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# Variation in SiMn Composite Composition Using Modified Polydimethylsiloxanes (PDMS) on Corrosion Properties and Contact Angles

Eka Cahya Muliawati[1*], & Dwi Lulu Laurantini[2]
[1*]Institut Teknologi Adhi Tama Surabaya, Indonesia, [2]Universitas Andalas,Indonesia
*e-mail: ekacahya@itats.ac.id

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*Hydrophobic, Contact Angle, Corrosion Resistance, Polydimethylsiloxanes (PDMS), Silica Oxide (SiO2), and Manganese (Mn)*

**ABSTRACT**
*Corrosion is one of the main challenges faced by advanced industries today because it can cause major losses in terms of safety and economy. One of the common protection methods used to reduce the impact of corrosion is polymer-based coating, which can provide hydrophobic properties on the substrate surface. This study aims to examine the effect of variations in the composition of silica-manganese (SiMn) composites reinforced with polydimethylsiloxane (PDMS) on hydrophobic properties, corrosion resistance, and contact angles. The coating method used is spin coating, with the substrate being a mixture of hard and strong silica and manganese which has corrosion-resistant properties. The SiMn compositions varied were 40%:60%, 50%:50%, and 60%:40%. This study is experimental, using tools such as HEM-3D, XRD, SEM, and FTIR. The coating process was carried out by mixing 2.5 grams of PDMS with silica and manganese powders with a total weight of 1 gram, according to the composition variations. The contact angle test was conducted using a DSLR camera, while the corrosion resistance test was conducted using the immersion method in sulfuric acid with the mass loss method. The results showed that variations in composition affected the contact angle and corrosion resistance of the SiMn-PDMS layer. The composition of 0.6 grams of silica and 0.4 grams of manganese produced the highest contact angle of 120.66$^0$, indicating higher hydrophobic properties. Conversely, the composition of 0.4 grams of silica and 0.6 grams of manganese showed the lowest corrosion rate, which was 1.57 cm/hour.*

***Keywords:*** *Hydrophobic, Contact Angle, Corrosion Resistance, Polydimethylsiloxanes (PDMS), Silica Oxide (SiO2), and Manganese (Mn)*


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## INTRODUCTION

Corrosion is one of the main problems faced by advanced industries today. Corrosion occurs due to electrochemical reactions that cause a decrease in the quality of materials in the surrounding environment. According to Rochmat et al. (2016), corrosion can occur in various places and can cause great losses, both economically and in terms of safety. The impacts of corrosion includes increased maintenance costs, decreased production capacity, shutdowns, product contamination, environmental pollution, and occupational health and safety disturbances. Therefore, efforts to prevent and protect against corrosion are very important to reduce its negative impact.

One of the most commonly employed strategies for mitigating corrosion is the application of polymer-based coatings. These coatings function as protective barriers that prevent corrosive agents from interacting directly with metal surfaces (*Huang et al., 2025*). Through this approach, the coated substrate exhibits hydrophobic characteristics—meaning it repels water and remains cleaner over time. Such hydrophobicity results from a combination of specific surface structures and an increased level of roughness. Notably, surfaces with higher roughness tend to exhibit superior hydrophobic behavior, enhancing their protective capabilities (*Huang et al., 2025*).

The hydrophobic characteristics of a surface are measured through the angle of contact with water. If the water contact angle is in the range of 0° to less than 90°, the surface is categorized as hydrophilic. If the contact angle ranges from 90° to 120°, then the surface is said to be hydrophobic, while a contact angle greater than 150° is categorized as superhydrophobic. To produce composites with hydrophobic properties, natural materials such as manganese can be utilized because of its properties that are able to increase corrosion resistance. Manganese in the form of oxide ($MnO_2$) can be used as a corrosion-inhibiting pigment and as a nanofiller in hydrophobic coatings (Putri et al., 2018).

Several studies have discussed the use of manganese in the manufacture of hydrophobic coatings. According to Cao et al. (2018), the combination of $MnO_2$ with stearic acid (SA) and stearic acid diethanolamide (SDEA) results in a hydrophobic layer with a contact angle of 137°. Meanwhile, Lu et al. (2019) compared two types of manganese-based hydrophobic coatings, namely with Laurate Diethanolamide (LDEA) boosters and a combination of Laurate Diethanolamide and stearic acid (LDEA-SA). The results showed that the LDEA-SA hydrophobic layer had better corrosion resistance than LDEA, with contact angles of 124° and 114°, respectively.

In addition to manganese, silica is also often used in the formation of hydrophobic layers due to its strong and thermally stable properties (Wardani & Zainuri, 2019). Silica is not available in free form in nature, but it is found in the form of other compounds that need to be purified before use. Research by Irawati & Zainuri (2016) shows that the PDMS/$SiO_2$ composite, applied using the spray gun method, produces a contact angle of 100.1°. When heated between 100-500°C, the highest contact angle is reached at 400°C by 126.4° and decreases to 72.4° at 500°C, indicating a shift in properties from hydrophobic to hydrophilic.

