Synthesis of Silica Aerogel from Bagasse Ash by Ambient Pressure Drying

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Abstract. Silica aerogels having very high surface area and pore volume have been successfully synthesized from bagasse ash by ambient pressure drying (APD) method. Silica in bagasse ash was extracted by alkali extraction to produce sodium silicate solution. This is done by boiling bagasse ash in 2 N NaOH solution under continuous stirring for 1 h. To avoid the collapse of gel structure during drying at ambient pressure condition, the silica surface was modified with alkyl functional groups by a single step sol-gel process. Silicic acid produced by exchanging Na⁺ ions in dilute sodium silicate solution with H⁺ ions from cation resin was added with trimethylchlorosilane (TMCS) and let the reaction of TMCS with water pore proceeds for several minutes to produce hexamethyldisilazane (HMDS) and HCl. Then, HMDS was added to allow the modification of silica surface in which the silanol groups were exchanged with alkyl groups originating from HMDS. The solution pH was then adjusted to 8–9 by adding NH₄OH solution to induce gel formation. The hydrogel was aged at 40°C for 18 h and at 60°C for 1 h. Then, it was dried at 80°C at ambient pressure condition. The silica aerogels obtained have specific surface area, as measured by BET method, ranging from 450.2 to 1,160.4 m²/g depending on the synthesis condition. The pore volume was ranging from 0.7 to 1.9 cm³/g. It seems that silica aerogels with very high surface area and pore volume can be obtained if the silanols group in the silica surface was exchanged successfully with alkyl groups from HMDS.

Keywords: bagasse ash, silica aerogel, ambient pressure drying

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INTRODUCTION

Sugar mills often use bagasse as a primary fuel source to supply all the needs of energy to move the plants. Bagasse is a cellulose fiber remaining after the extraction of the sugar-bearing juice from sugarcane. Burning bagasse as an energy source yields ash which is considered as a waste causing disposal problems. Bagasse ash is rich in silica, approximately 51%, and it can be economically viable raw material to produce silica gel and powder [1].

Affandi et al. demonstrated that high purity silica gel with relatively high surface area can be produced from bagasse ash by alkali extraction and acidification [1]. The silica gel has relatively high adsorption capacity of water vapor. Recently, silica aerogel, a unique porous materials with excellent properties, e.g. low density, very high specific surface area and low thermal conductivity, has attracted considerable attentions. Such kind of materials has many potential applications such as thermal insulator [3], catalyst support [4], adsorbents [5] and drug delivery system [6,7].

Silica aerogel was first discovered by Kistler in 1931 by water supercritical drying of hydrogel produced from sodium silicate. The supercritical drying has been a common method to synthesize aerogel although there are some modification in the method such as exchange of water with alcohol or carbon dioxide before supercritically drying. In recent years, there has been an attempt to develop a novel drying technique that made it possible to synthesize aerogels at ambient pressure instead of supercritical drying [8]. The key technique for successful ambient pressure drying (APD) is the effective removal of pore water from wet gels without shrinkage or cracks during the process.

The gel collapse during drying is mainly caused by the irreversible condensation of silanol groups on the silica surface. Therefore, the approach should be modification of silanol groups with non-reactive organic radicals using a sililation agent. The surface modification is typically carried out by sililation agents such as alkoxysilane or chlorosylane [2,8-10]. The surface area of silica aerogels synthesized using this method may reach 900 m²/g using sodium silicate as the silica precursor.

In this paper, we report on the synthesis of silica aerogels from bagasse ash using APD method. Silica in bagasse ash was first extracted by alkali extraction. The resulted sodium silicate was then used as precursor to produce silica aerogel by APD method.