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Preliminary Study as Temperature Sensor of Nanosilica Based on Coastal and River Sand

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Abstract

The synthesis of nano-silica gel based on magnetic minerals from the coastal sand and river sand of Lombok Island has been carried out. The synthesis method used is sol-gel with HCl acid and NH4OH base. The results showed that nano-silica based on coastal sand has a greater silica content than nanosilica based on river sand. The morphology of nanosilica based on coastal is granular with a smaller grain size of nanosilica based on coastal sand compared to nanosilica based on river sand. To a temperature sensor, nano-silica based on coastal sand has a larger coefficient when compared to nanosilica based on river sand. This indicates that nano-silica based on coastal sand has better physical properties as a temperature sensor than nanosilica based on river sand.

INTRODUCTION

Indonesia is one of the largest producers of iron sand magnetic minerals in the world. This is because Indonesia is the country with the fourth longest coastline in the world. Apart from the coast, Indonesia also has rivers as a producer of iron sand magnetic minerals [1]. Iron sand magnetic minerals have mineral content that varies depending on the local source [2]. In general, iron sand magnetic minerals consist of Fe, Si, Ti, and Ni elements [3], [4].

One of the areas in Indonesia that contains iron sand is the island of Lombok [5]. The areas of Lombok Island that have a large enough iron sand magnetic mineral content are the Mataram area [1], Telindung [6] and Pringgabaya. In general, the most dominant magnetic mineral content found on Lombok Island is quartz sand (SiO2).

Silica is one of the most widely used compounds in daily life such as raw materials for solar cells [7], oil purifiers [8], catalysts [9], [10], antimicrobial [11], filler [12], [13], [14] and sensor [15], [16], [17]. The application of nano-silica as a sensor is an interesting study because of its economical nature [18], [19].

Sensors are electronic devices used to detect physical and chemical quantities in the surrounding environment [20], [21]. One of the most important sensors in life is the temperature sensor [22], [23], [24]. In general, temperature sensors use CMOS (complementary metal oxide semiconductor) material based on silica (SiO2) as the temperature field. Silica is a material that is widely contained in iron sand magnetic materials [25].

Previous research on the synthesis and utilization of nano silica based on magnetic minerals has been carried out. Ananda & Aini, (2021) successfully synthesized mesopore silica by using the sol gel method. Meiliyadi et al., (2023) synthesized nanosilica using the wet method and found that the nanosilica based on iron sand formed was influenced by the molarity of the NaOH solution used in the synthesis process. Bramantya et al., (2018) synthesized silica aerogel from sea sand as an oil spill absorbent and produced nano-silica absorbents that can absorb an average oil of 13.98 g per mass of silica aerogel.

However, the utilization of nano silica based on coastal sand and river sand as sensors has not been carried out. Nano silica is the basic material of CMOS which is a temperature sensor. Therefore, it is necessary to study and research the characteristics of nano silica based on river and coastal sand as temperature sensors.

EXPERIMENTAL METHOD

The synthesis method used in this study was the sol-gel [1]. In addition, the materials used are HCl with a concentration of 10 M Physical Analysis (99%). NH4OH with a concentration of 9 M Physical Analysis (99%) and deionized water. Mineral magnetic river sand and coastal then dried in the sun for 2 days to dry. Mineral magnetic river sand and coastal are then separated from impurities using a permanent magnet. Furthermore, washing is done using distilled water 5 times and dried. After washing, the magnetic minerals of river sand and coastal sand are dried in an oven at 80 oC for 12 hours to remove the water content in them [28]. The flow chart of the synthesis of silica is shown in Figure 1. The synthesis metode as the previous study [1], [5].

Morphological characterization of nano-silica gel was carried out by using SEM and mineral content analysis by using EDX type Jeol 700. The measurement of nano silica characteristics as a temperature sensor is shown in Figure 2.

Measurement of nano-silica gel temperature sensor characteristics by using the circuit shown in Figure 2. The laser beam used has a wavelength of 250 nm. The light intensity used uses a lux meter type Benetech GM1010.