Polydimethylsiloxane (PDMS) is one of the polymers with low surface energy that is often used in the manufacture of hydrophobic surfaces. PDMS has non-toxic properties, is transparent, stable against high temperatures, and can function as a barrier against corrosive ions. However, PDMS has weaknesses such as low mechanical resistance and poor adhesion to substrates (Jena et al., 2021). Therefore, this study aims to explore the combination of silica and manganese as fillers in the PDMS matrix to improve corrosion resistance and produce an optimal hydrophobic layer. This study will investigate the effect of variations in silica-manganese composite (SiMn) composition on the contact angle and corrosion resistance of the formed hydrophobic layer.

## METHODS

This research is a type of experimental research. Experimental research is carried out by providing treatment to the object of research, thus enabling the identification of causal relationships. This study examines the effect of variations in SiMn composite composition using PDMS on corrosion properties and contact angles. The material used is Silica Manganese (SiMn) particles which are varied and then mixed into PDMS (Polydimethylsiloxane). This research was carried out in several stages, including the synthesis of Manganese Silica (SiMn) particles using High Energy Milling (HEM). Synthesis of Manganese Silica (SiMn) composites reinforced with PDMS. Other characterization tools used to see the Crystal Structure, Phase, and Crystal size of Silica and Manganese composites are *X-Ray Diffraction* (XRD), to see the functional groups of the surface of the hydrophobic layer, namely *Fourier Transform Infrared Spectroscopy* (FTIR), to see the surface morphology of the hydrophobic layer *Scanning Electron Microscope* (SEM). Furthermore, the SiMn composite contact angle test was carried out using a DSLR camera and to test the corrosion resistance of the polymer particle layer that had been developed in the test using sulfuric acid by calculating the corrosion rate.

## RESULTS

### A. Data Description

The results of this study consisted of the identification of contact angle data taken from the measurement results on a thin layer of Manganese Silica (SiMn) composite which was reinforced using Polydimethylsiloxane (PDMS) which had been tested using *ImageJ software*. The results of the next study are in the form of identification of the crystalline structure of Silica Manganese (SiMn) composite which has been strengthened using Polydimethylsiloxane (PDMS) which has been tested using XRD, FTIR is used to determine the functional group of compounds in the hydrophobic layer, SEM is used to determine the surface morphology and particle size, and corrosion resistance testing is carried out using *the weight loss* method by calculating the corrosion rate.

**1. Contact Angle Measurement Data**

**a. Composition of Si 0.4 grams and Mn 0.6 grams**

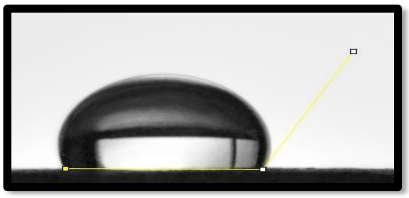

**Figure 1. Measurement of SiMn Contact Angle 0.4 gr : 0.6 gr**

**Table 1. Results of Contact Angle Measurement on SiMn Composition 0.4 gr**

| Contact Angle | | |
|---|---|---|
| Calculation Results | | Calculation Results |
| Θ Right | Θ Left | Θ |
| 120.71 $^0$ | 120.75 $^0$ | 120.73 $^0$ |
| 120,823 $^0$ | 120.437 $^0$ | 120.63 $^0$ |
| 120,767 $^0$ | 120,593 $^0$ | 120.68 $^0$ |
| 120,798 $^0$ | 120.312 $^0$ | 120,555 $^0$ |
| 120,877 $^0$ | 120,579 $^0$ | 120.728 $^0$ |
| Average | | 120.6646 $^0$ |

**b. Composition of Si 0.5 grams and Mn 0.5 grams**

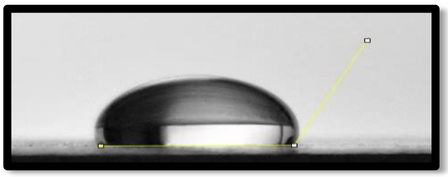

**Figure 2. Measurement of SiMn Contact Angle 0.5 gr : 0.5 gr**

**Table 2. Results of Contact Angle Measurement on SiMn Composition 0.5 gr : 0.5 gr**

| Contact Angle | | |
|---|---|---|
| Calculation Results | | Calculation Results |
| Θ Right | Θ Left | Θ |
| 114.094 $^0$ | 114.145 $^0$ | 114.1195 $^0$ |
| 114,882 $^0$ | 114.203 $^0$ | 114.5425 $^0$ |
| 114,369 $^0$ | 113,891 $^0$ | 114.13 $^0$ |
| 114,193 $^0$ | 113,962 $^0$ | 114.0775 $^0$ |
| 114,193 $^0$ | 114.05 $^0$ | 114.1215 $^0$ |
| Average | | 114.1982 $^0$ |

