

## THE EFFECT OF RICE HUSK SILICA VARIATION ON THE SURFACE STRUCTURE AND HYDROPHOBIC PROPERTIES OF PDMS SHEETS

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### ABSTRACT

Polydimethylsiloxane (PDMS) is a polymer with high hydrophobic properties and good thermal stability, making it widely used in various functional material applications. However, the stability of its hydrophobic properties can be improved by adding filler particles such as silica. This study aims to analyze the effect of varying concentrations of silica from rice husks on the surface structure and hydrophobic properties of PDMS sheets. PDMS-silica sheets were fabricated using the spin coating method with varying silica concentrations of 1 wt%, 2 wt%, 3 wt%, 4 wt%, and 5 wt%. Characterization was performed using a Scanning Electron Microscope (SEM) to observe the surface morphology and water contact angle measurement to determine the degree of hydrophobicity. The results showed that the addition of rice husk silica affected the surface morphology of PDMS, where an increase in silica concentration caused the surface to become rougher and less homogeneous. The optimum condition was obtained at a variation of 4 wt% with a maximum contact angle value of 141.3°, which indicates an increase in hydrophobic properties due to changes in the surface structure. Thus, the addition of rice husk silica proved to be effective in increasing the hydrophobic properties of PDMS through modification of its surface morphology.

**Keywords :** PDMS; rice husk silica; surface structure; morphology; hydrophobic properties.



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## I. INTRODUCTION

In the field of functional materials, the development of materials with good surface properties and water resistance is important for various industrial and technological applications [1]. Such materials are able to prevent water absorption and damage caused by moisture, so they can be used as protective coatings, waterproof materials, and microelectronic components. One material widely used for this purpose is polydimethylsiloxane (PDMS), because it is lightweight, flexible, chemical resistant, and easily molded as needed [2].

PDMS has natural hydrophobic properties that prevent water from sticking to or being absorbed by its surface. These properties make PDMS stable in humid or wet environments, such as in protective coating applications, biomedical devices, and polymer-based sensors [3]. In addition, the production process is relatively simple and fast, making it suitable for various industrial and research applications.

Although PDMS has many advantages, its quality still needs to be improved, especially in terms of water resistance and surface stability [4]. One method that has been widely developed is the addition of filler particles, such as silica, which can increase the roughness and change the surface energy of PDMS. Silica from rice husks, which is an agricultural waste product, is an attractive option because it contains high levels of silica (around 80%) and is environmentally friendly [5].

The use of agricultural waste such as rice husks not only helps reduce waste, but also provides an economical and sustainable source of natural silica [6]. Compared to synthetic silica, silica from rice husks is cheaper and

involves a simpler process, thus potentially increasing the production efficiency of PDMS-based materials. Therefore, the use of rice husk silica as a filler also supports efforts to develop environmentally friendly and sustainable materials [7].

Vallabhuneni's (2018) research reported that adding silica from rice husks to PDMS can increase water resistance and surface roughness. As the amount of silica increases, the PDMS surface becomes rougher at the micro or nano scale, thereby decreasing its surface energy and increasing the water contact angle [8]. This means that the material becomes more hydrophobic and has a better ability to repel water.

However, to date, there have been few studies that specifically examine the effect of variations in rice husk silica concentration on the surface structure and hydrophobic properties of PDMS in depth [9]. Therefore, this study was conducted to determine how variations in rice husk silica affect the morphology and hydrophobic properties of PDMS sheets. It is hoped that the results can contribute to the development of environmentally friendly and economical water-repellent coating and surface protection materials [10].

Overall, the use of rice husk waste as a source of silica in the development of PDMS materials is an innovative and sustainable solution. In addition to reducing agricultural waste, this approach can also produce materials with better surface properties, high water resistance, and broad application potential in industry, biomedicine, and functional coatings [11].

## II. METHOD

This study used several main materials, namely Polydimethylsiloxane (PDMS), Silica, and hexane. PDMS was used as the main material for sheet production, while Silica served as a hydrophobic particle filler. Hexane was used as a solvent to prepare the silica suspension. These materials are very important for making modified PDMS sheets to improve hydrophobic properties and dielectric strength.

