DAFTAR PUSTAKA

Makalah penelitian yang dirujuk 66 karya, yang sebagian besar diterbitkan dalam lima tahun terakhir dan artikel terkemuka yang relevan dari jurnal atau konferensi. Perbandingan temuan dengan penelitian terbaru menunjukkan peningkatkan dan kemajuan yang signifikan atas temuan karya ilmiah.

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LAMPIRAN

Lampiran 1. Sertifikat HAKI

REPUBLIK INDONESIA
KEMENTERIAN HUKUM DAN HAK ASASI MANUSIA

SURAT PENCATATAN CIPTAAN

Dalam rangka pelindungan ciptaan di bidang ilmu pengetahuan, seni dan sastra berdasarkan Undang-Undang Nomor 28 Tahun 2014 tentang Hak Cipta, dengan ini menerangkan:

Nomor dan tanggal permohonan	:	EC002023132463, 14 Desember 2023
Pencipta		
Nama	:	**Mustamin, S.T.,M.T**
Alamat	:	JL. AMD Antang Perumahan Bukit Bersinar Blok A No.1, RT004/RW004, Kel. Antang, Kec. Manggala, Kota Makassar, Manggala, Makassar, Sulawesi Selatan, 90234
Kewarganegaraan	:	Indonesia
Pemegang Hak Cipta		
Nama	:	**Mustamin, S.T.,M.T, Prof.Dr.Ir.Salama Manjang, M.Sc. dkk**
Alamat	:	JL. AMD Antang Perumahan Bukit Bersinar Blok A No.1, RT004/RW004, Kel. Antang, Kec. Manggala, Kota Makassar, Manggala, Makassar, Sulawesi Selatan, 90234
Kewarganegaraan	:	Indonesia
Jenis Ciptaan	:	**Karya Tulis (Artikel)**
Judul Ciptaan	:	**Investigation Of SiO2/ATH/TiO2 Micro-nanofillers To Improve Performance Of Silicone Rubber Toward UV Radiation And Partial Discharge On High Voltage Outdoor Insulators**
Tanggal dan tempat diumumkan untuk pertama kali di wilayah Indonesia atau di luar wilayah Indonesia	:	14 Desember 2023, di Makassar
Jangka waktu pelindungan	:	Berlaku selama hidup Pencipta dan terus berlangsung selama 70 (tujuh puluh) tahun setelah Pencipta meninggal dunia, terhitung mulai tanggal 1 Januari tahun berikutnya.
Nomor pencatatan	:	000565417

adalah benar berdasarkan keterangan yang diberikan oleh Pemohon.
Surat Pencatatan Hak Cipta atau produk Hak terkait ini sesuai dengan Pasal 72 Undang-Undang Nomor 28 Tahun 2014 tentang Hak Cipta.

a.n. MENTERI HUKUM DAN HAK ASASI MANUSIA
Direktur Hak Cipta dan Desain Industri

Anggoro Dasananto
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Lampiran 2. Artikel jurnal internasional

International Journal on Electrical Engineering and Informatics - Volume 15, Number 4, December 2023

Investigation of SiO_2/ATH/TiO_2 Micro-nanofillers to Improve the Performance of Silicone Rubber for High Voltage Outdoor Insulators

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Abstract: Hydrophobic properties are the advantages of silicon insulators over other types of insulators. This paper discusses the investigation to improve the performance of the SR insulator matrix with micro-nanofillers to maintain hydrophobic properties. A new polymer insulator with the best filler composition and concentration is expected to be produced in this research to be effectively applied as a high-voltage outdoor insulator in the tropics. Investigations were conducted to determine the performance of the SiO_2, ATH, and TiO_2 micro-nanofillers to improve the properties of hydrophobic, water diffusion, and UV radiation of insulator matrix SR. The materials used are selected from well-performing composites and fillers and then combined to obtain the right insulator matrix to improve the performance of silicone rubber for outdoor high-voltage polymer insulators. Mixers under vacuum conditions are applied to reduce agglomeration and voids from cavitation when fabricating an insulator matrix. Investigation of the performance of the SR insulator matrix includes testing and analysis of physical, electrical, and chemical test characteristics according to IEC standards including hydrophobic transfer, water diffusion, permittivity, resistivity, and FTIR. The results showed that the performance of the SR insulator matrix with SiO_2, ATH, and TiO_2 micro-nanofiller with concentrations of 15 wt% and 20 wt% has the potential to improve the performance of high-voltage polymer insulators.

Keywords: Hydrophobic; water diffusion; resistivity; permittivity; micro-nanofiller.

1. Introduction

The polymer insulator matrix is the main material of polymer insulators as housing. The quality of polymer insulators is largely determined by the performance of the polymer insulator matrix [1]. The main materials of the polymer insulator matrix used in this research are RTV683 silicone rubber (SR) and SiO_2, ATH, and TiO_2 micro-nanofillers. The SR has hydrophobic properties that can convert pollutants on the surface into hydrophobic which is very well used as a high-voltage outdoor insulator [2], [3]. To improve the performance of polymer insulators, the SR can add quality fillers according to the environmental constraints in which the insulator will be used. The combination of micro-nanofillers can expand the filler surface, and improve stability and thermal distribution to prevent cavities caused by cavitation and air trapped in the fabrication of an insulator matrix [4].

Silicone rubber has external and internal constraints on its use as a high-voltage outdoor insulator [5]. Physical, electrical, and chemical constraints on the application of polymer insulators need to be eliminated by engineering composites and fillers with the right composition and concentration to produce the best-performing insulator matrix such as SiO_2 micro-nanofillers for hardness, and electrical resistivity [6], [7], alumina trihydrate (ATH) for flame resistance [8]–[11], and TiO_2 for UV radiation [12], tracking, and erosion [13], [14]. The combination of micro-nanofillers with the right composition and concentration can maintain hydrophobic transfer properties, and improve thermal stability, tracking, and erosion resistance [15], which can improve the performance and service life of polymer insulators [16].

The SR insulator matrix by engineering SiO_2, ATH, and TiO_2 micro-nanofillers has been investigated to determine the performance of the combination of micro-nanofillers to improve

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the properties of hydrophobic, tracking, and UV radiation of the SR insulators matrix [17], [18]. The tests and analyses of the sample before and after surface pollution and water diffusion treatment are then performed including hydrophobic transfer, water diffusion, permittivity, resistivity, and FTIR [12]. The novelty of this paper is the composition and concentration of the SR insulator matrix with SiO_2, ATH, and TiO_2 micro-nanofillers to improve the physical, electrical, and chemical performance of polymer insulators with the addition of TiO_2 that can improve UV radiation resistance, water diffusion, flashover, corona, and tacking to maintain the hydrophobic properties of polymer insulators.

2. Materials and Methods

A. Material and Insulator Matrix Fabrication

In this research, the material used consisted of the best composite SR provided by CV. Intraco and support from PT. Serambi Gayo Sentosa. The filling material uses the best quality filler materials including SiO_2, ATH, and TiO_2 micro-nanofillers with specifications and physical characteristics according to Table 1.

Table 1. Specifications and characteristics of particle filler [4]

Particle	Particle size	Shape	Supplier
TiO_2	~ 20 nm	amorphous	Poshopku
ATH	~ 20 nm	amorphous	Shanghai Xinglu Chemical Technology Co., Ltd.
SiO_2	8.19 ~ 8.57 µm	amorphous	HW
SiO_2	20 ~ 30 nm	hexagonal	Nanomaterial, China

Sample fabrication follows the standing operating procedure of making an insulator matrix. Initially, all fillers are stored separately in an oven at 60 °C for 48 hours to remove air moisture, then weighed and mixed with other materials according to a predetermined composition and concentration. The dry filling material was then put into a mixer container with a certain composition and concentration. The weight percentage (wt%) of each filler was weighed at room temperature, stirred well gently before mixing with silicone rubber. The SR is added to the filler mixture with a percentage of weight according to the design of the mixture concentration [19]. The composition and concentration of fillers in the SR insulator matrix are described in [4]. In this study, filler concentration was increased by up to 20 wt% in each type of the SR insulator matrix.

The dough of the SR insulator matrix is placed on the mixer machine and stirred under vacuum conditions for 30 minutes using a mixer with a balloon whisk beater. The mixer speed was set at P1 and P3 speed for 5 and 25 minutes, respectively. Next, the dough is added hardener as a catalyst and rotated again at P1 and P5 speed for 1 and 4 minutes, respectively to spread the hardener on the dough [4]. The sample is printed 3 mm thickness with unpressurized mold at room temperature for 24 hours. The molded and dried dough is cut into an SR insulator matrix of size 70x70x3 mm^3 and other sizes according to the design. The SR insulator matrix is cut and washed with 96% alcohol and heated in an oven at 60 °C for 24 hours [19].

B. Hydrophobic Transfer Insulator Matrix Test

Investigation of the hydrophobic transfer characteristics of the SR insulator matrix was carried out with two treatments of kaolin surface pollution, namely: (1) applied pollution above the surface then exposed at room temperature, (2) pollution applied above the surface is then exposed to UVa radiation (340nm) [17], each for 120 hours. Before processing, pure condition samples must be ensured that all parameters have been measured according to the procedure including thickness, capacitance, weight, volume and surface resistance, and contact angle measurements [19].

After the pure condition measurement is completed, the sample is then placed in a container and coated with 2 mm thick kaolin for surface pollution treatment [19]. Next, the contact angle is measured in a pure state shortly after the kaolin contaminant is applied as the initial condition (H0). Contact angle testing was repeated every 3 hours for 5 days until the kaolin contaminant became hydrophobic, and then hydrophobic properties were measured every 24 hours until the contact angle condition was relatively constant [4]. All samples that have completed surface contaminant treatment have their parameters measured again including weight, capacitance, resistance, PD, flashover, BD, SEM, EDS, and FTIR for comparison of performance before and after treatment [4].

