

# Synthesis of Silica Nanoparticles from Sugarcane Bagasse by Sol-Gel Method

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## ABSTRACT

The silica nanoparticles have been successfully synthesized from sugarcane bagasse using the sol-gel method. Sugarcane bagasse contains abundant silica, so it can use as an alternative source of silica nanoparticles. Sugarcane bagasse was calcined at 650°C for 2 hours, and then it was extracted using NaOH to obtain sodium silicate solution. The solution was titrated with HCl for gelling process. The synthesized of silica nanoparticles from sugarcane bagasse were characterized using FTIR and XRD. Based on the XRD characterization, the results showed that the silica had an amorphous phase, and the FTIR spectrum has siloxane and silanol groups. The synthesized silica nanoparticles have an average size of 53 nm which was calculated using Scherrer Formula. From the data obtained, sugarcane bagasse can use as a source of silica nanoparticles.

## INTRODUCTION

The large amount of solid agricultural waste can be an environmental problem due to garbage accumulation, leads odor and health problem for human, including sugarcane bagasse. Sugarcane is one of the principal agricultural crop in Indonesia and it is the second largest agro-based industry after palm oil [1]. Sugarcane bagasse has been only used as animal feed, fertilizer production or reused as fuel in sugar factories and the ashes just thrown away. Chindaprasirt and Rattanasak [2] stated that sugarcane bagasse ash has a rich content of silica, where sugarcane roots play an important role in absorbing silica from the soil and transporting it to shoots, so it can used as a source of silica nanoparticle. Source of silica can found in various agricultural waste such as in sugarcane leaf and bagasse, rice husks, wheat husk, corn cob, nut grass, etc. Among many different natural resources available, sugarcane is one of the main potential source for silica extraction and subsequent transformation on nanostructured silicon [3].

Currently, nanotechnology is widely used in various important fields of science and technology such as electronics, medical, industry, etc. Development of ceramic nanoparticles with

improved properties has been studied with much success in synthesis and surface science such as silica, alumina, titania, zirconia, silicon nitride, silicon carbide, etc [4]. Silica is the second most abundant element in the earth surface, which accounts for approximately 32% of the total weight of it [5]. From previous studies, silica nanoparticles are used in various application such as sensor [6], polymer filler [7], drug delivery system [8] and dye-synthesized solar cell [9].

The synthesis of oxide nanoparticles attracts more and more attention because these nanoparticles exhibit electrical, optical and magnetic properties that are different from their bulk counterparts [10]. Application of silica nanoparticles as fillers in the preparation of nanocomposite of polymers has drawn much attention, due to the increased demand for new materials with improved thermal, mechanical, physical, and chemical properties [4]. Li et al. [7] prepared solid-state electrolyte with a walnut-like silica as nano-fillers and could effectively promote the mechanical property and electrochemical performance for next generation all solid-state lithium battery. Therefore, the synthesis of silica nanoparticles needs to be considered and research improved to develop its application.

Several method has used in preparation of silica nanoparticles including hydrolysis, pyrolysis, precipitation and sol-gel method [11]. Sol-gel process is a proper route to synthesis silica nanoparticles due to its ability to form high purity and homogeneous products at proper conditions [12]. Sodium hydroxide (NaOH) is preferred for alkali-SiO<sub>2</sub> extraction method for production of silica instead of sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>), because Na<sub>2</sub>CO<sub>3</sub> produces enormous amount of CO<sub>2</sub> during the process of extraction and this makes the process unsustainable to the environment [13]. Sugarcane bagasse ash is one of the most rich material of silica containing about 88% to 98% silica after purification [3,12,14]. The main impurities in silica present in industrial ash are Fe<sub>2</sub>O<sub>3</sub> and Al<sub>2</sub>O<sub>3</sub> (19.3 and 15.6 wt %, respectively), as a result of the mechanical processes of harvesting, cutting, transporting, milling and storing bagasse, whereas in the ash prepared

