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Synthesis and Characterization of Industrial Casting Sand Based Silica Aerogel

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Abstract: In this study, a commercial foundry sand (Seydisehir Eti Aluminium Co. Inc.) was provided as the starting material. Using this supplied casting sand, silica aerogel production was carried out by sol-gel method. Starting materials chemical components were determined by doing XRD and XRF analyses to starting industrial casting sand respectively. After analysing studies, sodium silicate solution was produced from commercial casting sand. During silica aerogel synthesize, 5 different pH degree was investigated including 2-4-6-8 and 9. Silica aerogel modification (Super hydrophobic) was made by choosing the optimum pH value. Afer then, on the synthesized experiment sample, FT-IR, BET, SEM and contact angle characterization studies were realised respectively. As a result of preliminary experiments done with different pH experiments, sample with the lowest density was determined as pH 8 value.
Keywords: Casting sand, Sol-gel, Silica aerogel

I. INTRODUCTION

The wealth of the casting industry in our country is of great importance in terms of Turkey's metal casting production worldwide. Casting sand is used in sand molds involved in the production of metal parts in foundries. Metal sand in a liquid state is cooled through pouring into molds, and the desired metal design is obtained. Approximately 4-5 tons of commercial casting sand are required for 1 ton of casting, and the casting sand added to the system is used several times [1].

In this context, one of the different application areas of commercial casting sands which are casting technology inputs is related to the synthesis of material by sol-gel method.

Among them, silica aerogel has been mostly encountered as the material that attract attention recently [2]. In recent years, researchers have gradually increased their studies on silica aerogels with unusual properties [3]. Silica aerogels are widely used in many different fields, including storage and transportation media, insulation, sensor, catalyst, ion exchange, and separation processes [4]. Silica aerogels have many unique properties, such as being open-celled, high porosity (80-99.8%), high surface area (500–1200m^2/g), low density (~0.003 g/cm^3), low thermal conductivity (0.005 W/M K), low dielectric constant (~1.0–2.0), and hydrophobicity [5,7,8]. 95% of its structure is covered with air. Thanks to this unique microstructure, it is known as the lightest solid in the world [6].

The synthesis studies of this material by the sol-gel method include the process of the transition from sol (solution) to gel by gelling. The gelling time depends on the amount of catalyst (HCl) added to the sol for gelling. The increase in the pH of sol increases the rates of condensation reactions and, thereby, silica clusters. At a low pH range (1-2), silica particles are positively charged and repel each other, so they have the longest gelling time. At values from pH 5 to 8, where the gelling of silica sol begins, the silica particles are negatively charged and repel each other. Gelling takes place with an increase in the viscosity value in this pH range [9].

Silica aerogels are produced by the sol-gel method, which is a simple, economical, and effective method. This method is carried out in four steps: solution creation and gelling, aging, drying, and condensation [10]. Silica aerogels can be hydrophilic (having a strong affinity for water) or hydrophobic (lacking an affinity for water) depending on the conditions during synthesis. The hydrophobicity of the material is measured by looking at the contact angle. Surfaces with a contact angle of less than 90° are hydrophilic, and water spreads on their surfaces. Surfaces with a contact angle between 90° and 150° are hydrophobic; water remains in the form of droplets on this type of surface and does not spread. Surfaces with a contact angle greater than 150°, on the other hand, are super-hydrophobic. These surfaces retain their hydrophobicity properties thanks to that silica aerogel repels water in humid and wet environments [11].

In this study, by using the sol-gel method, a silica aerogel synthesis was carried out with a commercial casting-sand starting material. After that, characterization studies of the synthesized silica aerogel experimental sample were carried out using different pH values.

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II. MATERIAL AND METHOD

For the synthesis of silica aerogel material by using the sol-gel method, a commercial casting sand (product of Eti Aluminum) was used. X-ray Diffraction (XRD) and X-ray Fluorescence (XRF) analyses were performed for the chemical composition of the starting material. The purification process of commercial casting sand was carried out by mixing it with pure water in a magnetic stirrer. 1M HCl was added to the stirrer until the pH value was 1. The prepared aqueous solution was mixed in a heating magnetic stirrer at 80 ºC for 2 hours. The mixture was filtered through a black tape filter paper and washed with pure water. It was dried for 1 day at 105 ºC in a drying oven. The solution was obtained by adding NaOH to the dried commercial casting sand. The prepared solution was reacted in an autoclave at 250 ºC for 2 hours. The sodium silicate was obtained by filtering the mixture, occurred at the end of the reaction, through the filter paper and separating it from the main solution.
Then, sodium silicate solution was obtained using commercial casting sand. After resting the prepared solutions, they were used for silica aerogel synthesis. In order to examine the effect of pH on silica aerogel production, 5 different pH values (2, 4, 6, 8, and 9) were screened (Figure 1). By adding 1M HCl to 10 ml of sodium silicate solution, it was ensured that the pH was 2, 4, 6, 8, and 9, respectively, with the help of a magnetic stirrer with fish. These prepared samples were kept at 25 °C for 24 hours and thus the gelling process was completed.