C. Water Diffusion Insulator Matrix Test

Water diffusion test treatment is carried out by placing samples measuring 70x70x3 mm³ in the distilled water container and treated with two temperature conditions, namely exposed in a container in an open place at room temperature, and exposed in a distilled water container at a water container with a temperature of 70 °C.

The sample weight of the SR insulator matrix is measured at pure condition (H0) before being put into the container. In water diffusion treatment investigations, parameters measured periodically every 24 hours include weight, capacitation, resistance, and contact angle [20]. This measurement is repeated every 24 hours until the weight change is relatively constant. Furthermore, additional measurements are performed after the constant including PD, flashover, BD, SEM, EDS, and FTIR. Based on the data obtained, analysis and evaluation were carried out by comparing parameters before and after water diffusion treatment [19].

D. Permittivity Insulator Matrix Test

Investigations of the permittivity of the SR insulator matrix are carried out by measuring the capacitation of each sample periodically and comparing permittivity conditions before and after treatment. Permittivity testing by measuring capacitance to samples with 2 types of treatment, namely: (1) permittivity testing of water diffusion treatments with exposure to room temperature, and 70°C; (2) hydrophobic transfer permittivity testing with two treatments, namely kaolin surface pollution exposed to room temperature, and UVa radiation, each exposed for 18 days.

Capacitance measurements are carried out in pure conditions and then continued daily periodically for water diffusion treatment, while hydrophobic transfer treatment measurements are carried out in pure conditions and at the finally of processing. The capacitance measurement results are then used to analyze permittivity with the formula as follows.

$$\varepsilon = C \cdot d / A \quad (1)$$

$$\varepsilon_r = \varepsilon / \varepsilon_0 \quad (2)$$

where, ε_0 = 8.854187817.10^{-12} (F/m), C = capacitance (Farad), d = sample thickness (m), A = surface area (m^2), ε_r = relative permittivity.

E. Resistivity Insulator Matrix Test

One method for measuring resistivity is to use a Kyoritsu-type KEW3123A insulation tester to measure the volume and surface resistance of the SR insulator matrix. The sample used for resistivity testing is 70x70x3 mm³. Pure condition resistance measurement is carried out after the sample is cured, then continued resistance measurement at each test stage according to the treatment procedure [19]. Next, the volume resistance measurement results are analyzed to determine the volume resistivity using the formula as follows.

$$\rho_v = R_v \cdot A / d \quad (3)$$

where ρ_v = volume resistivity (Ohm.cm), R_v = volume resistance (Ohm), A = surface area (cm^2), and d = sample thickness (cm).

The same sample is used for surface resistance measurement using insulation testers. This module uses two 2x7 cm^2 electrodes with a distance of 5 cm between the two electrodes. The

sample insulator matrix is placed under both electrodes [19]. The surface resistance measurement results are analyzed to determine surface resistivity using the formula as follows.

$$\rho_s = R_s . l / r \quad (4)$$

where ρ_s = surface resistivity (Ohm), R_s= surface resistance (Ohm), l = electrode length (cm), and r = electrode distance (cm).

F. Fourier Transform Infrared (FTIR) Spectroscopy

FTIR analysis is one of the instruments that can be used to understand intermolecular interactions in the SR insulator matrix. FTIR testing of the SR insulator matrix on pure samples and after treatment was carried out to determine the effectiveness of the interaction between filler and composite on the SR insulator matrix with a combination of micro-nanofillers. The FTIR spectrum presented in this figure is the result of FTIR study of SR insulator matrix for all compositions with filler concentrations of 15 wt% and 20 wt% [19].

3. Results

Investigation of SR insulator matrix characteristics includes testing and analysis of hydrophobic transfer, water diffusion, permittivity, resistivity, and FTIR, some other data that we have published previously [4], This paper is a continuation of the results of the research investigation. The test results and data analysis are presented as follows.

A. Hydrophobic Transfer Performance Analysis

The results of the investigation of the hydrophobic transfer characteristics of the SR insulator matrix from the contact angle analysis during processing are shown in Figure 1.

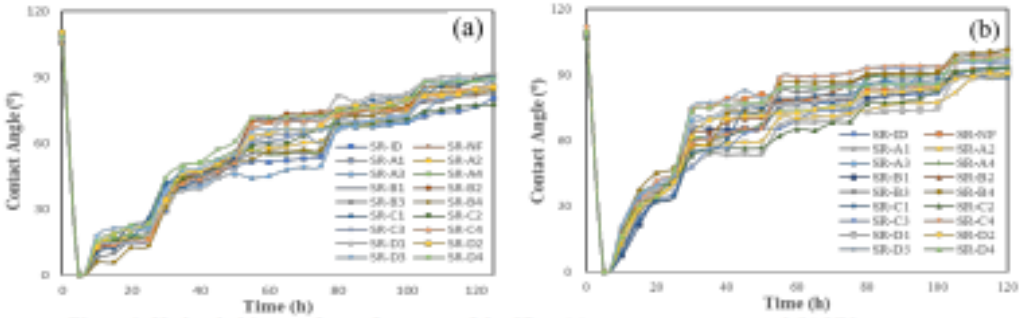

Figure 1. Hydrophobic transfer performance of the SR at (a) room temperature, and (b) UVa treatments

Recovery of hydrophobic with UVa exposure is faster than exposure at room temperature. Hydrophobic transfer analysis with comparing the contact angles of each SR isolator matrix from both treatments for 120 hours. Based on the results of the analysis, it was found that hydrophobic transfer exposed to UVa occurs after 75 hours 96.44°, 91.22°, 91.22°, 90.61°, 90.10°, and 90.10° for SR-D4, SR-NF, SR-ID, SR-C4, SR-A4, and SR-B4, respectively. The speed of recovery of contact angles exposed to room temperature occurred after 110 hours at 91.18°, 90.87°, 90.59°, and 90.09° for SR-B2, SR-A4, SR-C1, and SR-D1, respectively. This happens because the addition of TiO_2 fillers can reflect UV radiation [12] to improve thermal stability and reduce low molecule weight to surface of the insulator matrix [16], [21].

B. Water Diffusion Performance Analysis

Diffusion analysis of water of the same composition can determine the influence of the weight of the filler, while the comparison with the same concentration can determine the influence of the type of filler. The results of the analysis can be shown in Figure 2.

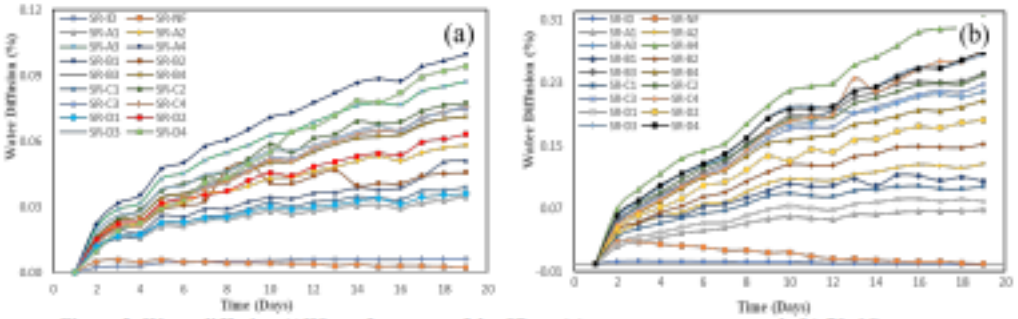

Figure 2. Water diffusion (ΔW) performance of the SR at (a) room temperature, and (b) 70 °C treatments.

On the graph, it can be seen that the diffusion of water is faster saturated at lower temperatures, as well as the percentage of water diffusion is greater if the temperature is higher. Meanwhile, at the same temperature and concentration, the diffusion of SR-D water is better than that of SR-C, SR-B, and SR-A. Likewise, the higher the concentration of filler will increase the percentage of water diffusion with water absorption less than 0.25%.

C. Permittivity Performance Analysis

The results of permittivity analysis of the SR insulator matrix that has been exposed to water diffusion treatment at room temperature and 70 °C for 18 days can be seen in Figure 3.

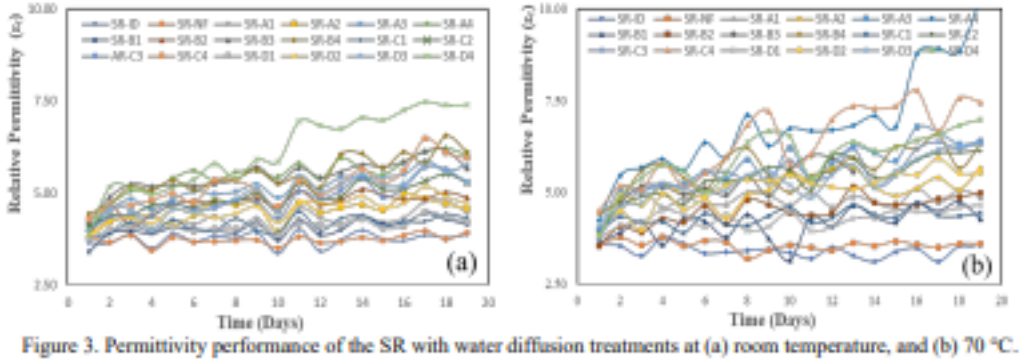

Figure 3. Permittivity performance of the SR with water diffusion treatments at (a) room temperature, and (b) 70 °C.

The permittivity performance of the SR insulator matrix with micro-nanofiller at water diffusion treatment at 70 °C is greater than at room temperature, relative permittivity ranges from 3–7. It was also seen that the addition of filler concentration would increase relative permittivity, even if SR-A4 samples failed after the 15th day. However, the addition of filler concentration will increase the permittivity of the SR insulator matrix, so it must be a consideration in engineering the insulator matrix [22].

D. Resistivity Performance Analysis

Analysis of the resistivity performance of the SR insulator matrix was carried out on pure samples and after treatment, namely: (1) after surface pollution treatment exposed to room temperature and UVa radiation, and (2) after water diffusion treatment exposed to room temperature and 70 °C. The results of volume and surface resistivity performance analysis are shown in Figure 4.