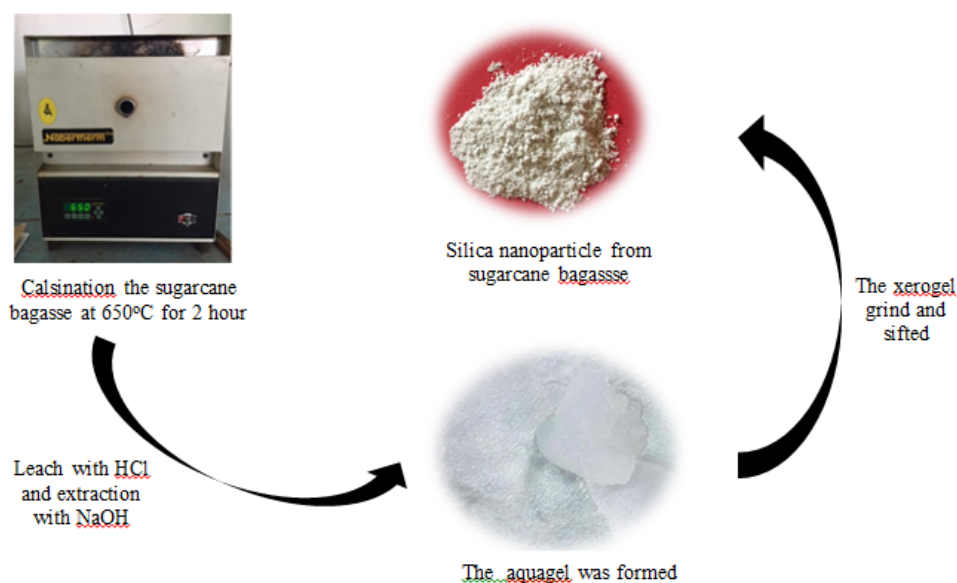
under controlled laboratory conditions, the main impurities are K<sub>2</sub>O and P<sub>2</sub>O<sub>5</sub> (24.8 and 11.5% by weight, respectively) [3]. The amount of the silica content in sugarcane bagasse is varied depending on the surrounding environment, nature of soil, period of harvesting and process involve [14].

According to Vaibhav et al. [15], synthesis silica nanoparticle from sugarcane bagasse obtained the high purity of 98% with the yield of 71%. Another study reported by Falk et al. [3] stated that synthesis silica nanoparticle from sugarcane bagasse ash by sol-gel method showed an average size ~10 nm, high level of purity ~97% and predominantly amorphous character. Based on the described background, in this study sugarcane bagasse from waste of juice shop used to synthesis silica nanoparticles through sol-gel method. Chemical composition, crystalline phases and particle size were characterized.

## EXPERIMENTAL

### Synthesis Silica Nanoparticle from Sugarcane Bagasse

Extraction of silica nanoparticle was carried out through sol-gel method [3]. The source of sugarcane bagasse was collected from waste juice shop around Surabaya, Indonesia. The sugarcane bagasse was washed and dried then cut into smaller size. Sugarcane bagasse calcined at 650°C for 2 hours. 1 gram of sugarcane bagasse ash was leached with 10 ml HCl 1 M (HCl 37% Merck) and stirred under constant stirring for 1 h at 100°C. The leached sugarcane bagasse ash was filtered and the residue was washed with distilled water several times. The residue was added with 8 mL NaOH 1 M (Merck) and stirred under constant stirring at 100°C for 1 h. The mixture filtered and the filtrate taken, it was sodium silicate. The solution was titrated with HCl 1 M for gelling process. The aquagel formed was then left for 24 h to ageing process and washed with distilled water several times then dried. The xerogel of synthesized silica grinded in an agate mortar up to powder. The silica nanoparticle obtained, and then sifted with a 200 mesh sieve to obtain a homogeneous size of silica nanoparticle.



**Scheme 1:** Synthesis of silica nanoparticle from sugarcane bagasse.

## Characterization

Fourier transform infrared spectroscopy (FTIR) was carried out to characterize the silica nanoparticles from sugarcane bagasse. An FTIR spectrum was acquired with a Shimadzu FTIR-8400 spectrometer over a wavenumber range from 400-4000  $\text{cm}^{-1}$  at room temperature [16].

The crystalline phase of the synthesized silica nanoparticle was determined by X-Ray diffraction (XRD) using Philips X-Pert XRD with a Cu-K $\alpha$  light source ( $\lambda = 1.5405\text{\AA}$ , 40 kV and 30 mA). Samples were analyzed in the range of  $2\theta = 5^\circ$ - $60^\circ$  with a scan speed of 0.5 $^\circ$ /min at room temperature [17]. The crystallite size estimated using Scherrer Formula (1) and (2):

$$FWHM(2\theta) = \frac{b\lambda}{D \cos \theta} \quad (1)$$

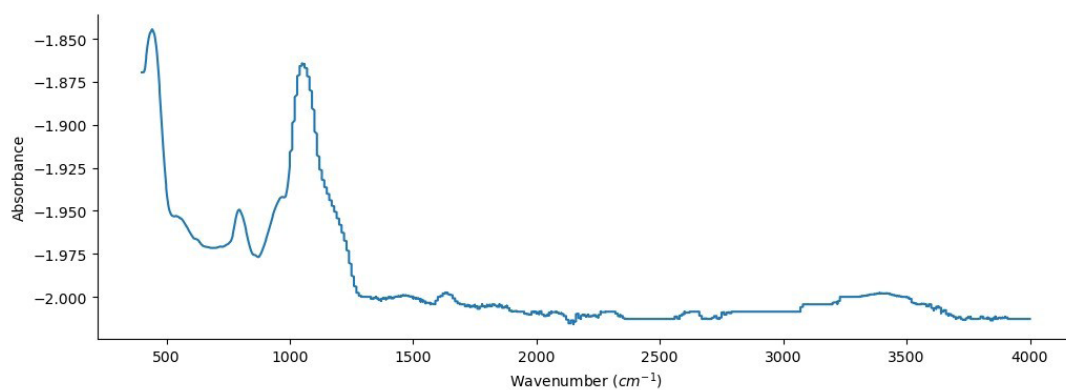
$$D = \frac{b2\pi}{FWHM(Q)} \quad (2)$$

Where FWHM is the full width of the peak,  $\lambda$  is the wavelength, Q is the magnitude of the scattering vector, b is a constant, which normally takes a value between 0.89 and 0.94 depending on the function used to fit the peak and D is the dimension of the crystallites monodisperse in size [17].