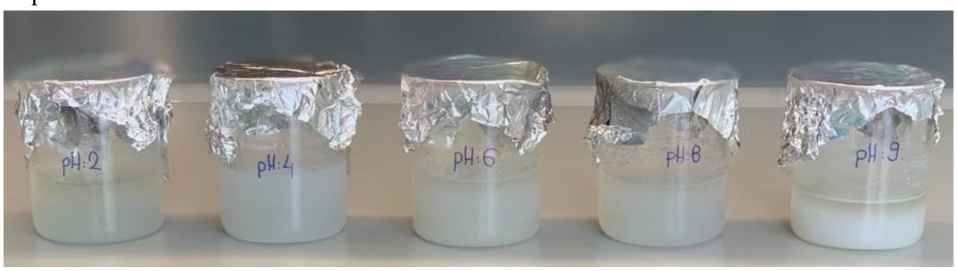

Fig 1. After pH study of sodium silicate solution

For the aging process, the samples whose gelling process had been completed were kept in the drying oven for 24 hours at 50°C to remove the water from their bodies (Figure 2). At the aging stage, 4 ml of ethanol was added to each of the samples.

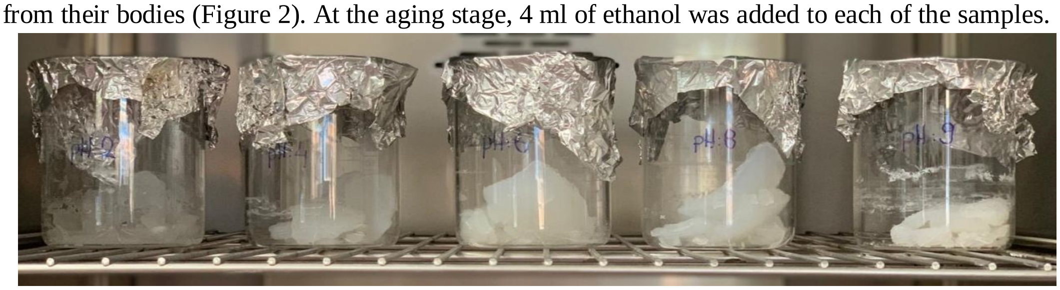

Fig 2. Aging process of silica aerogel

After the aging stage, the samples were left to dry. The samples were kept in the drying oven for 24 hours at 105 °C. In order to remove the salts contained in the structure of the synthesized aerogels, washing with pure water was performed and they were dried at 50 °C for 24 hours. In order to synthesize silica aerogel particles by using the sol-gel method, the study parameters specified in Table 1 were used. The initial commercial casting sand, which would be used in accordance with the specified study parameters, was made ready for synthesis studies.

TABLE I
Parameters used in the production of aerogel from commercial foundry sand

pH	Aging temperature (°C)	Aging time (hours)	Drying type
2	50	24	50^oC - fixed drying
4	50	24	50^oC- fixed drying
6	50	24	50^oC- fixed drying
8	50	24	50^oC- fixed drying
9	50	24	50^oC- fixed drying

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Depending on the synthesis studies of the experimental samples, FT-IR spectrum studies were performed to determine the bond structure in terms of identifying the structure of silica aerogel. In addition, density measurements of experimental samples were carried out depending on different pH parameters. The density measurements of the experimental samples were performed using volume calculation. Surface modification studies of commercial casting sand sample were carried out with TMCS (chlorotrimethylsilane). Then, Contact Angle measurement was made to determine the super-hydrophobicity of the sample.