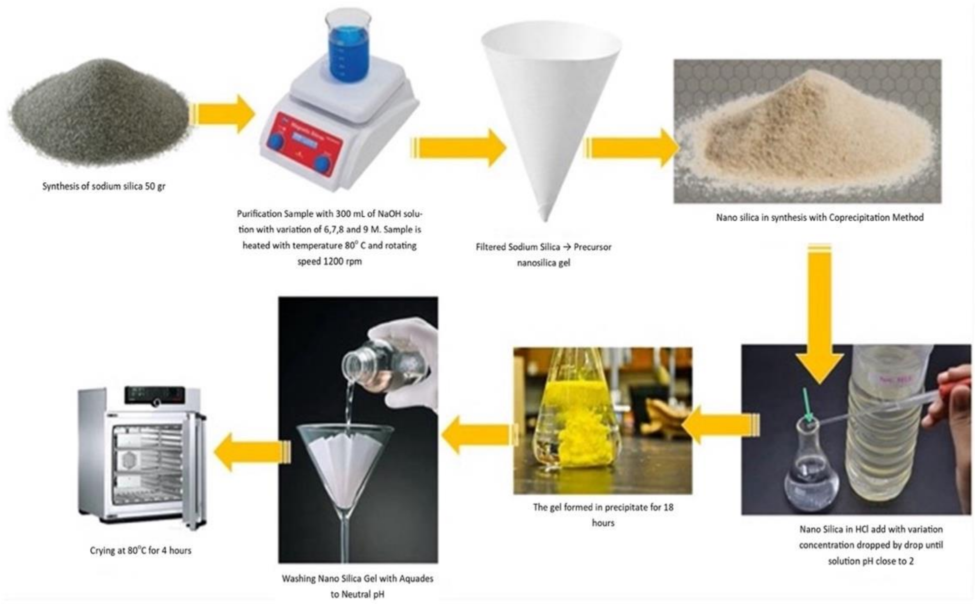


Figure 1. Flowchart of Nanosilica Synthesis Based on Coastal and River Sand

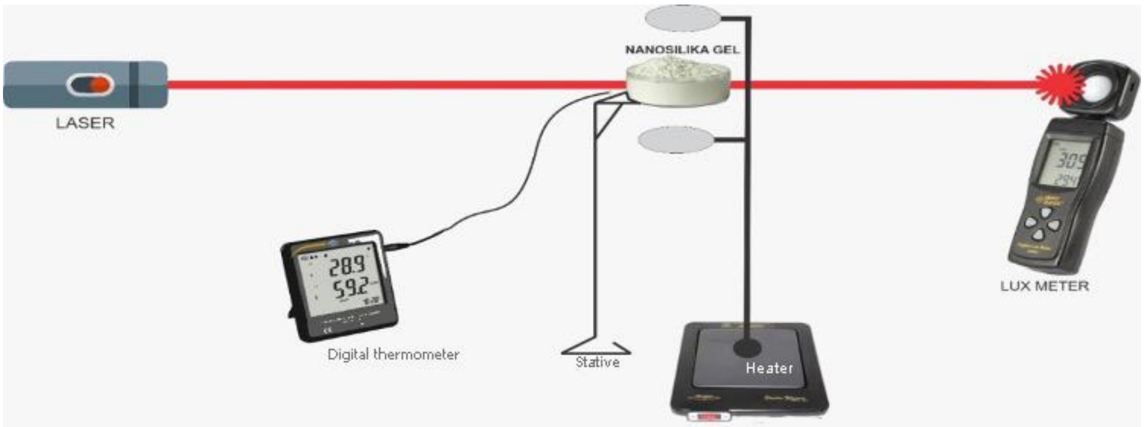
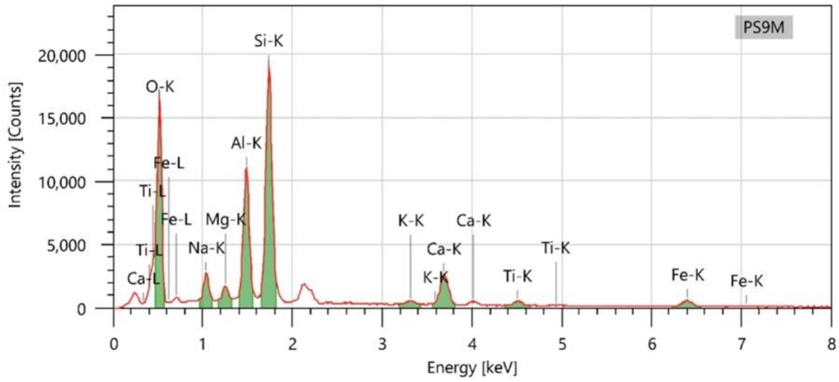