**c. Composition of Si 0.6 grams and Mn 0.4 grams**

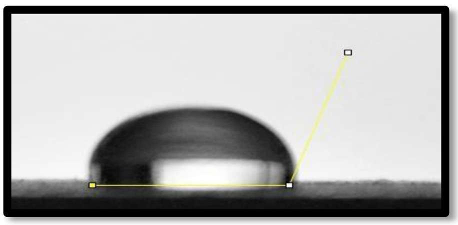

**Figure 3. Measurement of SiMn Contact Angle 0.6 gr : 0.4 gr**

**Table 3. Results of Contact Angle Measurement on SiMn Composition 0.6 gr : 0.4 gr**

| Contact Angle | | |
|---|---|---|
| Calculation Results | | Calculation Results |
| θ Right | θ Left | θ |
| 109.109 ⁰ | 108.352 ⁰ | 108.7305 ⁰ |
| 108.139 ⁰ | 108.531 ⁰ | 108.335 ⁰ |
| 108.738 ⁰ | 107.692 ⁰ | 108.215 ⁰ |
| 108.834 ⁰ | 108.525 ⁰ | 108.6795 ⁰ |
| 108.489 ⁰ | 107.745 ⁰ | 108.117 ⁰ |
| Average | | 108.4154 ⁰ |

**d. Silica 0.2 grams 100 ⁰**


**Figure 4. Measurement of Silica Contact Angle 0.2 gr**

In Figure 41, it can be seen that the results of the contact angle test on a 0.2 gr silica sample were strengthened using PDMS. The results of the contact angle test were obtained to be 100.2 ⁰ (Irawati & Zainuri, 2016).

**e. Manganese 0.4 g 100 ⁰**

**Figure 5. Measurement of Manganese Contact angle 0.4 g**

**Table 4. Manganese Contact Angle Measurement Results 0.4 gr**

| Contact Angle | | |
|---|---|---|
| Calculation Results | | Calculation Results |
| ϴ Right | ϴ Left | ϴ |
| 107.136 ⁰ | 111.701 ⁰ | 109.4185 ⁰ |
| 110,098 ⁰ | 109.654 ⁰ | 109.876 ⁰ |
| 111,493 ⁰ | 109,496 ⁰ | 110.4945 ⁰ |
| 110.515 ⁰ | 111.448 ⁰ | 110.9815 ⁰ |
| 110.138 ⁰ | 109,344 ⁰ | 109.741 ⁰ |
| Average | | 110.1023 ⁰ |

In Table 4, it can be seen that the results of the contact angle test on a 0.4 gr manganese sample reinforced using *polystyrene*. The test results of the contact angle were obtained to be 110.1023 ⁰ (T. A. Putri et al., 2018).

**2. X-Ray Difraction *(XRD)* Measurement Results Data**

**a.** The results of characterization using XRD composite Silica Manganese (SiMn) reinforced using Polydimethylsiloxane (PDMS) using a composition of Si 0.4 grams and Mn 0.6 grams can be shown in Figure 5.

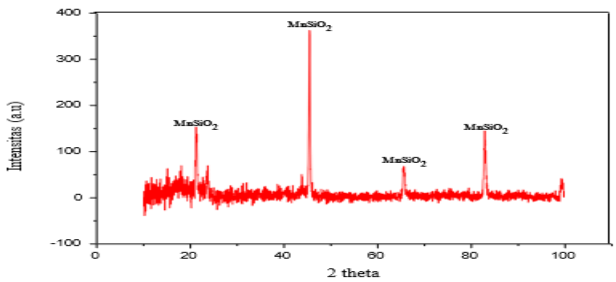


**Figure 5. Data of XRD SiMn Test Results 0.4 gr : 0.6 gr**

**Table 5. Data for Each Peak of Significant Intensity of SiMn Diffraction Pattern 0.4 gr : 0.6 gr**

| Top | 2ϴ(⁰) | I(%) | Phase | Crystal System |
|---|---|---|---|---|
| 1 | 21.4344 | 34.43 | MnSiO2 | Anorthic |
| 2 | 45.4996 | 100.00 | MnSiO2 | Orthorhombic, Anorthic, Monoclinic |
| 3 | 65.5949 | 16.51 | MnSiO2 | Anorthic, Monoclinic |
| 4 | 82.9297 | 34.73 | MnSiO2 | Anorthic, Monoclinic |

**b.** The results of characterization using XRD composite Silica Manganese (SiMn) reinforced using Polydimethylsiloxane (PDMS) using a composition of Si 0.5 grams and Mn 0.5 grams can be shown in Figure 6.

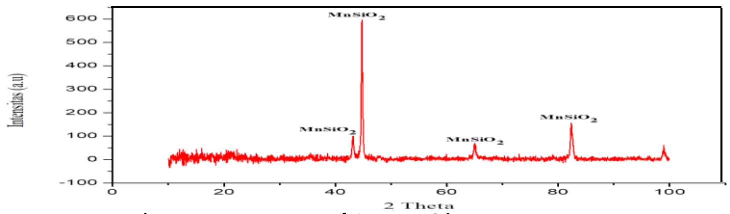


**Figure 6. Data of XRD SiMn 0.5 gr : 0.5 gr**

**Table 6. Data for Each Peak of Significant Intensity of SiMn Diffraction Pattern 0.5 gr : 0.5 gr**

| Top | 2θ(⁰) | I(%) | Phase | Crystal System |
|---|---|---|---|---|
| 1 | 43.1545 | 16.95 | MnSiO2 | Anorthic |
| 2 | 44.7463 | 100.00 | MnSiO2 | Orthorhombic, Anorthic, Monoclinic |
| 3 | 65.0738 | 8.95 | MnSiO2 | Anorthic, Monoclinic |
| 4 | 82.3717 | 24.99 | MnSiO2 | Anorthic, Monoclinic |

**c.** The results of characterization using XRD composite Silica Manganese (SiMn) reinforced using Polydimethylsiloxane (PDMS) using a composition of Si 0.6 grams and Mn 0.4 grams can be shown in figure 7.