The sample preparation process began with the manufacture of PDMS sheets using the spin coating method. PDMS material with the trade name 184 silicon elastomer base and its curing agent were mixed at a volume ratio of 10:1 [8]. The mixture is stirred carefully using a spatula to prevent air bubbles from forming and to ensure homogeneity. Next, the homogeneous PDMS mixture is dripped onto a clean 1 cm × 1 cm glass substrate. The spin coating process is then carried out at a speed of 800 rpm for 60 seconds to distribute the PDMS mixture evenly on the substrate surface [12]. After spin coating, the sheet was dried in an oven at 90°C for 30 minutes to activate the cross-linking process. The dried PDMS sheet was then cooled at room temperature for 30 minutes to stabilize its structure.

The preparation of the silica suspension involved weighing silica according to four different concentrations: 100 mg, 200 mg, 300 mg, 400 mg, and 500 mg. Each silica concentration was dissolved in 20 ml of hexane and stirred until a homogeneous suspension was formed. This silica suspension was used to modify the surface of the PDMS sheet.

Surface modification was carried out by applying each silica suspension to the surface of the dried PDMS sheet using a spin coating technique at a speed of 800 rpm for 45 seconds [13]. This procedure allowed the formation of a thin silica layer on the surface of the PDMS film. Next, the modified film was placed in an oven at 90°C for 15 minutes to remove residual solvents and stabilize the silica layer, thus completing the surface modification process.

Characterization of the resulting sheets involved several analytical techniques. A scanning electron microscope (SEM) was used to observe the surface morphology and particle distribution on the modified PDMS sheets, providing insight into the structural effects of silica particles.

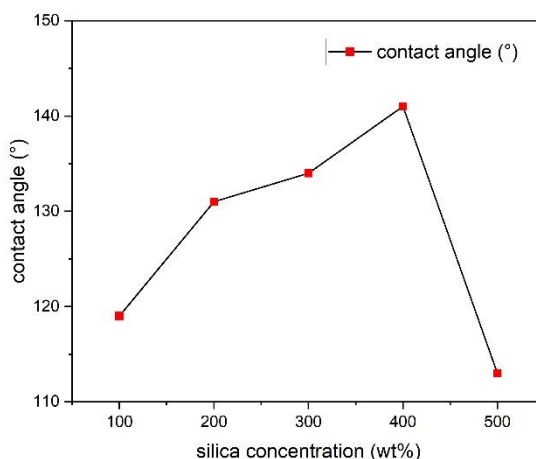
The hydrophobicity of the PDMS sheets was measured using the sessile drop method to determine the contact angle. This analysis involved measuring the contact angle formed by water on the surface of each coated PDMS sheet [14]. This combined characterization technique provides a deep understanding of the structural and functional properties of the modified PDMS sheets.

## III. RESULTS AND DISCUSSION

The data from this study consists of contact angles obtained from measurements of the silica solution layer on PDMS sheets, and morphological data on coated PDMS sheets.

### 1. Result of Contact Angle Characterization Analysis

Contact angle testing was conducted on silica concentrations of 1 wt%, 2 wt%, 3 wt%, 4 wt%, and 5 wt%. These measurements were taken to determine the optimum silica concentration for the hydrophobic coating to be produced. The contact angle data results can be seen in the graph below.

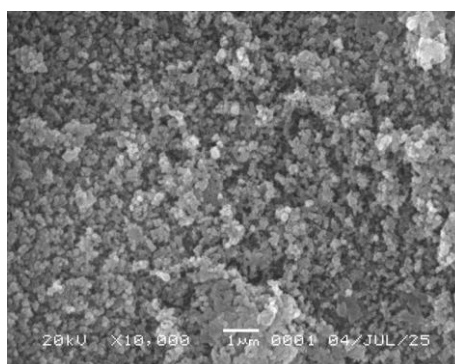


**Fig 1.** Graphical results of contact angle testing

The graph shows that the contact angle gradually increases as the silica concentration increases from 1 wt% to 4 wt%, with the highest value of  $141.3^\circ$  at a concentration of 4 wt%. This proves that the addition of silica can strengthen the hydrophobic properties of PDMS through increased surface roughness and more even particle distribution [15]. However, at a concentration of 5 wt%, the contact angle value decreases dramatically to  $113.5^\circ$ , indicating uneven distribution of silica particles or agglomeration on the surface. This condition actually reduces the material's ability to repel water. Thus, the optimum concentration for producing the highest hydrophobic properties in this study is 4 wt%, while higher concentrations have the potential to reduce performance due to surface morphology instability [16].