III. RESULTS AND DISCUSSION

The chemical and structural properties of commercial casting sand, which was the starting material, were determined using XRF and XRD analyses. As can be seen in the XRF analysis result given in Table 2, it was found that there was silica content at a rate of 97.8% in the commercial casting sand. In addition, other chemicals were also observed to involve in trace amounts. When the XRD analysis result in Figure 3 was examined, it was determined that quartz (SiO2, PDF no: 00-046-1045) was included in the structure of the commercial casting sand.

TABLE III
XRF analysis for Commercial Foundry Sand (%)

Sample	SiO_2	Al_2O_3	MgO	CaO	Fe_2O_3	Na_20	K_20	P_2O_5
Commercial Foundry Sand	97.80	1.01	0.02	0.04	0.23	-	-	-

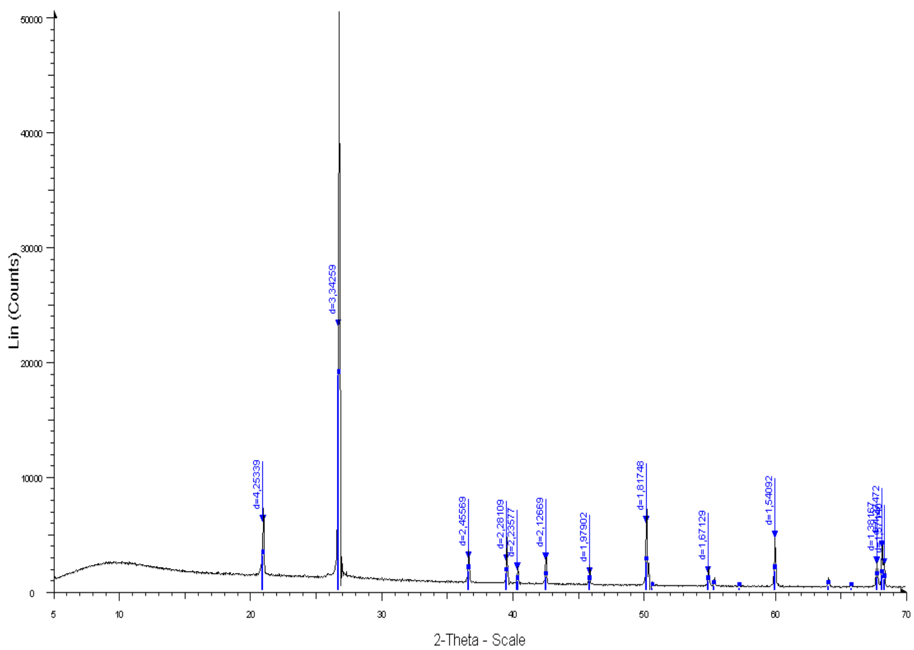

Fig 3. XRD analysis for Commercial Foundry Sand

In a similar study conducted by Mermer et al. in order to synthesis aerogel from sand by using the ultrasound-assisted sol-gel method, the most severe peak of the SiO_2 structure was identified at a similar distance of 2θ. In this regard, it was determined that the commercial casting sand analyzed with XRD gave a similar peak at a distance of 2θ [4-12]. In the production of silica aerogels from commercial casting sand at different pH values, the effect of pH was studied by keeping all parameters constant. Based on the density graph of the experimental samples in Figure 4, the lowest density (0.59 g/cm^3) was determined at pH 8.

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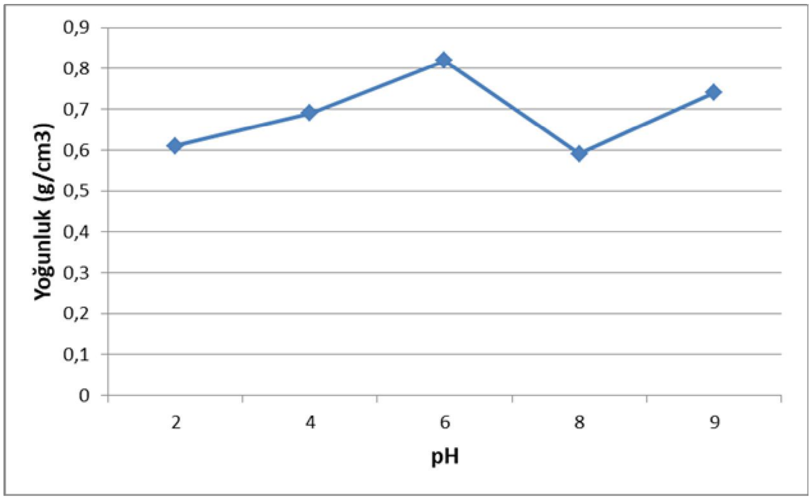