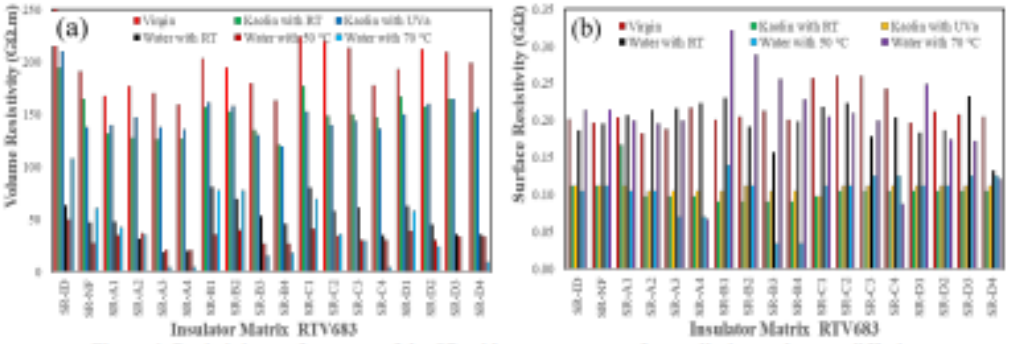

Figure 4. Resistivity performance of the SR with exposure to surface pollution and water diffusion at (a) volume resistivity, and (b) surface resistivity.

Based on the results of resistivity analysis, it is known that the addition of filler concentration decreases the volume and surface resistivity of the polymer insulator. In the surface pollution treatment, it was seen that samples SR-C and SR-D containing TiO_2 nanofillers had greater volume resistivity. Furthermore, when comparing sample types of the same concentration, it can be seen that the volume and surface resistivity of SR-D samples are greater than the other samples at room temperature up to 70 °C. This is a consideration in choosing the type, composition, and concentration of fillers because a decrease in volume resistivity reduces the performance of polymer insulators.

E. FTIR Performance Analysis

FTIR analysis has been performed on all samples. In this section, SR-A, SR-B, SR-C, and SR-D samples with filler concentrations of 15 wt% and 20 wt% are displayed to determine the effectiveness of micro-nanofiller to improving the performance of polymer insulator matrix in high-voltage outdoor insulators. Each SiO_2, ATH, and TiO_2 filler particle can undergo $H^{+\delta}$-$O^{-\delta}$ covalent bonding at a given temperature on the surface of the polymer insulator [3], [4]. The results of FTIR data analysis from each SR insulator matrix using the OriginLab application can be shown FTIR spectra on Figure 5.

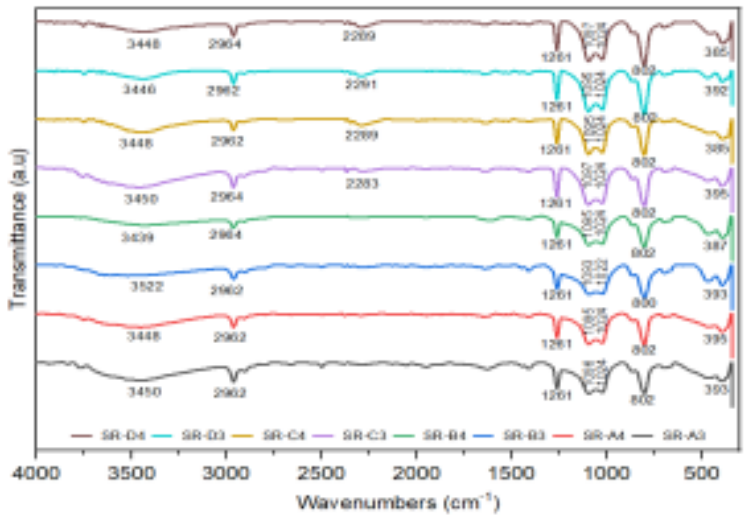

Figure 5. FTIR spectra of the SR insulators matrix with SiO_2, ATH, and TiO_2 micro-nanofillers.

The results of FTIR analysis in the wavenumber range of 300–4000 cm^{-1} can be known as the intensity of absorption bands for SR-A, SR-B, SR-C, and SR-D samples with concentrations of 15 wt% and 20 wt%. The intensity of the absorption band in the region of 3200–3700 cm^{-1}

was the lowest at 60.98%T and the highest at 89.77%T for SR-A3 and SR-D3, respectively. Meanwhile, the highest intensity of the absorption band in the region of 2962–2964 cm^{-1} is 86.24%T, 2283–2299 cm^{-1} is 97.84%T, 1261 cm^{-1} is 69.51%T, 1093–1097 cm^{-1} is 56.22%T, 1022–1024 cm^{-1} is 58.32%T, 800–802 cm^{-1} is 55.14%T, and 385–395 cm^{-1} is 85.98%T for SR-C4, SR-B4, SR-C4, SR-C4, SR-C4, and SR-D3, respectively. This means that SR-C and SR-D the SR insulator matrix with micro-nanofillers have greater absorption intensity than other insulator matrix samples.

4. Discussion

The SR insulator matrix with SiO_2, ATH, and TiO_2 micro-nanofillers has been investigated according to IEC standards. Evaluation of the relationship between surface pollution and water diffusion treatment from the results of physical, electrical, and chemical characteristics analysis is discussed below:

A. Hydrophobic Transfer Performance Evaluation

Hydrophobic recovery with UVa exposure is faster than room temperature exposure, because UV exposure can accelerate the movement of silicone rubber particles, but the combination of micro-nanofillers and TiO_2 particles having excellent radiation reflection ability increase thermal stability and inhibit the movement of particles to the surface of the insulator matrix [2]. This suggests that the addition of TiO_2 fillers for UV resistance to polymer insulators is important because it impacts polymer performance and service life [21].

B. Water diffusion Performance Evaluation

The results of the SR insulator matrix water diffusion analysis found that the higher the filler concentration will increase the percentage of water diffusion. Meanwhile, it is also seen that the diffusion of water is lower and quickly saturated at lower temperatures due to the interaction of silanol bonds on the surface of the insulator matrix is slower. Furthermore, at the same temperature and concentration the diffusion of SR-D water is better than that of SR-C, SR-B, and SR-A. The SR insulator matrix with micro-nanofillers has more silanol bonds on the surface of the polymer insulator matrix to reduce water diffusion.

C. Permittivity Performance Evaluation

The permittivity of the SR insulator matrix with micro-nanofiller increases at higher temperatures because the density of the filler decreases so that the voids enlarge which increases capacitance and permittivity. This is certainly greater at higher filler concentrations, therefore a combination of micro-nanofillers that have good thermal stability is needed. Fillers with a combination of micro-nanofillers in addition to having a stronger structure also increase the surface area of the filler and thermal stability so that the permit performance is better [22].

D. Resistivity Performance Evaluation

The results of the resistivity analysis of the SR insulator matrix with micro-nanofiller showed that the addition of filler concentration decreased the resistivity of volume and surface after treatment. The decrease in volume and surface resistivity with water diffusion treatment at heavier filler concentrations occurs because the percentage of water absorbed by the insulator matrix is higher so that it is moist and conductive. Meanwhile, the decrease in volume and surface resistivity with surface pollution treatment is caused by kaolin residues on the surface of the insulator matrix so that it is more moist than in pure conditions. Volume and surface resistivity of SR-D samples is better than other samples at room temperature up to 70 °C due to the influence of TiO_2 and SiO_2 nanofillers with a composition of 16.67 wt% of filler concentration respectively [7].

E. Chemical Performance Evaluation

Based on the results of FTIR analysis in the wavenumber range of 300–4000 cm^{-1}, it can be known the intensity of the absorption band for SR-A, SR-B, SR-C, and SR-D samples with concentrations of 15 wt% and 20 wt%. From the intensity of the spectrum, it is known that SR-C and SR-D samples have greater absorption intensity than other insulator samples. This shows that the presence of SiO_2 and TiO_2 nanofillers in addition to improving physical and electrical performance, can also play an effective role in reflecting UV radiation on polymer insulators. In addition, TiO_2 fillers can form O-H bonds with SiO_2 and ATH fillers [3]. The three fillers form the dehydroxylation of O-H compounds so that they can release H_2O compounds if the temperature is met, which is needed in polymer insulators to improve the dielectric performance of polymer insulators SR [6].

5. Conclusions

Investigation of the performance of the SR insulator matrix with SiO_2, ATH, and TiO_2 micro-nanofillers has been carried out experimentally according to IEC standards including testing and analysis of physical, chemical, and electrical characteristics by surface pollution treatment exposed to room temperature and UVa, as well as diffusion treatment of water exposed to room temperature and 70°C. The findings of this study can be summed up as follows.

1. The performance of the SR insulator matrix with micro-nanofillers containing TiO_2 particles showed better performance of water diffusion and hydrophobic transfer. The addition of nanofiller particles can improve the performance of the SR insulator matrix to reduce the filler concentration to overcome the constraints of water diffusion.
2. The addition of TiO_2 nanofillers has the potential to improve the performance of polymer insulators, it can be seen that the addition of filler concentrations up to 20 wt% in SR-C and SR-D samples containing TiO_2 nanofillers shows better permittivity and resistivity compared to SR-NF, SR-A, and SR-B.
3. The results of FTIR analysis of the insulator matrix SR-D with SR-C show that the electromagnetic radiation and chemical structure of the SR-D insulator matrix are better than SR-C. This confirms that the addition of hexagonal nanofillers SiO_2 and TiO_2 of 16.67 wt% each can improve the performance of polymer insulators for high-voltage outdoor insulator applications.

6. Acknowledgment

We want to thank PT. Serambi Gayo Sentosa for its assistance in carrying out this research, and also thanks to BRIN RI for its assistance in validating the particle size of the filler used in this research. Hopefully, this research is sustainable and optimal results will be useful in electricity development.