Figure 2. Schematic of Nanosilica Measurement as a Temperature Sensor

RESULT AND DISCUSSION

Mineral Content by EDX

EDX is used for the characterization of the mineral content of silica. The secondary electron source in EDX will hit the sample and the detector in EDX will capture the maximum intensity in each sample [29], [30]. The spectrum of EDX analysis results is shown in Figure 3.



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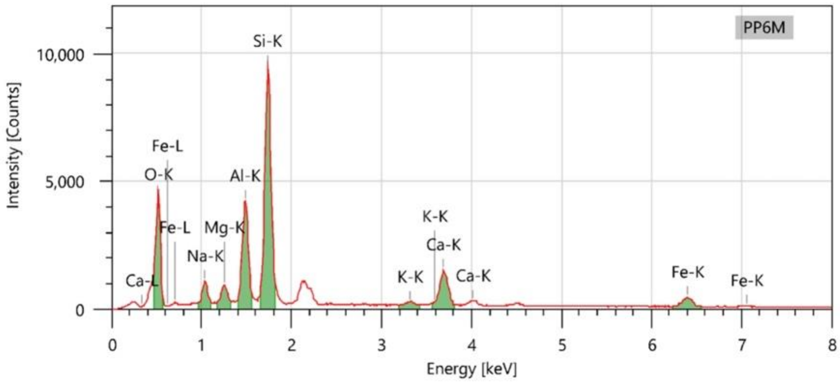


(b)

Figure 3. EDX Analysis Spectra of Nanosilica Sample Content Based on (a) Coastal and (b) River.

EDX can be used to qualitatively and quantitatively analyze. Quantitatively analyzes the percentage of each element [31]. The mineral content of nano-silica analyzed using EDX is shown in Table 1.

Table 1. Mineral Content of Synthesized Nanosilica

Element	Atomic percentage (%)

	Nanosilica based on River sand	Nanosilica based on Coastal Sand
O	58.64±0.55	47.51±0.85
Na	3.57±0.0.09	3.76±0.16
Fe	1.90±0.08	3.96±0.18
Ca	3.76±0.08	5.77±0.15
Si	19.35±0.17	25.63±0.31
K	0.39±0.02	0.46±0.04
Al	10.34±0.12	10.73±0.0.20
Ti	0.70±0.04	-
Mg	1.35±0.05	2.18±0.10

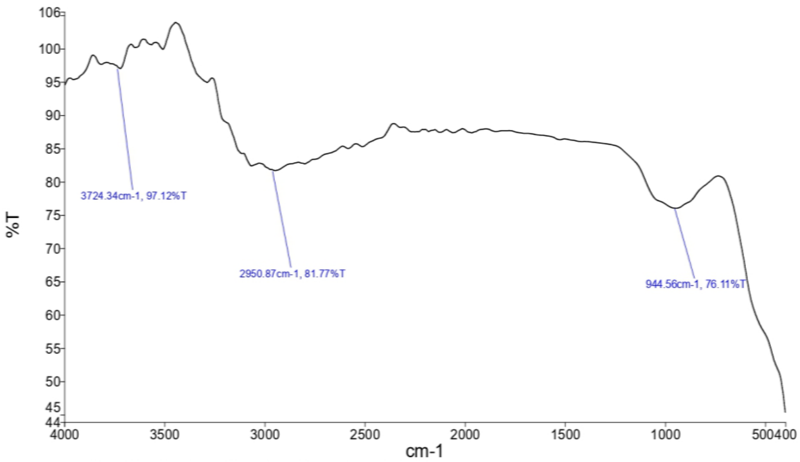
Table 1 shows the mineral content of nano-silica analyzed by using EDX. Table 1 shows that the largest mineral content based on coastal and river sand is silica. Where there is (19.35 ± 0.17) % in river sand-based silica and (25.63 ± 0.31) % in coastal-based silica. However, no titanium content was found in the nano-silica based on coastal sand. This indicates that the impurities of nanosilica based on coastal sand are less than nanosilica based on river sand [32].