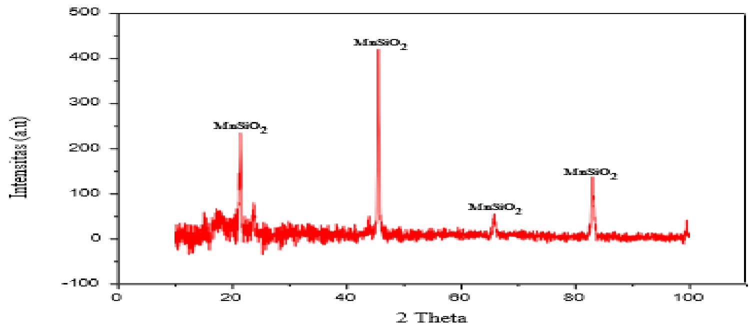


**Figure 7. Data of XRD SiMn 0.6 gr : 0.4 gr**

**Table 7. Data for Each Peak of Significant Intensity of SiMn Diffraction Pattern 0.6 gr : 0.4gr**

| Top | 2θ(⁰) | I(%) | Phase | Crystal System |
|---|---|---|---|---|
| 1 | 21.4924 | 56.02 | MnSiO2 | Anorthic |
| 2 | 45.6350 | 100.00 | MnSiO2 | Orthorhombic, Anorthic, Monoclinic |
| 3 | 65.8141 | 10.27 | MnSiO2 | Anorthic, Monoclinic |
| 4 | 83.0166 | 28.70 | MnSiO2 | Anorthic, Monoclinic |

### 3. Characterization Data Using SEM

**a. SEM Characterization Results on the composition of Si 0.4 grams and Mn 0.6 gr**

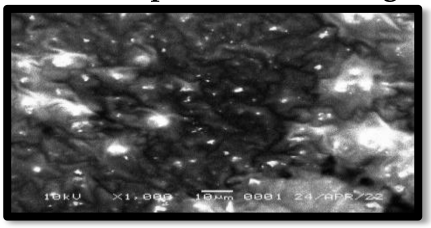

**Figure 8. Surface Morphology SiMn 0.4 gr : 0.6 gr**

Figure 8. is a composite morphology of Silica Manganese (SiMn) which is strengthened using Polydimethylsiloxane (PDMS) as much as Si 0.4 grams and Mn 0.6 grams. Using 1,000 magnifications, granules can be seen that are irregular in shape but have similar shapes such as protrusions on the surface. In this composition, the average particle size is 841.0578 nm.

**b. SEM Characterization Results on Si 0.5 grams and Mn 0.5 grams**

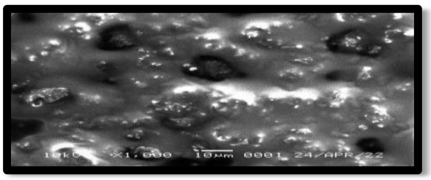

**Figure 9. Surface Morphology SiMn 0.5 gr : 0.5 gr**

Figure 9 is the composite morphology of Silica Manganese (SiMn) reinforced using Polydimethylsiloxane (PDMS) of Si 0.5 grams and Mn 0.5 grams. Using 1,000 magnifications, granules can be seen that are irregular and clumpy in shape but have similar shapes such as even protrusions on the surface. In this composition, the average particle size is 870.9771 nm.

**c. SEM Characterization Results on the composition of Si 0.6 grams and Mn 0.4 grams**

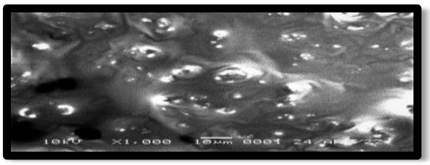

**Figure 10. Surface Morphology SiMn 0.6 gr : 0.4 gr**

Figure 10 is the composite morphology of Manganese Silica (SiMn) reinforced using Polydimethylsiloxane (PDMS) as much as Si 0.6 grams and Mn 0.4 grams. Using 1,000 magnifications, granules can be seen that are irregular in shape but have similar shapes such as many protrusions on the surface. In this composition, the average particle size is 929.9625 nm.