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Lampiran 3. Artikel prosiding internasional

2023 4th International Conference on High Voltage Engineering and Power Systems (ICHVEPS)

Investigation of SiO_2/ATH/TiO_2 Micro-nanofillers to Improve Performance of Silicone Rubber toward UV Radiation and Partial Discharge on High Voltage Outdoor Insulators

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***Abstract*—This paper discusses the characteristics of polymer insulator matrix from RTV683 composites with micro-nanofillers to improve the performance of polymer insulators. Research is expected to obtain a new polymer insulator matrix with the best filler composition that is effectively applied to high-voltage outdoor insulators in tropical climates. Investigations were conducted to develop new materials that can improve hydrophobic performance by reducing partial discharge and increasing the UV resistance of silicone rubber insulators. The method used was to choose the material with the best performance and then combine it to overcome the obstacles of applying polymer insulators as outdoor high-voltage insulators. Furthermore, developing a manufacturing method for making a polymer insulator matrix using RTV683 silicone rubber with SiO_2, ATH, and TiO_2 micro-nanofillers. Insulator matrix fabrication using mixers under vacuum conditions for filler dispersion and elimination of voids in polymer insulator matrix. Testing and analysis of polymer insulator matrix characteristics including physical, electrical, and chemical tests according to IEC standards include hydrophobic transfer, water diffusion, scanning electron microscopy (SEM), partial discharge (PD), and Fourier transform infrared spectroscopy (FTIR). The results showed that the RTV683 polymer insulator matrix with a combination of SiO_2, ATH, and TiO_2 micro-nanofillers has the potential to improve the performance of high-voltage polymer insulators.**

Keywords*—partial discharge, polymer insulator, UV radiation, silicone rubber, micro-nanofiller.

I. INTRODUCTION

The polymer insulator matrix is the main material of polymer insulators as housing. The quality of polymer insulators is largely determined by the performance of the polymer insulator matrix [1]. The main materials of the polymer insulator matrix studied are RTV683 silicone rubber (SR) and SiO_2, ATH, and TiO_2 micro-nanofillers. This SR has hydrophobic properties that can convert pollutants on the surface into hydrophobic which is very well used as a high-voltage outdoor insulator [2]. To improve the performance of the polymer insulator matrix from SR, it is necessary to add a quality filler according to the environmental constraints where the insulator is used. The combination of micro-nanofillers expands the filler surface, improving stability and thermal distribution to prevent capitation causing voids in the fabrication process that can be engineered on the insulator matrix [3].

Silicone rubber has external constraints in the use of high-voltage outdoor insulators, such as tearing, burning, and biting animals, insects, and microbiology [4], blistering, absorbing water, and UV radiation [1], and internal constraints such as flashover, PD, and dry band art (DBA) [5]. These physical, electrical, and chemical constraints need to be overcome by engineering the best quality micro-nanofillers such as silicon dioxide (SiO_2) fillers for hardness and alumina trihydrate (ATH) for high-temperature resistance [6], and titanium dioxide (TiO_2) to increase resistance to UVa exposure [7][8]. The combination of SiO_2 micro-nanofillers can improve the mechanical strength and stability of hydrophobic transfer, while our ATH uses nano-sizes to improve the durability of polymer insulators from flashover, PD, and DBA causing tracking and erosion in polymer insulators. In this research, we investigated the effectiveness using of SiO_2, ATH, and TiO_2 micro-nanofillers to improve the performance and service life of polymer insulators [9][10].

Investigation of RTV683 silicone rubber insulator matrix by engineering SiO_2, ATH, and TiO_2 micro-nanofillers to determine high-voltage polymer insulator physical, electrical, and chemical characteristics for outdoor applications. Surface pollution treatment and water diffusion, then conduct testing and analysis including hydrophobic transfer, water diffusion, scanning electron microscopy (SEM), partial discharge (PD), DC breakdown voltage, and Fourier transform infrared spectroscopy (FTIR)[11].

The novelty of this research is the combination of TiO_2 nanofiller with SiO_2 and aluminum trihydrate (ATH) on RTV683 silicone rubber. The addition of TiO_2 is expected to improve the performance of polymer insulators against UV exposure in maintaining hydrophobic properties.

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II. Materials And Methods

A. Materials and Sample Fabrication

The material used in this study is RTV683 silicone rubber composite supplied by CV. Intraco and support from PT. Serambi Gayo Sentosa. While filler materials use SiO_2, ATH, and TiO_2 with specifications and physical characteristics according to Table I.

TABLE I. Characteristics Of Particles According To Supplier Data.

Particle	Particle size	Shape
TiO_2	~20 nm	amorphous
ATH	~20 nm	amorphous
SiO_2	8.19~8.57 µm	amorphous
SiO_2	20~30 nm	hexagonal

Initially, all fillers are stored in an oven at 60°C for 48 hours to remove air moisture. The dried filler material is put into the mixer container and weighed according to the weight percentage (wt%) of each filler using electronic balance type SS-A1000. Once the filler composition is appropriate, it is then stirred to evenly distribute the filler and remove the agglomeration of the filler when mixed with silicone rubber. RTV683 silicone rubber is then added to the filler that has been stirred evenly with a percentage of weight according to the planned mixture concentration.

RTV683 composite material and filler that have been inserted into the container are then placed on the mixer machine to be stirred evenly under vacuum conditions for 30 minutes using a balloon whisk mixer of 5 minutes at P1 speed, and 25 minutes at P3 speed respectively. Next, a catalyst with a certain concentration is added, then mixed with P1 speed for 1 minute and P5 speed for 4 minutes to spread hardener in composite dough and filler. It is then printed using an unpressurized container with a thickness of 3 mm at room temperature for 24 hours. The dried material is cut into an insulator matrix measuring 70x70x3 mm^3 and others according to the test design. Before testing, the insulator matrix sample was washed with 96% alcohol and then heated in an oven at 60°C for 24 hours [11].

B. Hydrophobic Transfer Test on Insulator Matrix

Hydrophobic transfer testing of insulator matrix is carried out with two types of treatment: (1) the sample is placed in a container and given contaminants on its surface exposed to room temperature, (2) the sample is placed in a container and given contaminants on one side then exposed to UVa light during the test process.

Before being placed into the container, the sample in virgin condition must be ensured that the parameters have been measured according to the procedure. The measurements carried out include sample thickness using a digital micrometer, capacitance using a CM8601A+ type capacitance meter, weight using an AUW220D type analytical balance, measuring volume and surface resistance using a KEW 3123A type insulation tester, and measuring the contact angle with water droplets from a 50 microliter Joanlab type micropipette, then water droplets are recorded with a digital camera and analyzed using ImageJ software [11].

After the measurement of the virgin condition is complete, the sample is put into a container and coated in 2 mm thick kaolin contaminants. Next, the sample was treated with contaminants, measured the contact angle as virgin condition (H0) and then repeated once every 24 hours until the contact angle condition was relatively constant. After the treatment of contaminants exposed to room temperature and UVa is complete, all samples are then tested again for capacitance, weight, resistance, partial discharge, DC breakdown voltage, SEM, and FTIR to compare parameters before and after treatment.

C. Water Diffusion Test on Insulator Matrix

Sample treatment with water diffusion is carried out by placing the sample in a container of distilled water and then treated with two conditions, namely exposed to room temperature in an open space, and exposed to a constant temperature of 50 °C in a container of water.

The sample size used in this test is 70x70x3 mm^3. Samples with similar fillers can be placed in distilled water in the same container with different concentrations of fillers. Weight measurement of the insulator matrix sample is carried out at virgin condition (H0) before being inserted into the container. During water diffusion treatment, measurements of weight, capacitation, and contact angle are performed every 24 hours until the relative weight change is constant [11].

Measurement and testing according to procedures include capacitance, volume and surface resistance, contact angle, weight, PD, DC breakdown voltage, SEM, and FTIR. Then conduct analysis and evaluation by comparing parameters before and after treatment.

D. Scanning Electron Microscope (SEM)

The sample size used is 10x10x3 mm^3 according to the SEM module specimen design. The samples analyzed by SEM include SR-C1, SR-C2, SR-C3, SR-D1, SR-D2, and SR-D3, namely the RTV683 insulator matrix containing TiO_2 elements with filler concentrations of 5wt%, 10wt%, and 15wt% respectively to determine the morphology and topography of the combination of SiO_2, ATH, and TiO_2 micro-nanofillers in the polymer insulator matrix. This SEM test was carried out at the Microstructure Laboratory of the Faculty of Engineering Universitas Muslim Indonesia.

E. Partial Discharge Test on Insulator Matrix

The PD testing of the insulator matrix to determine the partial discharge value of the phase angle change and the magnitude of the partial discharge with the amount of discharge occurring to help understand the electrical insulation behavior under operating conditions in performing more reliable polymer insulator matrix engineering [12]. The sample dimensions of the insulator matrix used are 70x70x3 mm^3, this sample is placed on an HV9134 type module with a round plate electrode 5 cm in diameter [13]. The PD testing with a test voltage of 10.15 kV on each insulator matrix sample under virgin conditions and after aging treatment. This test uses a digital partial discharge meter type HV9160 for AC voltage at the High Voltage Laboratory of Universitas Hasanuddin.

F. DC Breakdown Voltage on Insulator Matrix

DC breakdown voltage testing to determine the dielectric strength of the insulator matrix material [12]. The sample size used is 70x70x3 mm^3. The sample is placed between two

acrylic plates, each 24 mm thick with a width corresponding to the sample size to prevent charge from flowing through the surface of the insulator. In the center of the acrylic plate, a needle conductor is given to connect the electrode with the insulator matrix sample. The sample attached between the two acrylics is then placed on both 1.5 mm diameter tube electrodes on the HV9133 type spare gap module. DC breakdown voltage testing of the insulator matrix was performed against each virgin insulator sample and after treatment. This test uses a Terco brand HV module with peak voltmeter measurement type HV9151.