FTIR Analysis

FTIR (Fourier Transform Infrared), is a modern infrared spectroscopy method equipped with Fourier transform techniques for detection and analysis of spectrum results [33]. The absorption spectrum as analyzed result of FTIR is shown in Figure 4.

Figure 4 shows wave absorption spectra from FTIR analysis of nano-silica based on (a) coastal and (b) river sand. The standard used is ASTM E1252. The mid-infrared region is the 400-4000 cm-1 wavenumbers. Unlike EDX, which determines the percentage of mineral content using secondary electrons fired from a source, FTIR uses molecular vibrational wavelength analysis to determine the functional groups of a material [34], [35]. The functional group of nano-silica as FTIR analysis is shown in Table 2.

Table 2 shows the functional groups of nano-silica at specific absorption wavelengths. It appears that both coastal sand and river sand-based nano-silica have almost all absorption wavelengths with the same functional groups. Both river sand and coastal sand-based nano-silica have three functional groups namely OH group stretch vibrations in H_2O and Si-OH, Si-O stretch vibration of Si-O-Si (siloxane), Si-O asymmetric stretch vibration of silanol (Si-OH) [36], [37].



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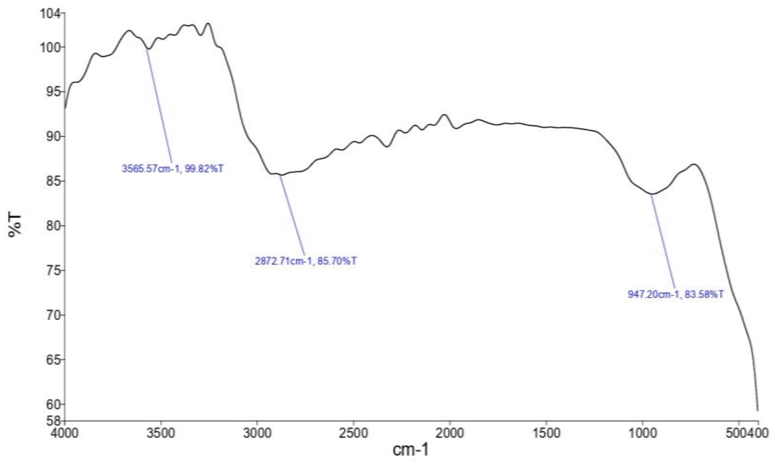


(b)

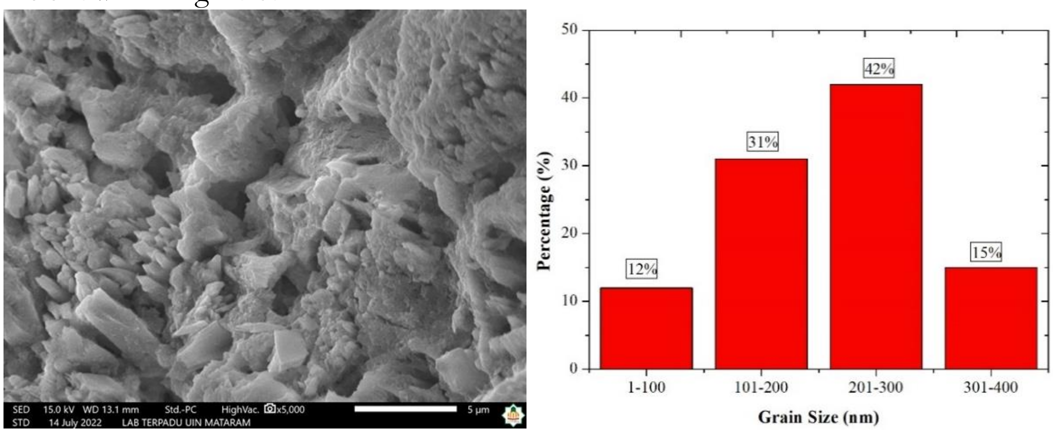
Figure 4. Wave Absorption Spectra From FTIR Analysis of Nanosilica Based on (a) Coastal Sand and (b) River Sand.