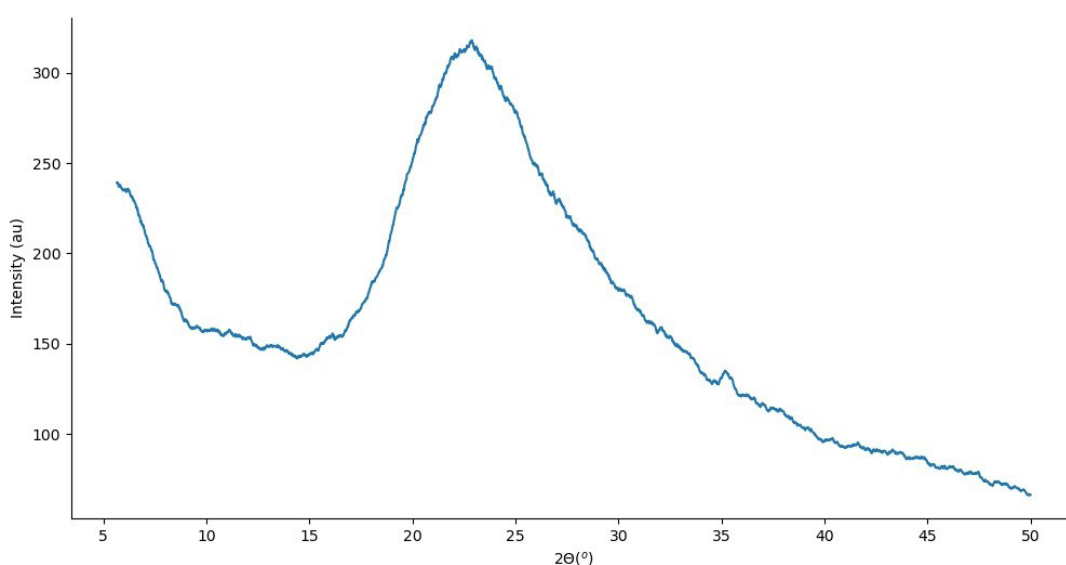
## RESULT AND DISCUSSION

Silica nanoparticle was produced from sugarcane bagasse ash using sol-gel method. The chemical composition of synthesized silica is shown in Figure 1 represents FTIR spectra of silica nanoparticle from sugarcane bagasse. The adsorption bands at 3421  $\text{cm}^{-1}$  is due to stretching vibration of the -OH bond, whereas peak at 1636  $\text{cm}^{-1}$  is attributed to bending vibration of H<sub>2</sub>O from silanol group (Si-OH) [13]. The bands at 1050  $\text{cm}^{-1}$  are assigned to Si-O-Si asymmetric stretching vibration and peak at 793  $\text{cm}^{-1}$  shows symmetric stretching vibration of Si-O-Si bond [18]. The peak at 436  $\text{cm}^{-1}$  is related to bending vibration of Si-O-Si bond. The solubilization of sodium silicate with hydrochloric acid leads the formation of silanol groups, while siloxane groups are formed due to condensation [19]. The FTIR spectra clearly indicating the formation of silica synthesized from sugarcane bagasse well formed.

Figure 2 represents the XRD pattern of silica nanoparticle from sugarcane bagasse ash which can be used to qualitatively and quantitatively analyze the degree crystalline. Falk et al., [3] stated that the crystalline peaks observed in sugarcane bagasse ash related to SiO<sub>2</sub> in the form of quartz (JCPDS 01-085-0796), Al<sub>2</sub>O<sub>3</sub> (JCPDS 01-0851337), and Fe<sub>2</sub>O<sub>3</sub> (JCPDS 01-087-1164). The characteristic peak corresponding to silica observed at  $2\theta$  of 22.6 $^\circ$ . Based on the peak at the XRD pattern, it showed a wide peak indicate to amorphous phase of silica [20]. The crystallite size estimated by the Scherrer formula based on the peak at  $2\theta$  of 22.6 $^\circ$  was 53 nm.



**Figure 1:** FTIR spectra of silica nanoparticle from sugarcane bagasse using sol-gel method.



**Figure 2:** XRD pattern of silica nanoparticle from sugarcane bagasse using sol-gel method.

## CONCLUSION

The silica nanoparticle has been successfully synthesized from sugarcane bagasse through sol-gel method. This method is simple and effective for synthesis silica nanomaterial from sugarcane bagasse. From XRD spectra, silica nanoparticle was an amorphous phase and has average size is 53 nm.

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