G. Fourier Transform Infrared Spectroscopy (FTIR)

FTIR analysis of RTV683 insulator matrix to determine the chemical structure of the insulator matrix and the effectiveness of using SiO_2, ATH, and TiO_2 micro-nanofillers in outdoor high-voltage polymer insulators [11]. The test was carried out at the Organic Chemistry Laboratory, Faculty of Mathematics and Natural Sciences, Hasanuddin University. The sample size used is 10x10x3 mm^3 according to the required specimen design. Samples tested by FTIR are described in Table II.

TABLE II. MATRIX INSULATOR DESIGN.

Sample Code	Filler	Concentration (Weight %)
SR-I	Silicone rubber from the industry	
SR-NF	Non-filler	-
SR-A1	micro SiO_2+ nano ATH	5
SR-A2	micro SiO_2+ nano ATH	10
SR-A3	micro SiO_2+ nano ATH	15
SR-B1	micro/nano SiO_2+ nano ATH	5
SR-B2	micro/nano SiO_2+ nano ATH	10
SR-B3	micro/nano SiO_2+ nano ATH	15
SR-C1	micro SiO_2+ nano ATH+ nano TiO_2	5
SR-C2	micro SiO_2+ nano ATH+ nano TiO_2	10
SR-C3	micro SiO_2+ nano ATH+ nano TiO_2	15
SR-D1	micro/nano SiO_2+ nano ATH+ nano TiO_2	5
SR-D2	micro/nano SiO_2+ nano ATH+ nano TiO_2	10
SR-D3	micro/nano SiO_2+ nano ATH+ nano TiO_2	15

FTIR is one of the instruments used to see intermolecular movement and electromagnetic radiation at wavelengths of 0.75–1,000 µm or wavenumbers 13,000–10 cm^{-1}. FTIR examination is carried out on all insulator matrix samples, both new materials and from the industry as a comparison to determine the bonds and deflective groups of chemical elements from each insulator matrix.

III. RESULTS

Investigation of polymer insulator matrix by analyzing physical, electrical, and chemical characteristics includes hydrophobic transfer testing, water diffusion, SEM, PD, DC breakdown voltage, and FTIR. The results of the research whose data can be analyzed below.

A. Hydrophobic Transfer Analysis

Hydrophobic transfer testing of the RTV683 polymer insulator matrix has been performed by two treatment methods, each test exposed to room temperature and UVa with a wavelength of 340 nm [9] for 18 days. The results of measuring the contact angle during the treatment process are shown in Fig.1.

The recovery rate of hydrophobic transfer exposed to UVa has a faster hydrophobic transfer than those exposed to room temperature. Furthermore, by comparing the average hydrophobic transfer rates of the contact angles of each insulator matrix sample from both treatments it can be found that hydrophobic transfer exposed to UVa occurs on day 2 SR-C3 (92.45°), SR-D3 (94.66°), SR-B3 (99.00°), SR-B2 (97.59°), SR-I (90.22°) faster than those exposed to room temperature. It was seen that the RTV683 insulator matrix with a filler concentration of 15wt% experienced faster recovery than others, SR-C and SR-D samples containing TiO_2 filler experienced slower recovery, and the contact angle of SR-D was greater than SR-C for the same filler concentration. The comparison of the recovery speed of the contact angles SR-D1; SR-D2; and SR-D3, it is known that the recovery speed of the contact angle of SR-D3 with a contact angle of 91.08° on the 8th day exposed to room temperature and a contact angle of 94.66° on the 5th day exposed to UVa, is superior to other samples.

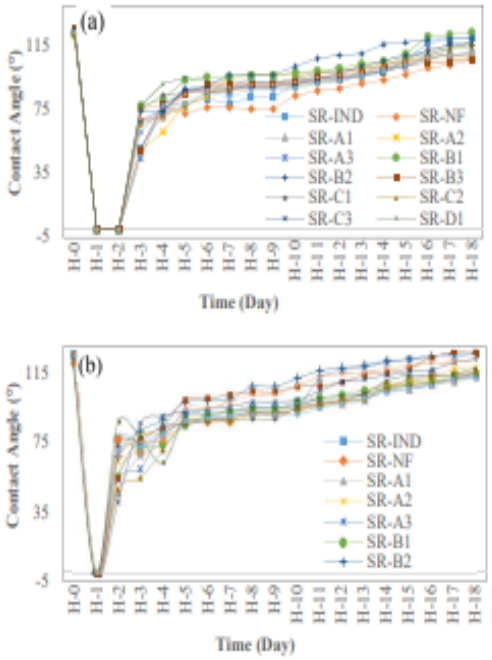

Fig. 1. Hydrophobic transfer characteristic of insulator matrix RTV683, at (a) room temperature, and (b) UVa treatments.

B. Water Diffusion Analysis

Water diffusion analysis in insulator matrix samples was carried out by comparing water diffusion from each insulator matrix with the same filler composition to determine the effect of filler type, also comparing filler concentration to determine the effect of filler weight on the characteristics of RTV683 insulator matrix on water absorption.

In Fig.2. It can be seen that the higher the concentration of insulator matrix filler, the higher the water absorption with water absorption of less than 10%. However, when compared between samples with the same composition it can be seen that the water diffusion of SR-D3 is lower than SR-C3, SR-B3, and SR-A3. The low diffusion of water from the RTV683 matrix with micro-nanofillers SiO_2, ATH, and TiO_2 is due to the presence of more silanol bonds on the insulator surface so that the ability to expel hydrogen elements from water is stronger. In addition, the bond of RTV683 silanol with nano SiO_2 is more elastic so it is easier to interact in repelling water entering the surface of the polymer insulator [11]. It was also seen that RTV683 non-filler (SR-NF) repelled water from day

3. Comparison of water diffusion of samples exposed to room temperature with a temperature of 50°C until day 18 shows that the percentage rate of water diffusion is faster at 50°C.

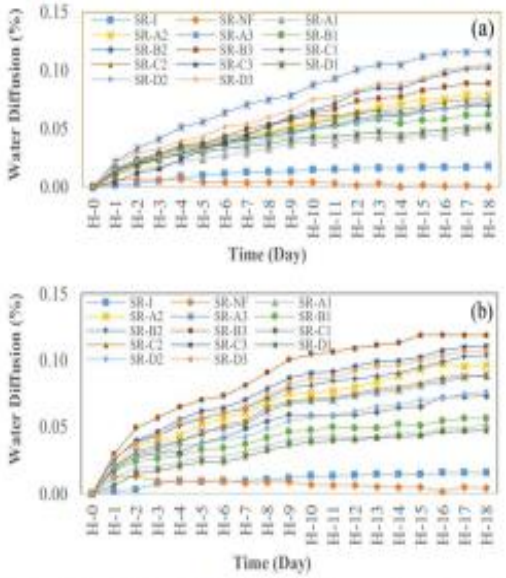

Fig. 2. Water diffusion (ΔW) RTV683 at (a) room temperature, and (b) 50°C treatments.

C. Scanning Electron Microscope (SEM) Analysis

SEM investigation was conducted by analyzing the morphology and topography of the RTV683 insulator matrix including SR-C1, SR-C2, SR-C3, SR-D1, SR-D2, and SR-D3 for SiO_2, ATH, and TiO_2 micro-nanofillers. The presence of TiO_2 nanofillers appears shiny in a brighter insulator matrix as shown in Fig.3.

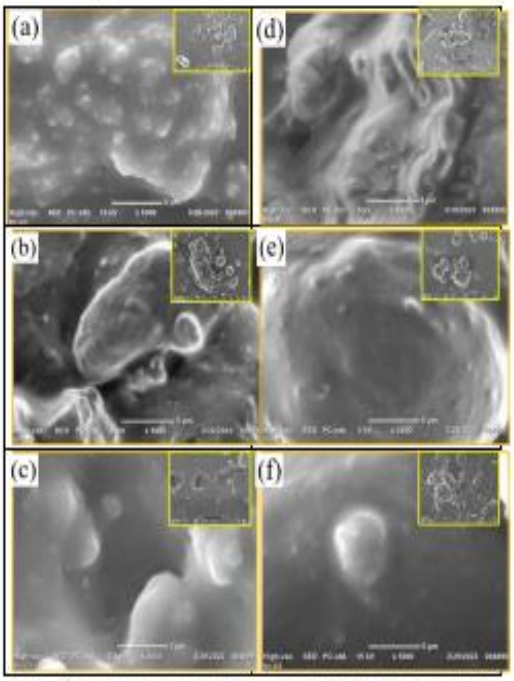

Fig. 3. SEM micrographs of the insulator matrix RTV683 with filler TiO_2 : (a) SR-C1, (b) SR-C2, (c) SR-C3, (d) SR-D1, (e) SR-D2, (d) SR-D3.

Based on the results of SEM analysis with the magnification of 500x and 5000x, it is known that the morphology and topography of the insulator matrix of RTV683 with SiO_2, ATH, and TiO_2 micro-nanofillers still have agglomeration in SR-D3 samples of 6.67 µm and coarse textures in SR-C2 samples also have holes in SR-C3 samples of about 44.4 µm².

When compared morphology and topography at concentrations of 5wt%, 10wt%, and 15wt% it can be seen that the agglomeration of SR-D3 samples is smaller and more evenly distributed than SR-D2 and SR-D1. Likewise, when comparing the different compositions between SR-C and SR-D at the same concentration, it can be seen that the agglomeration of SR-D samples is smaller than SR-C. This means that the morphology of SR-D3 is better than other samples. While at 5000x magnification SR-CD3 samples with concentrations of 15wt% are smoother than others. This means that the topography of the SR-D3 insulator matrix is better than that of other samples.