Table 2. Absorption Wavelengths of FTIR results.

Nanosilica source	Wavelength absorption (cm-1)	Functional Group
Coastal sand	3724.34	OH group stretch vibrations in Si-OH and H2O
	2950.87	Si-O stretch vibration of siloxane (Si-O-Si)
	944.56	Si-O asymmetric stretch vibration of silanol (Si-OH)
River sand	3565.57	OH group stretch vibrations in Si-OH and H2O
	2872.71	Si-O stretch vibration of siloxane (Si-O-Si)
	947.20	Si-O asymmetric stretch vibration of silanol (Si-OH)

Morphological Characteristics

The morphology and grain size distribution of nano-silica were analyzed using a scanning electron microscope. Grain size is one of the most important physical properties because it can affect the general physical properties of materials such as optical properties, electrical properties, mechanical properties and magnetic properties [38], [39]. The morphology and grain size distribution of nano-silica gel is shown in Figure 5.



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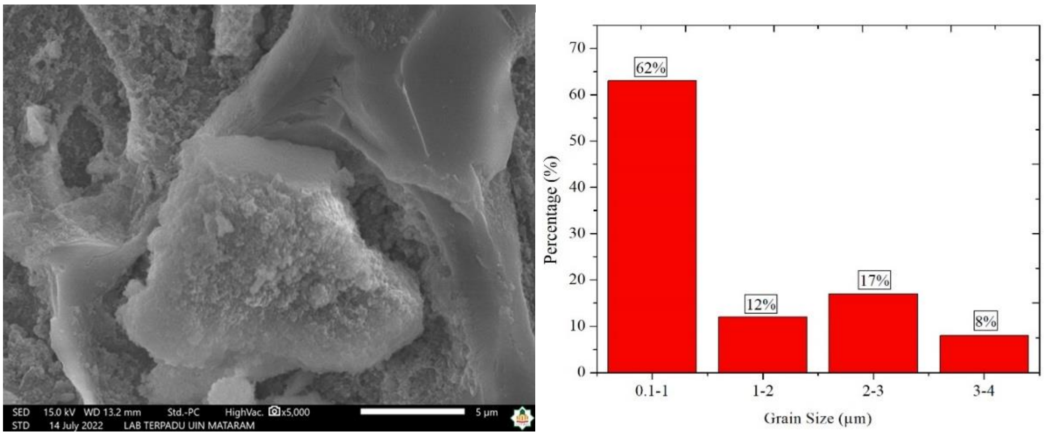


(b)

Figure 5. Morphology and Grain Size Distribution of Nanosilica Analyzed Using SEM (a) Coastal Sand and (b) River Sand.

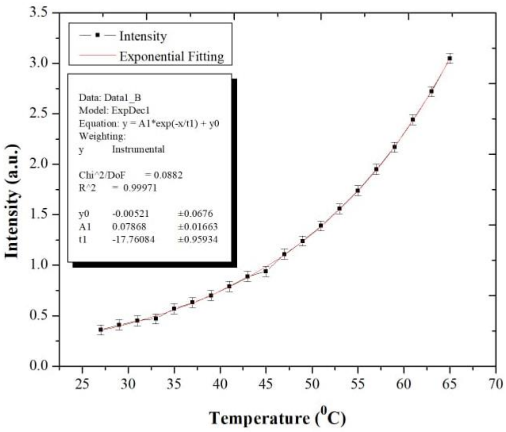
Figure 5 shows the morphology and grain size distribution of nano-silica analyzed using SEM. It appears that the nano-silica synthesized from coastal sand and river sand has a grain-shaped morphology. The coastal-based nanosilica has an average grain size of 359.47 nm which is much smaller than the river sand of 892.73 nm. Coastal sand has a much finer size than river sand. This is because coastal sand sediments are formed due to sea wave energy so that they have a finer structure. While river sand comes from limestone deposits that have fine and coarse structures [31].