Fig 4. Density changes with different pH values

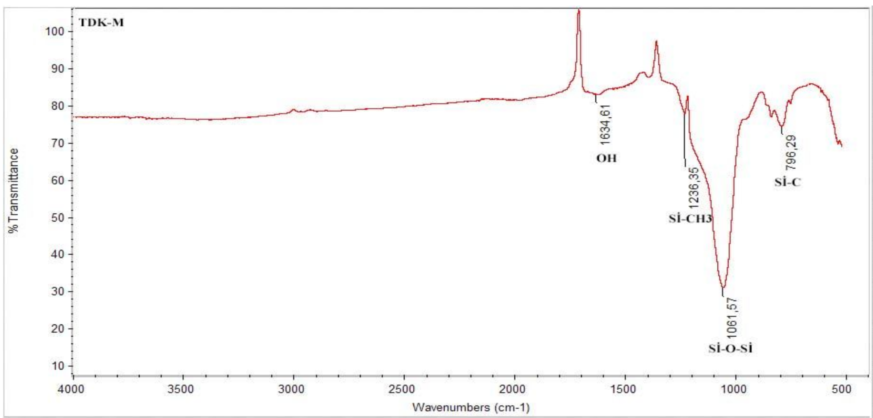

Fig 5. FT-IR spectrum of pH-8 sample

As seen in the FT-IR analysis of the optimum sample given in Figure 5, Si-C and Si-CH_3 absorption bands were observed as a result of binding TMCS to the structure. This shows that the synthesized experimental sample is hydrophobic, that is, it has the property of repelling water. When the values obtained from the XRD analysis of silica aerogel produced from commercial casting sand were examined (Figure 6), it was determined that there was an amorphous silicon peak at 2θ = 24° [4-12].

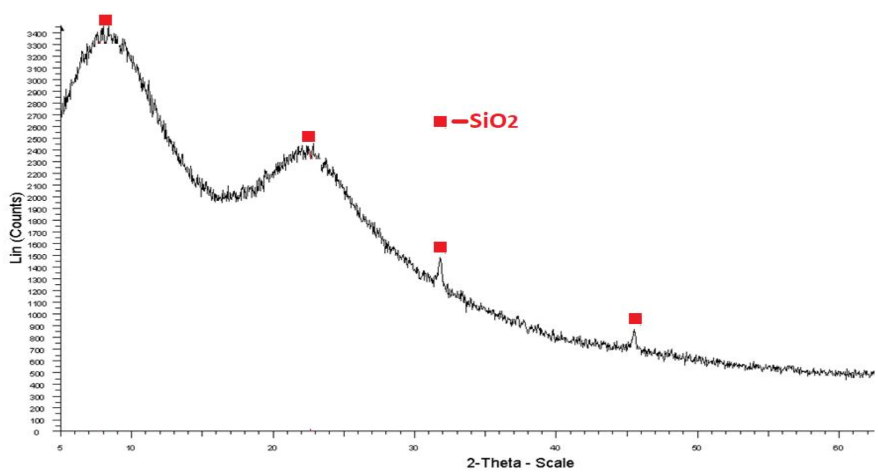

Fig 6. XRD analysis of the sample of superhydrophobic silica aerogel

Figure 7 shows an overview of the silica aerogel sample whose surface has been modified with TMCS. As can be seen in Figure 7-a, the contact angle of the silica aerogel sample was measured to be 167°. This value indicates that the silica aerogel sample produced from commercial casting sand has a super hydrophobic property. The image of the silica aerogel material whose synthesis and characterization have been completed in accordance with these experimental studies is shown in Figure 7b. It is also observed that silica aerogel material is white and powdery and also tends to clump/cluster when it is in low micronized sizes.

Fig 7. Silica aerogel material; a) contact angle of super hydrophobic silica aerogel, b) General image

IV. CONCLUSIONS

In this study, by using commercial casting sand, studies were carried out on the synthesis and characterization of silica aerogel material, which attracted attention with its lightness and superior properties recently. The overall results obtained are summarized below;

According to the XRF and XRD results of commercial casting sand used in the synthesis studies of silica aerogel material, which had super hydrophobic properties, by the sol-gel method, the SiO2 phase structure was identified and the chemical composition was determined as 97.80%. In the synthesis studies performed using different pH values, the lowest density value was obtained as 0.59 g/cm^3 at a pH value of 8. As a result of the FT-IR study, the presence of Si-C, Si-O-Si, and $Si\text{-}CH_3$ basic absorption bands was determined. In addition, silica aerogel in amorphous structure and basic formation peaks were determined by the XRD analysis. Finally, in terms of super-hydrophobic material synthesis, the contact angle of silica aerogel material was measured as 167°.