**4. Characterization Data Using FTIR**

**a. FTIR characterization in Si 0.4 gram and Mn 0.6 gram composition**

**Table 8. FTIR Measurement Data on SiMn Composition 0.4 gr : 0.6 gr**

| Number of Waves ($cm^{-1}$) | Transmittance (%) | Function Clusters |
|---|---|---|
| 2941,21 | 58,91 | Q3 |
| 1459,33 | 74,40 | C-H |
| 1378,19 | 81,10 | C-H |
| 1258,09 | 77,97 | Si-CH3 |
| 1085,90 | 54,63 | Si-O-Si |
| 801,76 | 53,62 | Si-O |
| 539,68 | 59,21 | MN-O |
| 467,95 | 118,81 | MN-O |

**b. FTIR Characterization in the composition of Si 0.5 grams and Mn 0.5 grams**

**Table 9. FTIR Measurement Data on SiMn Composition 0.5 gr : 0.5 gr**

| Number of Waves ($cm^{-1}$) | Transmittance (%) | Function Clusters |
|---|---|---|
| 2942,60 | 61,12 | Q3 |
| 1459,92 | 80,36 | C-H |
| 1379,31 | 87,62 | C-H |
| 1257,26 | 81,51 | Si-CH3 |
| 1085,39 | 47,29 | Si-O-Si |
| 801,85 | 53,23 | Si-O |
| 539,57 | 67,51 | MN-O |
| 471,58 | 135,17 | MN-O |

**c. FTIR Characterization in the composition of Si 0.6 grams and Mn 0.4 grams**

**Table 10. FTIR Measurement Data on SiMn composition 0.6 gr : 0.4 gr**

| Number of Waves (cm-1) | Transmittance (%) | Function Clusters |
|---|---|---|
| 2944,84 | 63,28 | Q3 |
| 1459,41 | 80,74 | C-H |
| 1381,41 | 86,23 | C-H |
| 1257,03 | 73,03 | Si-CH3 |
| 1080,04 | 30,32 | Si-O-Si |
| 1029,88 | 31,03 | Si-O-Si |
| 799,96 | 33,35 | Si-O |
| 540,15 | 57,11 | MN-O |
| 454,14 | 103,42 | MN-O |

**5. Corrosion Resistance Test Data**

The corrosion resistance of the Manganese Silica (SiMn) composite layer reinforced using Polydimethylsiloxane (PDMS) on the iron plate was carried out by immersion testing using sulfuric acid and measured weight *loss*.

**a. Results of Corrosion Testing of Iron Plates Without Plating**

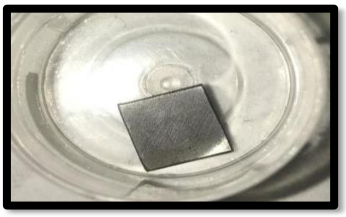

**Figure 11. Uncoated Iron Plate Before Immersion**

**Figure 12. Iron Plate Without Plating After Immersion**

Figure 11 is an iron plate without a composite layer of Silica Manganese (SiMn) reinforced using Polydimethylsiloxane (PDMS) which has not been soaked using sulfuric acid with an initial weight of 0.5964 g in a condition that is still smooth and clean without rust. In Figure 12, it is an iron plate that has been soaked using sulfuric acid for 12 hours with a final weight of 0.5746 grams in a rusty condition on the entire surface.

**b. Results of Corrosion Testing of Iron Plates Coated with a Aayer with a Silica Manganese (SiMn) Composition, namely Si 0.4 gr and Mn 0.6 gr**

**Figure 13. Iron Plate Coated with SiMn Layer 0.4 gr : 0.6 gr Before Immersion**

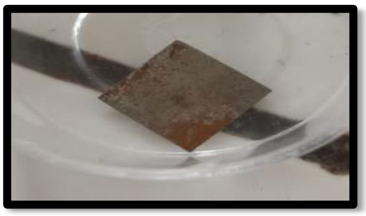

**Figure 14. Iron Plate Coated with SiMn Layer 0.4 gr : 0.6 gr After Immersion**

Figure 13 shows an iron plate with a composite layer of Silica Manganese (SiMn) reinforced using Polydimethylsiloxane (PDMS) with a composition of 0.4 g of silica and 0.6 g of manganese that has not been soaked using sulfuric acid with an initial weight of 0.5847 g in a condition that is still smooth and clean without rust coated with a coating. In Figure 14, it is an iron plate that has been soaked using sulfuric acid for 12 hours with a final weight of 0.5784 grams in a rusty condition on the edge of the surface.

**c. Results of Corrosion Testing of Iron Plates Coated with a Layer with a Composition of Silica Manganese (SiMn), namely Si 0.5 gr and Mn 0.5 gr**

**Figure 15. Iron Plate Coated SiMn Layer 0.5 gr : 0.5 gr before immersion**

**Figure 16. Iron Plate Coated SiMn Layer 0.5 gr : 0.5 gr After Immersion**

Figure 15 shows an iron plate given a composite layer of Silica Manganese (SiMn) reinforced using Polydimethylsiloxane (PDMS) with a composition of 0.5 g of silica and 0.5 g of manganese that has not been soaked using sulfuric acid with an initial weight of 0.6406 g in a condition that is still smooth and clean without rust coated with a coating. In Figure 16, it is an iron plate that has been soaked using sulfuric acid for 12 hours with a final weight of 0.635 grams in a rusty condition on the edge of the surface.