SEM uses electron beams to image the surface shape of the sample being analyzed. SEM has a higher resolution than an optical microscope (OM). This is due to the de Broglie wavelength which has shorter electrons than the OM wave. Because the smaller the wavelength used, the higher the resolution of the microscope. SEM has a higher resolution than OM. The resolution that OM can produce is only 200 nm, while the resolution that SEM can produce reaches 0.1 - 0.2 nm [39], [40].

There are several important signals generated by the SEM. From the inelastic reflection, the secondary electron signal and X-ray characteristics are obtained, while from the elastic reflection, the backscattered electron signal is obtained [40], [41]. The differences between the images of secondary and backscattered electron signals are as follows: Secondary electrons produce the topography of the analyzed object, and high surfaces are brighter in colour than low surfaces [36].

Temperature sensor characteristics of nano-silica

The nano-silica passed by the laser is very sensitive even at relatively small temperatures. When measurements were taken, the digital thermometer showed room temperature as the initial temperature. It appears that at about 35°C, the intensity on the lux meter starts to increase due to the thermal effect. The results for laser intensity transmission as a function of temperature for the increasing temperature without an external field are shown in Figure 6.



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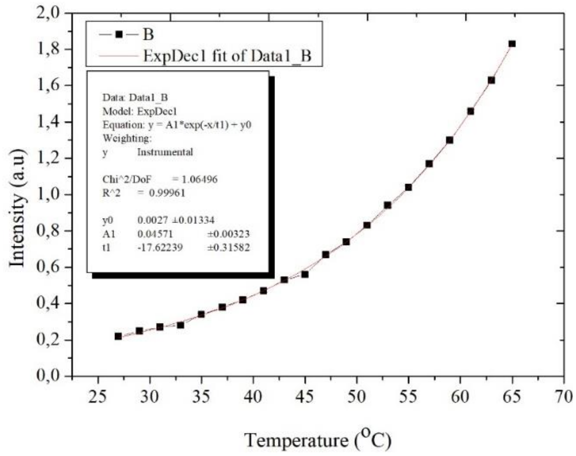

(b)

Figure 6. Graph Of Nanosilica Gel Response to Temperature (a) on Coastal Sand (b) River Sand

Figure 6 shows silica an impact on increasing the magnetic properties of the nano-silica agglomeration process due to thermal agitation and increasing the optical properties of magnetite which accelerates the transmittance process of the applied laser. The equation obtained after fitting results for nano-silica based on coastal and river sand is shown in Equation 1.

$$y = y_0 + Aexp\left(-\frac{x}{R}\right) \quad (1)$$

Where y is the intensity, x is the temperature, y0 is -0.00521, A is 0.07868, R0 is 0.05691 on the sand coastal and y0 is 0.0027, A is 0.04571, R0 is =17.62239 indicating that the intensity of the laser beam imposed on the nano-silica sample will be proportional to the exponential change in temperature by the theory.

Based on Figure 6, it can be seen that when the laser is passed through the silica without the influence of the external field, the maximum intensity achieved is about 3.5 lux with a maximum temperature of 65 °C. The intensity is initially 0.4 lux, as the temperature increases, the intensity value also increases with a relatively small temperature change [21].

Since thermal agitation can suppress the ability of agglomeration, optical transmission can be regulated by changing the ambient temperature around the nano-silica [42]. Thus, this preliminary study opens a great opportunity for the synthesized nano-silica to be applied as a temperature sensor, especially based on iron sand mineral magnetic.

CONCLUSION

Based on data analysis, it is obtained that nano-silica based on coastal sand has a greater silica than nanosilica based on river sand. The morphology of nanosilica based on coastal sand is granular with a smaller grain size compared to river sand. Concerning a temperature sensor, nano-silica based on coastal sand has a larger coefficient when compared to nanosilica based on river sand. This indicates that nano-silica based on coastal sand has better physical properties as a temperature sensor than nanosilica based on river sand.

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