D. Partial Discharge (PD) Analysis

Based on the results of partial discharge (PD) testing on Fig.4, it is known that the higher the filler concentration, the smaller the PD value of the insulator matrix. When comparing samples after treatment with water diffusion and surface pollution at filler concentrations of 5wt%, 10wt%, and 15wt%, it can be seen that the PD value of SR-D3 is lower than other samples. It can be seen that the SR-D3 insulator matrix has the smallest PD Value of 4.9 pC after water diffusion treatment at room temperature and 16.42 pC after water diffusion treatment at 50°C. Much smaller than the average PD value after treatment of all samples was 36.72 pC.

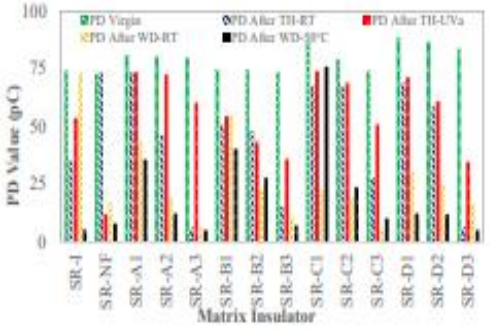

Fig. 4. PD value RTV683 with micro-nanofillers after surface pollution and water diffusion treatment.

E. DC Breakdown Voltage Analysis

DC breakdown voltage is one of the parameters to determine the dielectric strength of each polymer insulator matrix with different filler composition and concentration. DC breakdown stress test results of each insulator matrix sample as shown in Fig.5.

Based on the results of the DC breakdown voltage test above, it can be seen that the ratio of DC breakdown voltage at filler concentrations of 5wt%, 10wt%, and 15wt% shows that the DC breakdown voltage of SR-D samples is higher than SR-C, SR-B, and SR-A. This means that the dielectric strength of SR-D is better for the same concentration of filler.

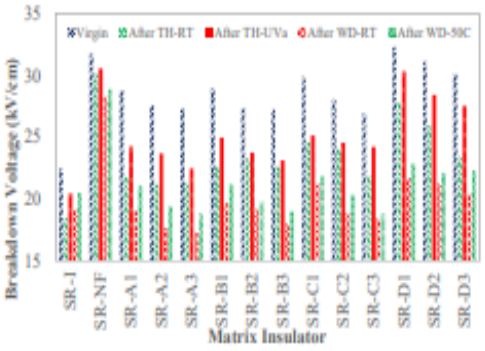

Fig. 5. DC breakdown voltage RTV683 after surface pollution and water diffusion treatment.

F. FTIR Analysis

FTIR analysis of the insulator matrix was performed on SR-C and SR-D samples. Each filler particle can undergo $H^{+\delta}$- $O^{-\delta}$ covalent bonds, that is, hydrogen atomic bonds with oxygen to elements that have strong electromagnetism. Based on the wave number transmitted to the sample of the insulator matrix, the peak, intensity, and area of each element of the insulator matrix and then normalized by application OriginLab can be shown the results of FTIR spectrum analysis from the insulator matrix on Fig.6.

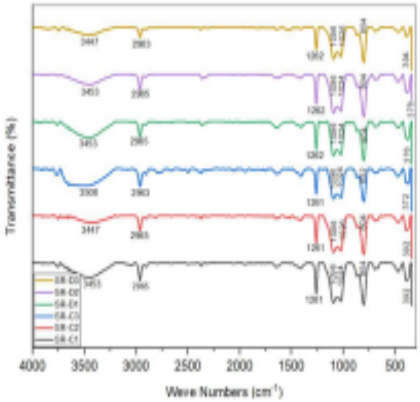

Fig. 6. FTIR spectra of RTV683 samples with SiO_2, ATH, dan TiO_2 micro-nanofillers in the wavenumber range from 300 to 4000 cm^{-1}.

From the results of FTIR analysis, it is known that the FTIR spectra of SR-C and SR-D are shown in the wavenumber range of 300–4000 cm^{-1} [7]. The three filler show three bands including a broad absorption band of about 3500 cm^{-1}. Stretching vibrations of O-H hydroxyl groups bound to the surface of SiO_2, ATH, and TiO_2 absorption bands at 2962 cm^{-1} due to Si-OH, Al-OH, and Ti-OH bands and absorption bands at 1262 cm^{-1} for Si-O, Ti-O, and Al-O modes, then about 804 cm^{-1} appeared Ti-O-Si chemical bond, then about 1024–1096 cm^{-1} appeared Si-O-Si strong band in SR-C and SR-D insulator matrix. There was an increase in transmittance in OH (3200–3700) from 61%T in SR-C3 to 89%T in SR-D3 with the addition of SiO_2 nanoparticles as much as 2.5wt% in SR-D3 samples.

IV. Discussion

Research on the RTV683 polymer insulator matrix with SiO_2, ATH, and TiO_2 micro-nanofillers has been carried out according to IEC standards. Testing and analysis of physical, chemical, and electrical characteristics include hydrophobic transfer, water diffusion, SEM, PD, DC breakdown voltage, dan FTIR. The relationship between surface pollution and water diffusion treatment with the physical, electrical, and chemical characteristics of polymer insulator matrix is discussed below:

A. Physical Performance Matrix Insulator Polimer

Based on the results of physical analysis including hydrophobic transfer, water diffusion, and SEM, to the RTV683 polymer insulator matrix with SiO_2, ATH, and TiO_2 micro-nanofillers. The relationship between each treatment can be explained from the results of testing and analysis of physical characteristics, as follows.

1) The contact angle and hydrophobic transfer of the RTV683 insulator matrix of SR-D and SR-C samples for heavier filler concentration are relatively better and stable, but the recovery is slower and the contact angle of SR-D is greater than SR-C. This happens because the combination of SiO_2, ATH, and TiO_2 micro-nanofillers extends the movement path of silicone rubber particles to the surface so as to maintain hydrophobic transfer properties and extend the life of the insulator [14].

2) The results of water diffusion analysis from the RTV683 insulator matrix found that the heavier the filler concentration, the more water diffusion. It was also seen that SR-D3 samples had lower absorption than SR-C3, SR-B3, and SR-A3. This happens because SR-D3 samples have more silanol bonds on the insulator surface in the presence of SiO_2, ATH, and TiO_2 micro-nanofillers so that the ability to repel water from hydrogen elements is stronger. In addition, RTV683 silanol bonds with nanofillers become more elastic in interacting to repel water entering the insulator surface.

3) The results of SEM analysis with the magnification of 500x and 5000x showed that the agglomeration and texture of SR-D3 were better than other samples. This occurs due to the influence of SiO_2, ATH, and TiO_2 micro-nanofillers added to the insulator matrix. The filler effect of nano TiO_2 fillers shows brighter samples that can better reflect sunlight on the insulator surface [7].

B. Electrical Performance Matrix Insulator Polimer

Based on the results of electrical analysis including PD, and DC breakdown voltage against the RTV683 polymer insulator matrix with SiO_2, ATH, and TiO_2 micro-nanofillers. The relationship can be explained from each electrical characteristic test result as follows.

1) The results of PD analysis with surface pollution treatment and water diffusion show that at high filler concentrations, the smaller the PD value. However, it can be noted that SR-C and SR-D samples have greater PD values than others, this happens because the addition of SiO_2, ATH, and TiO_2 micro-nanofillers increases the number of particles with different permeabilities that increase the PD value [15]. This is a consideration in filler engineering to improve the performance of polymer insulators.

2) Analysis of DC breakdown voltage by surface pollution treatment and water diffusion shows that increasing the concentration of filler decreases DC breakdown voltage [16]. At the same filler concentration, the SR-D insulator matrix has a higher DC breakdown voltage than other samples. This is related to the increase in capacitance and the

increase in the surface area of the filler from the increase in the filler concentration in the insulator matrix.

C. Chemical Performance on Insulator Matrix

The O-H bond produced by the three fillers allows chemical compounds to occur between the three elements of the particle if conditions are met. Dehydroxylation of O-H compounds from different fillers can release H_2O compounds needed in polymer insulators to improve the dielectric performance of polymer insulators [7]. Likewise, the hydrogen bonding of O-H compounds between fillers allows the insulator to absorb water, but in the presence of hydrophobic properties and hydrophobic transfer ability silicone rubber can repel water on the surface of the insulator matrix.

V. Conclusions

Investigation of RTV683 insulator matrix with SiO_2, ATH, and TiO_2 micro-nanofillers with testing and analysis of physical, chemical, and electrical characteristics has been carried out experimentally according to IEC standards with surface pollution treatment exposed to room temperature and UVa, as well as diffusion treatment of water exposed to room temperature and 50°C. The conclusions of the research findings are as follows.

1) Performance of the RTV683 insulator matrix containing TiO_2 fillers showed better hydrophobic transfer performance against UVa exposure, hydrophobic properties can be recovered on day 2 SR-C3 (92.45°), SR-D3 (94.66°). However, the increase in filler concentration needs to be carefully limited because it is proven to increase water diffusion.

2) RTV683 insulator matrix containing SiO_2, ATH, and TiO_2 micro-nanofillers with heavier filler concentrations in SR-C and SR-D samples showed better PD and DC breakdown voltages compared to SR-A and SR-B, indicating that the addition of TiO_2 nanofillers has the potential to improve the performance of polymer insulators

3) A comparison of the insulator matrix of the SR-D with SR-C on surface pollution and water diffusion treatment, under various conditions shows that SR-D performs better than SR-C. This confirms that the addition of SiO_2 hexagonal nanofillers and nano TiO_2 can improve the performance of polymer insulators for high-voltage outdoor insulator applications.

Acknowledgment

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[16] M. S. Hamzah, M. Mariatti, and M. Kamarol, "Breakdown characteristics of grafted polypropylene in PP/EPDM hybrid nanocomposite for electrical insulator applications," Polym. Bull., vol. 75, no. 6, pp. 2529–2542, 2018, doi: 10.1007/s00289-017-2167-z.