**d. Results of Corrosion Testing of iron Plates Coated with a Layer with a Composition of Silica Manganese (SiMn), namely Si 0.6 gr and Mn 0.4 gr**

**Figure 17. Iron Plate Coated with SiMn Layer 0.6 gr : 0.4 gr Before Immersion**

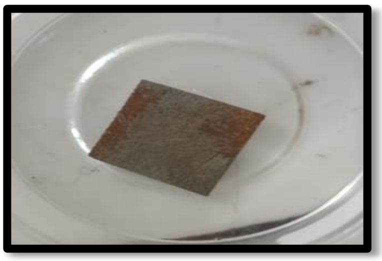

**Figure 18. Iron Plate Coated with SiMn Layer 0.6 gr : 0.4 gr After Immersion**

Figure 17 shows an iron plate given a composite layer of Manganese Silica (SiMn) reinforced using Polydimethylsiloxane (PDMS) with a composition of 0.6 g of silica and 0.4 g of manganese that has not been soaked using sulfuric acid with an initial weight of 0.6108 g in a condition that is still smooth and clean without rust coated with a coating. In Figure 18, it is an iron plate that has been soaked using sulfuric acid for 12 hours with a final weight of 0.6065 grams in a rusty condition on the edge of the surface.

**B. Data Analysis**

**1. Contact Angle Characterization Data Analysis**

The measurement of the contact angle is carried out directly using *ImageJ software*. The contact angle test was carried out with a variation in composition where the variation was 40%: 60%, 50%: 50%, and 60%: 40% or equal to 0.4 gr: 06 gr, 05 gr: 0.5 gr, and 0.6 gr: 0.4 gr. This contact angle measurement is important to find out which layer in the composition variation is more hydrophobic. Hydrophobic surfaces have a large contact angle of 90°C. Data on the influence of composition variations on contact angles can be seen in table 11.

**Table 11. Contact Angle Measurement Data**

| No. | Composition Si : Mn | Contact Angle |
|---|---|---|
| 1. | 0.4 gr : 0.6 gr | 120.6646 $^0$ |
| 2. | 0.5 gr : 0.5 gr | 114.1982 $^0$ |
| 3. | 0.6 gr : 0.4 gr | 108.4154 $^0$ |

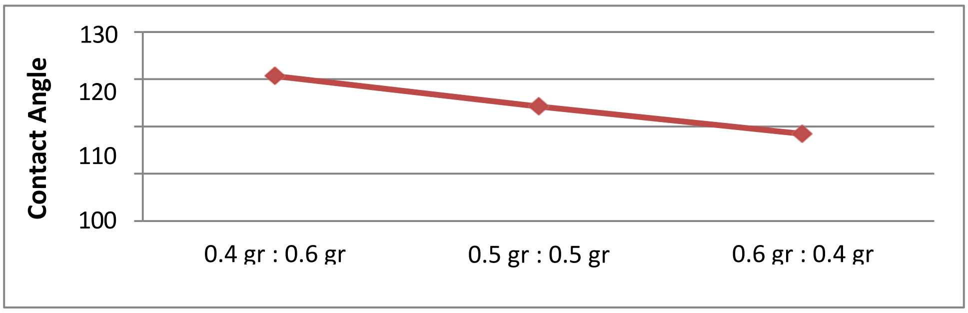


**Figure 19. Relationship of Composition with Contact Angle Measurement**

From the graph in Figure 19, it can be seen that the variation in composition greatly affects the contact angle produced. The highest contact angle was obtained in the composition of Si 0.4 gr : Mn 0.6 gr which is 120.6646 $^0$, in this condition the layer has hydrophobic properties. The lowest contact angle is obtained in the composition of Si 0.6 gr: Mn 0.4 gr, which is 108.4154 $^0$, in this condition the layer has hydrophobic properties. The relative error for repeated contact angle measurements is the relative error in the composition of Si 0.4 gr : Mn 0.6 gr by 0.04%, Si 0.5 gr : Mn 0.5 gr by 0.12%, and Si 0.6 gr : Mn 0.4 gr by 0.21%.

**2. Data Analysis of X-Ray Difraction (XRD) Measurement Results**

X-Ray Difraction (XRD) is used to see whether or not the crystal structure has formed. This can be seen by the presence of a peak in the spectrum. The X-ray diffraction pattern produced from a composite layer of Manganese Silica (SiMn) reinforced using Polydimethylsiloxane (PDMS) using a 1cm X 1cm iron plate using a variation in SiMn composition of 0.4 gr: 0.6 gr, 0.5 gr: 0.5 gr, and 0.6 gr: 0.4 gr which was analyzed with a peak of 2θ and intensity. In analyzing XRD data, the researcher used an application in the form of *high scrore plus* to determine the peak of 2θ and to determine the researcher's FWHM, to combine plots from XRD data, the researcher used *the Origin 8.5* application. The following are the results of XRD data plotted using *the Origin 8.5* application shown in Figure 22.

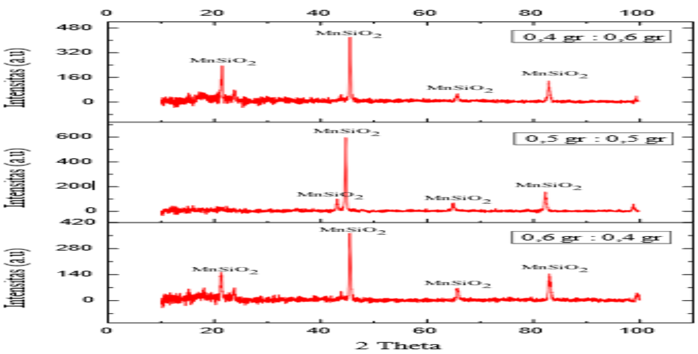


**Figure 20. XRD Data Analysis**

Figure 20 explains that there are several peaks of XRD data where there are peaks of $MnSiO_2$. The results of the analysis showed that there was a peak of the desired MnSiO2 composite layer in each of the composition variations. The peaks in the image look tall and not widened, indicating that the sample has a nanoscale size. In the composition of Si 0.5 gr : Mn 0.5 gr one of the peaks produced has shifted, this indicates the occurrence of phase shifting. The dominant phase formed is $MnSiO_2$. Furthermore, to determine the crystal size using the *Scherrer equation* from XRD data, it can be obtained in table 12.