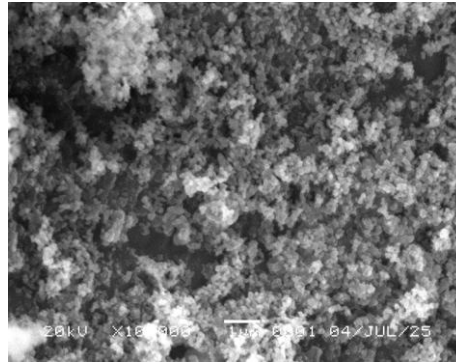
## 2. Results of SEM Morphological Analysis (Scanning Electron Microscope)

Characterization results using (SEM) were obtained to observe the morphological structure of the surface of PDMS sheets coated with various concentrations.



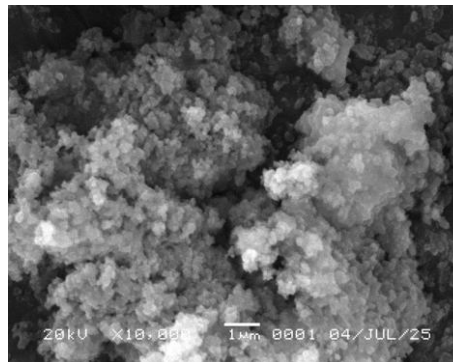
**Fig 2.** SEM Morphology at 1 wt% Silica Concentration Variation

Figure 2 Measurement of the average particle value from SEM data with 10,000x magnification yielded an average particle value of  $2598.2 \text{ nm}^2$ .



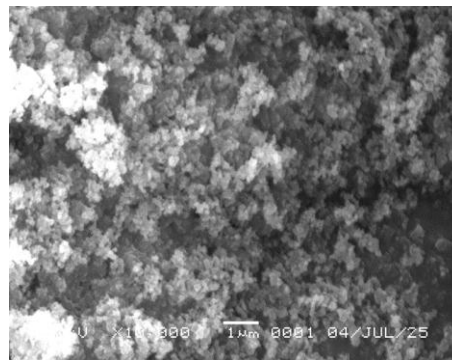
**Fig 3.** SEM Morphology at 2 wt% Silica Concentration Variation

Figure 3 Measurement of the average particle value from SEM data with 10,000x magnification yielded an average particle value of 2142.9 nm<sup>2</sup>.



**Fig 4.** SEM Morphology at 3 wt% Silica Concentration Variation

Figure 4 Measurement of the average particle value from SEM data with 10,000x magnification yielded an average particle value of 1933.1 nm<sup>2</sup>.



**Fig 5.** SEM Morphology at 4 wt% Silica Concentration Variation

Figure 5 Measurement of the average particle value from SEM data with 10,000x magnification yielded an average particle value of 1596.2 nm<sup>2</sup>.

Based on the image above, it can be seen that the average particle size of each concentration variation becomes smaller as the amount of silica used increases. At a concentration of 1 wt%, the average particle size reaches 2598.2 nm<sup>2</sup>, while at the highest concentration of 4 wt%, the size decreases to 1596.2 nm<sup>2</sup>. This decrease indicates that the more silica is added, the more evenly the silica particles tend to spread and not clump together. This occurs because the number of particles formed in the solution becomes greater, so that their size becomes smaller and they are more evenly distributed on the surface.

#### IV. CONCLUSION

If the silica concentration is increased from 1 wt% to 4 wt%, the contact angle value increases and the hydrophobic properties of the PDMS surface improve, with the highest contact angle of  $141.3^\circ \pm 0.4^\circ$  at 4 wt%. However, if the concentration is increased to 5 wt%, the contact angle decreases significantly to  $113.5^\circ \pm 0.3^\circ$  due to silica particle agglomeration. Therefore, it can be concluded that the optimum concentration for obtaining the best hydrophobic properties is 4 wt%.

Based on the SEM analysis results, an increase in rice husk silica concentration on PDMS sheets had a significant effect on surface morphology and particle size. At low concentrations (1 wt%), silica particles were relatively large and tended to agglomerate, indicating uneven dispersion. However, as the concentration increased to 4 wt%, the particle size decreased consistently from  $2598.2 \text{ nm}^2$  to  $1596.2 \text{ nm}^2$ , accompanied by a more homogeneous distribution across the PDMS surface. This condition shows that the addition of higher amounts of silica can improve particle dispersion, resulting in a smoother, denser, and more uniform surface morphology.

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