Lampiran 4. Sertifikat pemateri dan partisipan

CERTIFICATE

OF PARTICIPATION

This certificate is proudly presented to

Mustamin

as

PRESENTER

on the occasion of

2023 4th International Conference on High Voltage and Power Systems (ICHVEPS)

that has been held on August 6 - 10, 2023

at Prama Sanur Beach Denpasar, Bali, Indonesia

PROF. DR. SUWARNO

GENERAL CHAIRMAN

Organized by: STEI-ITB +HABAT

Sponsored by: Institut Teknologi Bandung 1920; IEEE Indonesia Section; IEEE ITB Student Branch; IEEE PES Power & Energy Society Indonesia Chapter

Supported by: PLN Mobile; PLN

CERTIFICATE

OF PARTICIPATION

THIS CERTIFICATE IS PROUDLY PRESENTED TO

Mustamin, Syafaruddin, Salama Manjang, and Paulina Taba

as authors of paper entitled

Investigation of SiO2/ATH/TiO2 micro-nanofillers to improve performance of silicone rubber toward UV radiation and partial discharge on high voltage outdoor insulators

on the occasion of

2023 4th International Conference on High Voltage and Power Systems (ICHVEPS)

that has been held on August 6 - 10, 2023

at Prama Sanur Beach Denpasar, Bali, Indonesia

PROF. DR. SUWARNO

General Chairman

Organized by: STEI-ITB +HABAT

Sponsored by: Institut Teknologi Bandung 1920; IEEE Indonesia Section; IEEE ITB Student Branch; IEEE PES Power & Energy Society Indonesia Chapter

Supported by: PLN Mobile; PLN

Lampiran 5. Data spesifikasi *MSDS* material

SAFC®

www.sigmaaldrich.com

LEMBAR DATA KESELAMATAN

menurut Peraturan (EC) No. 1907/2006

Versi 8.8
Revisi tanggal 05.07.2022
Tanggal Cetak 07.07.2022
MSDS Umum Uni Eropa - Tidak ada data untuk negara tertentu - Tidak ada OEL Data

BAGIAN 1: Identitas Bahan dan Perusahaan

1.1 Pengidentifikasi produk

Nama produk : Silikon dioksida koloidal, sangat terdispersi EMPROVE® ESSENTIAL Ph Eur,NF,JP,E 551

Nomor Produk	:	1.13126
No katalog	:	113126
Merek	:	Millipore
Nomor REACH	:	01-2119379499-16-XXXX
No-CAS	:	7631-86-9

1.2 Penggunaan yang relevan dari bahan atau campuran yang diidentifikasi dan penggunaan yang disarankan terhadap

Penggunaan yang teridentifikasi : Produksi farmasi

1.3 Rincian penyuplai lembar data keselamatan

Perusahaan : Merck KGaA
Frankfurter Str. 250
D-64271 DARMSTADT

Telepon	:	+49 (0)6151 72-0
Fax	:	+49 6151 727780
Alamat email	:	TechnicalService@merckgroup.com

1.4 Nomor telepon darurat

Nomer Telepon Darurat # : 001-803-017-9114 (CHEMTREC)

BAGIAN 2: Identifikasi bahaya

2.1 Klasifikasi bahan atau campuran

Bukan bahan atau campuran berbahaya menurut Peraturan (EC) No 1272/2008.

2.2 Elemen label

Bukan bahan atau campuran berbahaya menurut Peraturan (EC) No 1272/2008.

2.3 bahaya lainnya

Zat/campuran ini tidak mengandung satu komponen pun yang dianggap baik persisten, bioakumulatif, dan beracun (PBT) maupun sangat persisten dan sangat bioakumulatif (vPvB) pada kadar 0,1% atau lebih.

BAGIAN 3: Komposisi Bahan

3.1 Bahan

Rumus	:	SiO_2
Berat Molekul	:	60,08 g/mol
No-CAS	:	7631-86-9
No-EC	:	231-545-4

Tidak ada komponen perlu diungkapkan sesuai dengan ketentuan yang berlaku.

BAGIAN 4: Tindakan pertolongan pertama pada kecelakaan (P3K)

4.1 Penjelasan mengenai tindakan pertolongan pertama

Jika terhirup
Setelah menghirup: hirup udara segar.

Jika kontak dengan kulit
Bila terjadi kontak kulit: Tanggalkan segera semua pakaian yang terkontaminasi. Bilaslah kulit dengan air/ pancuran air.

Jika kontak dengan mata
Setelah kontak pada mata : bilaslah dengan air yang banyak. Lepaskan lensa kontak.

Jika tertelan
Setelah tertelan: beri air minum kepada korban (paling banyak dua gelas). Konsultasi kepada dokter jika merasa tidak sehat.

4.2 Kumpulan gejala / efek terpenting, baik akut maupun tertunda
Gejala dikenal dan efek yang paling penting dijelaskan dalam label (lihat bagian 2.2) dan / atau di bagian 11

4.3 Indikasi pertolongan medis pertama dan perawatan khusus yang diperlukan
Data tidak tersedia

BAGIAN 5: Tindakan Penanggulangan Kebakaran

5.1 Media pemadaman api

Media pemadaman yang sesuai
Gunakan tindakan pemadaman kebakaran yang sesuai untuk situasi lokal dan lingkungan sekeliling.

Media pemadaman yang tidak sesuai
Untuk bahan/campuran ini, tidak ada batasan agen pemadaman yang diberika n.

5.2 Bahaya khusus yang muncul dari bahan atau campuran
oksida silikon
Tidak mudah terbakar.
Api ambient dapat melepaskan uap yang berbahaya.

5.3 Saran bagi petugas pemadam kebakaran
Jika terjadi kebakaran, pakai alat bantu pernapasan SCBA.

5.4 Informasi lebih lanjut
Tekan (pukul kebawah) gas/uap/kabut dengan semprotan air jet.

Lampiran 6. Data hasil pengujian *surface rouhgness*

User ID: ADMIN
User name: Administrator
Description: FIRST ADMINISTRATOR

SR-A35
[Acquisition parameters]
Scanning mode: XYZ fast scan + Color
Image size[pixels]: 1024X1024
Image size[μm]: 640x643
Objective lens: MPLAPONLEXT20x
Zoom: 1x
DIC: Off

No.	Res	Sq[μm]	Ssk	Sku	Sp[μm	Sv[μm	Sz[μm	Sa[μm]	MTy	λc[μm]	λs[	λf[μ	File name
1		0.623	-2.254	44.146	6.759	10.164	16.923	0.370	R	800.000	-	-	SR-ID5
2		0.578	0.193	5.552	2.396	3.597	5.993	0.410	R	800.000	-	-	SR-NFS
3		0.611	0.681	19.363	6.588	11.897	18.485	0.418	R	800.000	-	-	SR-D15
4		1.479	-1.913	13.363	3.857	18.220	22.077	1.002	R	800.000	-	-	SR-D45
5		0.769	-2.386	23.662	2.980	11.297	14.277	0.505	R	800.000	-	-	SR-D25
6		0.363	-2.235	18.058	1.365	4.942	6.307	0.255	R	800.000	-	-	SR-D35
7		0.577	-2.632	17.222	1.386	8.271	9.657	0.394	R	800.000	-	-	SR-C45
8		2.242	-1.022	5.318	6.433	15.120	21.553	1.657	R	800.000	-	-	SR-C35
9		0.481	-0.670	4.252	1.934	4.250	6.184	0.352	R	800.000	-	-	SR-C25
10		2.260	-0.524	6.742	16.483	24.435	40.918	1.686	R	800.000	-	-	SR-B45
11		2.329	-3.097	29.579	5.718	33.088	38.805	1.581	R	800.000	-	-	SR-B25
12		1.533	-7.186	75.817	2.669	28.001	30.670	0.654	R	800.000	-	-	SR-C15
13		1.460	-0.214	5.770	6.006	12.310	18.315	1.029	R	800.000	-	-	SR-B35
14		0.284	-0.641	10.580	1.826	3.697	5.523	0.201	R	800.000	-	-	SR-B15
15		0.967	0.087	6.398	8.663	6.146	14.809	0.669	R	800.000	-	-	SR-A45
16		1.856	-0.230	3.608	7.754	11.844	19.598	1.437	R	800.000	-	-	SR-A15
17		0.686	-2.449	20.497	3.021	7.849	10.870	0.430	R	800.000	-	-	SR-A25
18		1.848	-3.943	35.440	9.863	28.664	38.527	1.008	R	800.000	-	-	SR-A35

Lampiran 7. Data hasil pengujian *tensile strenght* dan *elongation*

LAB. METALURGI FISISK DEP. TEKNIK MESIN FT UH

TENSILE

Key Word		Product Name	
Test File Name	SR C.ltax	Method File Name	Tensile Silicond rabber cf
Report Date	2214/01/04	Test Date	2213/01/05
Test Type	Tensile	Speed	250mm/min
Shape	Plate	No of Batches:	1
Qty/Batch:	4		

