which are utilitarian as well as interesting like self-cleaning [2,3], low drag [4–7], antisticking, anti-contamination [8] and antifouling [9–11]. Superhydrophobicity, aka lotus effect goes back to the work of Barthlott who investigated leaf surfaces of 200 species [2]. The plant surfaces where covered with wax like materials and has micro-scale papillae which are accountable for the superhydrophobicity [12]. Rice, the cradle of food for half the world population displays anisotropic superhydrophobic wetting behaviour [7,13]*i.e.,* they shed water droplets in a directional nature, by the dint of its anisotropic arrangement of papillae parallel to the longitudinal direction of the leaf.

In this paper, we report a facile method to prepare superhydrophobic inorganic-organic hybrid mesoporous (MCM 41) silica particles from RH. Currently, more research is going on in superhydrophobicity to unravel fluoro compounds, which had been extruded completely in this synthesis that makes it an effective method to gear up for mass–production of superhydrophobic mesoporous silica particles. MCM 41 silica has plethora properties like highly ordered and well controlled pore with tunable diameter, large surface area, thermal stability and high density of surface silanols. These characteristics bestowed MCM 41 silica, a desirable candidate for use as catalyst, catalyst support and adsorbent [14,15]. Still, there is a lot left out, here we had unleashed one such excellent property, superhydrophobicity. Rice husk (RH), an agricultural biomass comprise of 20% silica [16]. In RH, silica exists in amorphous form which was extorted by combustion at 700 °C [17].The metallic impurities in RH were confiscated by treating it with dilute hydrochloric acid as their respective metal chlorides.

In addition, the impact dynamics of water droplet on the prepared superhydrophobic porous material had been studied. Impact of water droplets over a solid surface is ubiquitous phenomena observed during rainfall and shower, but the phenomenon is still

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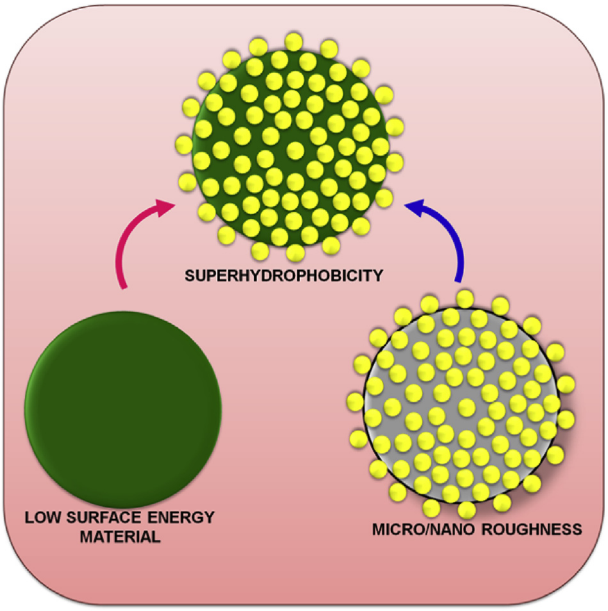


Scheme 1. Chemistry and physics of superhydrophobicity.

far being completely decoded and involves many field expertises like physics, engineering and mathematics. The shimmering of droplets takes place in a jiffy and the dynamics involved between the droplet and the surface can hardly be espied by the human eye. With the advent of high speed camera, the dynamics involved and the physics associated with the collateral interplay of surface tension, viscosity and impact velocity of the droplet could be studied with great accuracy. Over superhydrophobic surface water droplet customarily performs spectacular phenomena like bouncing, splashing, jetting and so on [18–20]. The reason is explicit that there is little interaction and the entrapped air in the superhydrophobic surface directs the outcome of the droplet. Mostly rebound dynamics on a superhydrophobic surface were done on hard substrate, whereas only very few were done on porous materials. Lu et al. had identified that one bounce was a criteria for a porous material to be superhydrophobic but it did not restricts, surfaces might be superhydrophobic even if there was no bounce [21].

2. Experimental

2.1. Materials and methods

2.1.1. Materials

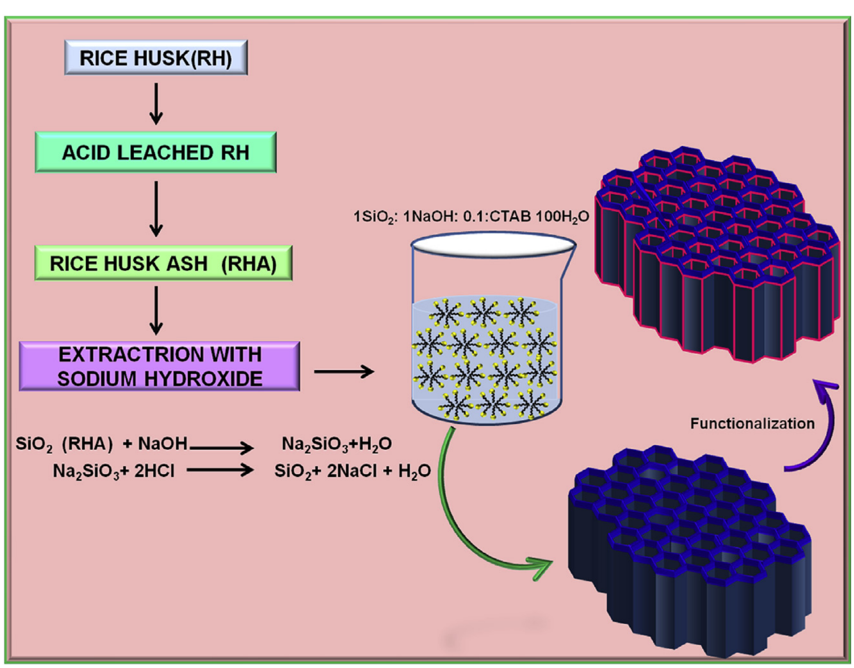
Rice husk was purchased from local rice mill. Sodium hydroxide, hydrochloric acid, cetyltrimethylammonium bromide (CTAB), acetone, toluene were procured from S D Fine Chemicals limited. 3-aminopropyl triethoxy silane, tri ethoxyoctyl silane, vinyl triethoxy silane, was purchased from Merck. The chemicals were used as such without further purification.

2.1.2. Preparation of silica

Silica was prepared by the following procedure. The overall strategy of the process was to introduce multiscale roughness by preparing mesoporous silica and then modifying with low surface energy material like silane that increases the contact angle. RH was washed with water and leached with 1 N hydrochloric acid for 1 h. After acid leaching RH was washed with water and dried at 100 °C in an air oven for 2–3 h. The resultant RH free from impurities was combusted at 700 °C for 6 h at a heating rate of 10 °C per minute in a muffle furnace. It was allowed to cool to room temperature and the obtained rice husk ash (RHA) was extracted as sodium silicate by refluxing it with 2.5 N sodium hydroxide for 3 h. The water glass (sodium silicate), thus obtained was filtered and neutralized with concentred hydrochloric acid and maintained at pH-7. The formed silica gel was successively washed with water to remove the excess acid and dried at 110 °C to obtain silica for 4 h.

2.1.3. Preparation and functionalization of mesoporous silica

Silica obtained from the above step was mixed with cetyltrimethyl ammonium bromide (CTAB), sodium hydroxide and



Scheme 2. Schematic representation for the preparation of functionalized mesoporous silica from rice husk.