**Table 12. XRD Data Processing Results**

| No. | Composition Si : Mn | Crystal Size (nm) |
|---|---|---|
| 1. | 0.4 gr : 0.6 gr | 41,56 |
| 2. | 0.5 gr : 0.5 gr | 37,67 |
| 3. | 0.6 gr : 0.4 gr | 35,977 |

### 3. Characterization Analysis Using SEM (Scanning Electron Microscopy)

The morphological shape and grain size of the Silica Manganese (SiMn) nanocomposites reinforced using Polydimethylsiloxane (PDMS) can be seen using SEM. Silica Manganese (SiMn) composites reinforced using Polydimethylsiloxane (PDMS) which have been varied in composition, namely Si 0.4 gr: Mn 0.6 gr, Si 0.5 gr: Mn 0.5 gr, and Si 0.6 gr: Mn 0.4 gr can be analyzed for grain size from the results of SEM characterization. The difference in morphological shape in each variation of composition can be seen in Figure 21.

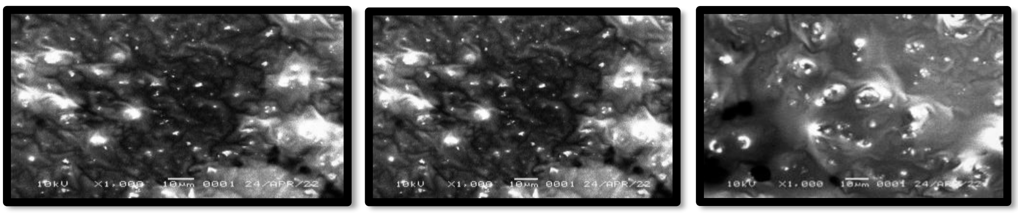

**Figure 21. Morphological Shape Differences of SiMn Composites Reinforced with PDMS (1) 0.4 gr : 0.6 gr (2) 0.5 gr : 0.5 gr (3) 0.6 gr : 0.4 gr**

In Figure 21, the morphological shape of the Silica Manganese (SiMn) composite reinforced using Polydimethylsiloxane (PDMS) can be seen in the variation in composition. At the time of the composition of Si 0.4 gr : Mn 0.6 gr morphology of the composite surface there are bulges and a few irregular lumps. For variations in the composition of Si 0.5 gr : Mn 0.5 gr morphology of composite surfaces in the form of bumps and irregular lumps. And when the composition of Si 0.6 gr : Mn 0.4 gr the morphology of the composite surface changes, namely there are bulges and lumps that are getting bigger and clearer. The particle size was 841.0578 nm, 870.9771 nm, and 929.9625 nm respectively. Based on the SEM analysis data, the grain size of the morphological analysis was obtained. The results of SEM analysis can be seen in Table 13.

**Table 13. Grain Size Relative to Composition Variation**

| No. | Composition Si : Mn | Particle size (nm) |
|---|---|---|
| 1. | 0.4 gr : 0.6 gr | 841,0578 |
| 2. | 0.5 gr : 0.5 gr | 870,9771 |
| 3. | 0.6 gr : 0.4 gr | 929,9625 |

**4. FTIR Data Analysis**

To identify the bonds of Silica Manganese (SiMn) composite groups strengthened using Polydimethylsiloxane (PDMS) can be analyzed using the FTIR test. The composite spectrum of Silica Manganese (SiMn) reinforced using Polydimethylsiloxane (PDMS) shows several peaks that identify the presence of multiple functional groups. Either those possessed by silica, manganese, or functional groups of impurities.

The number of waves observed is typical of the peak of the FTIR absorption transmitant range of 450cm-1 – 4000 $^{cm-1}$. For the desired clusters, namely Si-O, Mn-O, and $CH_3$, Si-O-Si, Si-CH3 which indicate the presence of PDMS. The peak absorption in the wave number region of 467.95 $^{cm-1}$ and 539.68 $^{cm-1}$ comes from the Mn-O bond stretch (Mn-O: 400-560 $^{cm-1}$ (Aulia, 2020.)). 799.96 $^{cm-1}$ comes from the Si-O stretch with a range of 782 - 805 $^{cm-1}$ (Padi, 2015), while for the functional group of PDMS there is a $CH_3$ group, Si-O-Si, Si-CH3, Si-O-Si and can be seen at the peak of absorption of the wavelength region of 2942.60 $^{cm-1}$ originating from the methylene/$CH_{3\,group}$, the peak absorption of the wavelength region of 1085.39 $^{cm-1}$ is derived from the Si-O-Si bond stretch, the peak of absorption of the wavelength region of 1257.26 $^{cm-1}$ is derived from the Si-CH bond stretch( wavelength $CH_3$, Si-O-Si, Si-CH3 are 2905.1 – 2961.4 $^{cm-1}$, 1045.6 $^{cm-1}$, 812.2 $^{cm-1}$ and