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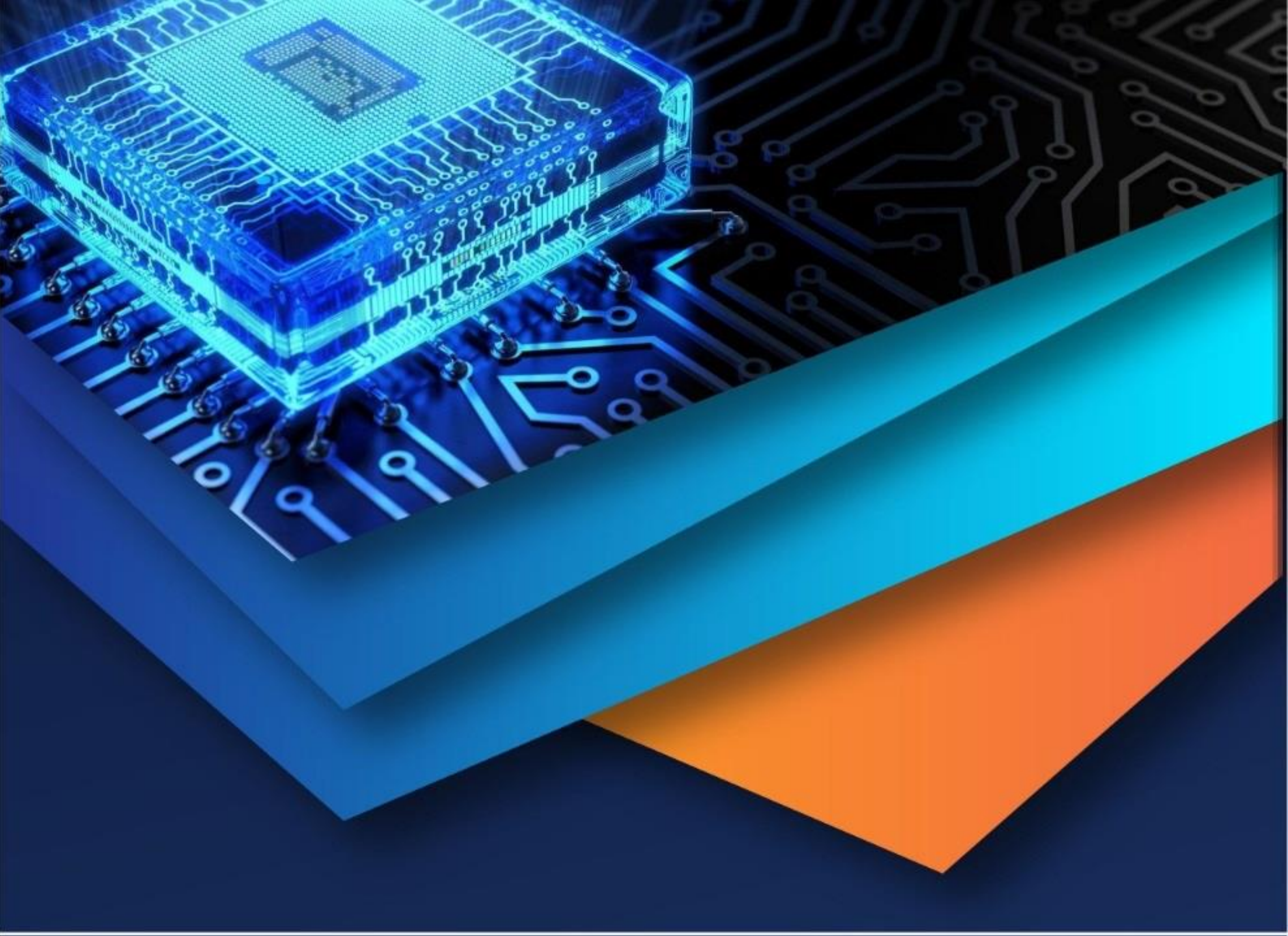

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