1262.7 $^{cm-1}$ (Luis & Moncayo, n.d.)). The combination of 2 materials, namely polydimethylsiloxane (PDMS) as a matrix and SiMn particles as a filler into a waterproof coating composite which has been successfully proven by the absence of new bonds that have emerged. This indicates that there is no microscopic change in the chemical structure at the time of the merger. In composite materials, only electrostatic bonds occur so that they do not form chemical bonds or valence bonds that form new compounds.

## 5. Corrosion Rate Data Analysis

The corrosion resistance test was carried out by measuring the corrosion rate of the iron plate by immersing the iron plate in a sulfuric acid solution for 12 hours, where the iron plate to be soaked was an iron plate without coating and the iron plate was given a composite layer of Silica Manganese (SiMn) which was reinforced using Polydimethylsiloxane (PDMS) with a variation in SiMn composition of 0.4 gr: 0.6 gr, 0.5 gr: 0.5 gr, and 0.6 gr: 0.4 gr. The data from the measurement of the corrosion rate can be seen in Table 14.

**Table 14. Corrosion Rate Measurement Results Data**

| No. | Iron Plate | Corrosion Rate (cm/hr) |
|---|---|---|
| 1. | No Coating | 8,009 |
| 2. | Si 0.4 gr : Mn 0.6 gr | 1,57 |
| 3. | Si 0.5 gr : Mn 0.5 gr | 2,06 |
| 4. | Si 0.6 gr : Mn 0.4 gr | 2,31 |

In Table 14, the data on the results of measuring the corrosion rate can be seen using the weight loss method on uncoated iron plates and iron plates given variations in layer composition, in the method used is to measure the initial weight of uncoated iron plates and iron plates given variations in layer composition and measure the final weight after the iron plate is soaked for 12 hours in a sulfuric acid solution. For weight loss that occurs on iron plates is 0.0218 gr on iron plates without coating, 0.0043 gr on iron plates with a SiMn layer composition of 0.4 gr: 0.6 gr, 0.0056 gr on iron plates with a SiMn layer composition of 0.5 gr: 0.5 gr, 0.0063 gr on iron plates with a SiMn layer composition of 0.6 gr: 0.4 gr. The highest corrosion rate was obtained on an uncoated iron plate of 8.009 cm/hr and the lowest corrosion rate was obtained on a coated iron plate with a composition of Si 0.4 gr: Mn 0.6 gr, which was 1.57 cm/hr.

## DISCUSSION

The results showed that the composition of SiMn had an effect on the hydrophobic properties and corrosion resistance of iron plates coated with SiMn composites reinforced with PDMS. The hydrophobicity of the coating is indicated by an increasingly large water contact angle, which means that the surface is more difficult for water to penetrate. This hydrophobic coating is obtained by utilizing the polymer properties of PDMS as a corrosion barrier and a combination of silica and manganese fillers that affect the morphology and energy of the coating surface.

Contact angle tests show that the higher the manganese content in the composite, the greater the contact angle obtained. The highest contact angle was found in the composition of Si 0.4 gr : Mn 0.6 gr of 120.6646°, while the lowest contact angle was found in the composition of Si 0.6 gr : Mn 0.4 gr of 108.4154°. This suggests that manganese has a greater contribution to increasing hydrophobicity than silica. This data is in line with previous research showing that manganese can improve hydrophobicity through increased surface roughness and interaction with PDMS.

Characterization with Scanning Electron Microscope (SEM) revealed that the particles that make up the layer are smaller at the top and tighter, thus increasing the surface roughness and enlarging the contact angle. In addition, Fourier Transform Infrared Spectroscopy (FTIR) shows that there are no significant changes in the chemical structure of the composite, which means that no new compounds are formed during the coating process.

The corrosion resistance test showed that the layer with a composition of Si 0.4 gr : Mn 0.6 gr had the lowest corrosion rate, which was 1.57 cm/hour, compared to the iron plate without the coating which had a corrosion rate of 8.009 cm/hour. This suggests that manganese has an effective corrosion inhibitor pigment, especially when combined with PDMS which acts as a corrosive ion barrier.

From the data obtained, it can be concluded that SiMn composites with a more manganese rich composition are more effective in improving the contact angle and corrosion resistance. This suggests that the combination of manganese and silica in PDMS can be a good alternative for the development of corrosion-resistant hydrophobic coating materials, especially for applications in industries that are susceptible to degradation due to water and corrosive environments

## CONCLUSION

With this variation in composition, it can be known the influence of contact angle and corrosion resistance, where manganese is more dominant than silica will produce a high contact angle and also have better corrosion resistance. In this study, it was known that the highest contact angle in the composition of Si 0.6 gr : Mn 0.4 gr was 120.6646º and good corrosion resistance was determined from the corrosion rate in the composition of Si 0.4 gr : Mn 0.6 gr which was 1.57 cm/hr.

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