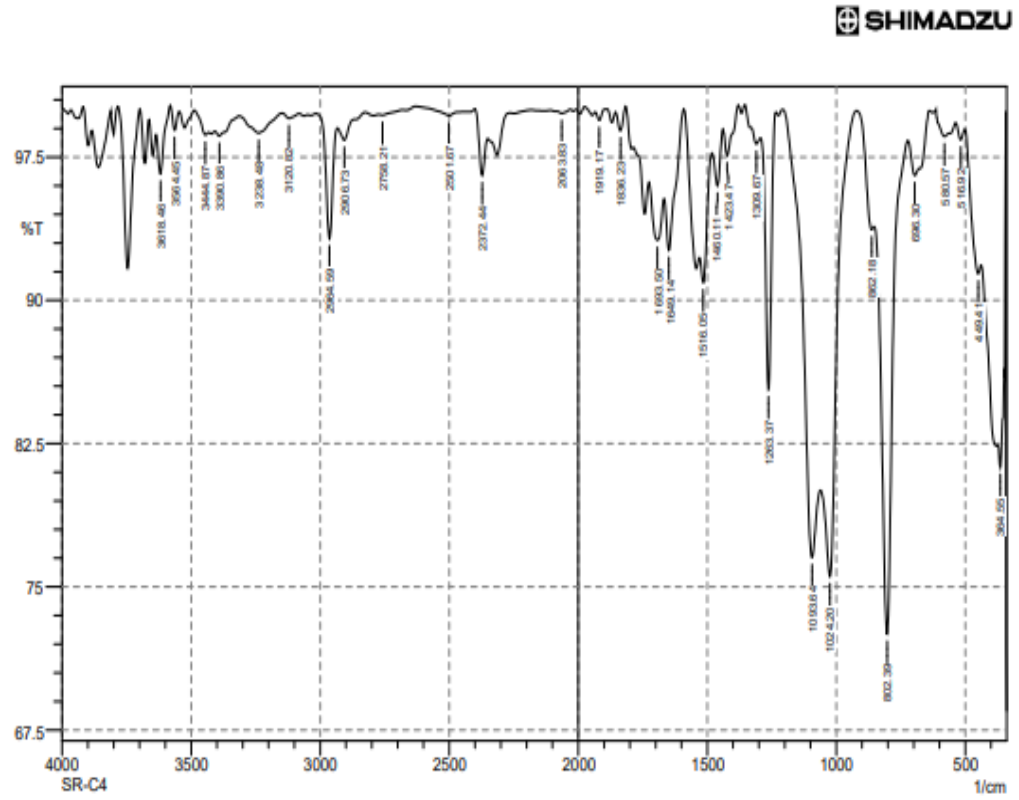
Name	Thickness	Width	Gauge_Length
Unit	mm	mm	mm
SR C1	3.3000	5.6000	50.0000
SR C2	3.9000	5.6000	50.0000
SR C3	3.9000	5.6000	50.0000
SR C4	3.9000	5.6000	50.0000

Name	Max_Force	Max_Disp.	Break_Force	Break_Disp.
Parameters	Calc. at Entire Area	Calc. at Entire Area	Sensitivity 10	Sensitivity 10
Unit	N	mm	N	mm
SR C1	37.9046	62.3960	37.7154	62.5110
SR C2	41.0843	127.053	28.0692	135.636
SR C3	25.9153	28.5943	–.–	–.–
SR C4	54.7139	68.6776	54.7139	68.6776

Name	YP(%)_Force	YP(%)_Disp.	Elastic
Parameters	0.1 %	0.1 %	Force 10 – 20 N
Unit	N	mm	N/mm2
SR C1	–.–	–.–	1.87499
SR C2	–.–	–.–	0.87899
SR C3	–.–	–.–	2.28959
SR C4	–.–	–.–	2.18599

Lampiran 8. Data hasil pengujian *FTIR*

a) *FTIR* setelah perlakuan difusi air

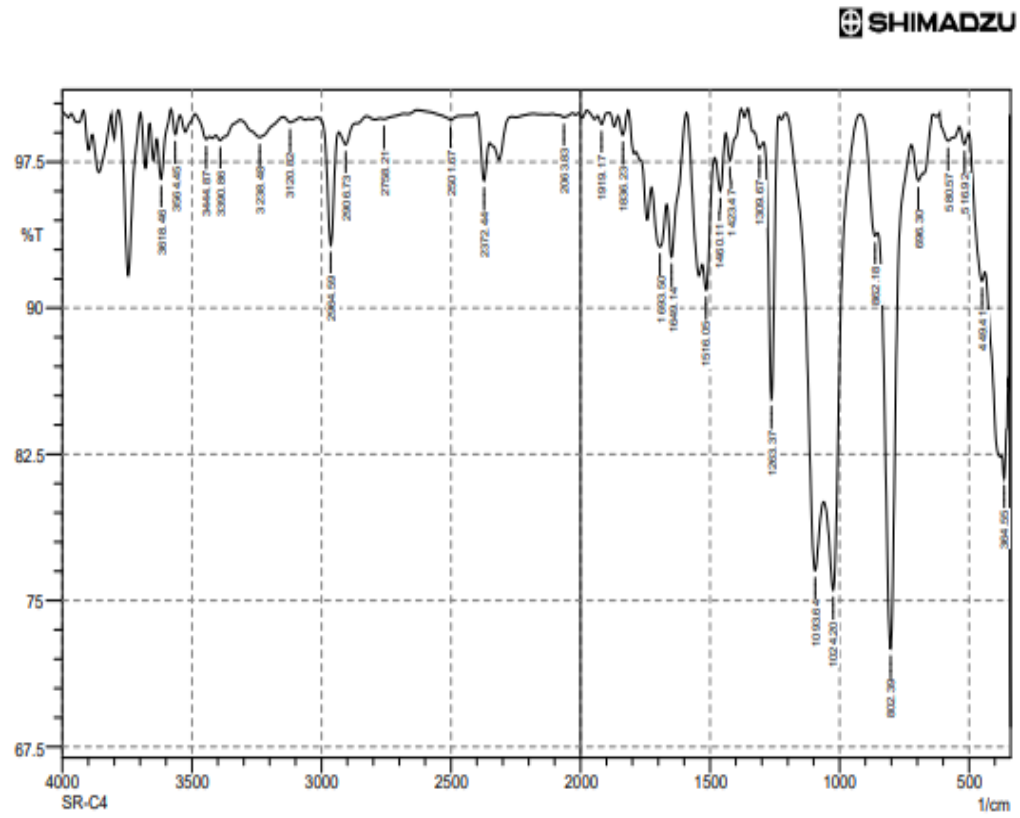


No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	364.55	81.273	2.409	374.19	351.04	1.919	0.173
2	449.41	91.399	1.54	501.49	439.77	1.632	0.326
3	516.92	98.413	0.677	538.14	501.49	0.196	0.055
4	580.57	98.584	0.616	613.36	561.29	0.251	0.105
5	696.3	96.537	0.978	723.31	677.01	0.576	0.094
6	802.39	72.53	23.074	852.54	723.31	7.148	4.925
7	862.18	93.709	0.988	921.97	852.54	0.954	-0.014
8	1024.2	75.539	9.753	1060.85	921.97	7.435	1.696
9	1093.64	76.537	7.755	1207.44	1062.78	7.794	1.461
10	1263.37	85.335	13.828	1292.31	1234.44	1.759	1.553
11	1309.67	98.188	0.534	1330.88	1294.24	0.239	0.042
12	1423.47	97.581	1.701	1438.9	1379.1	0.341	0.233
13	1460.11	96.002	2.329	1481.33	1438.9	0.523	0.213
14	1516.05	90.93	2.889	1529.55	1483.26	1.309	0.294
15	1649.14	92.628	3.765	1666.5	1591.27	1.377	0.615
16	1693.5	93.153	2.521	1724.36	1668.43	1.475	0.408
17	1836.23	98.88	1.118	1855.52	1816.94	0.098	0.098
18	1919.17	99.429	0.478	1934.6	1890.24	0.046	0.033
19	2063.83	99.792	0.144	2083.12	2031.04	0.03	0.018
20	2372.44	96.548	2.576	2401.38	2351.23	0.417	0.251
21	2501.67	99.667	0.307	2628.98	2428.38	0.075	0.085
22	2758.21	99.699	0.067	2773.64	2681.05	0.073	0.011
23	2906.73	98.389	0.811	2933.73	2866.22	0.32	0.098
24	2964.59	93.238	6.061	3016.67	2933.73	0.951	0.732
25	3120.82	99.527	0.26	3147.83	3082.25	0.099	0.038
26	3238.48	98.766	0.953	3313.71	3147.83	0.551	0.353
27	3390.86	98.609	0.389	3408.22	3313.71	0.381	0.073
28	3444.87	98.659	0.402	3489.23	3431.36	0.191	0.032
29	3564.45	98.918	1.134	3581.81	3545.16	0.077	0.084
30	3618.46	96.629	2.531	3635.82	3581.81	0.391	0.257

Comment;
SR-C4

Date/Time; 3/13/2024 11:36:15 AM
No. of Scans;
Resolution;
Apodization;

b) *FTIR* setelah perlakuan kontaminan



No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	364.55	81.273	2.409	374.19	351.04	1.919	0.173
2	449.41	91.399	1.54	501.49	439.77	1.632	0.326
3	516.92	98.413	0.677	538.14	501.49	0.196	0.055
4	580.57	98.584	0.616	613.36	561.29	0.251	0.105
5	696.3	96.537	0.978	723.31	677.01	0.576	0.094
6	802.39	72.53	23.074	852.54	723.31	7.148	4.925
7	862.18	93.709	0.988	921.97	852.54	0.954	-0.014
8	1024.2	75.539	9.753	1060.85	921.97	7.435	1.696
9	1093.64	76.537	7.755	1207.44	1062.78	7.794	1.461
10	1263.37	85.335	13.828	1292.31	1234.44	1.759	1.553
11	1309.67	98.188	0.534	1330.88	1294.24	0.239	0.042
12	1423.47	97.581	1.701	1438.9	1379.1	0.341	0.233
13	1460.11	96.002	2.329	1481.33	1438.9	0.523	0.213
14	1516.05	90.93	2.889	1529.55	1483.26	1.309	0.294
15	1649.14	92.628	3.765	1666.5	1591.27	1.377	0.615
16	1693.5	93.153	2.521	1724.36	1668.43	1.475	0.408
17	1836.23	98.88	1.118	1855.52	1816.94	0.098	0.098
18	1919.17	99.429	0.478	1934.6	1890.24	0.046	0.033
19	2063.83	99.792	0.144	2083.12	2031.04	0.03	0.018
20	2372.44	96.548	2.576	2401.38	2351.23	0.417	0.251
21	2501.67	99.667	0.307	2628.98	2428.38	0.075	0.085
22	2758.21	99.699	0.067	2773.64	2681.05	0.073	0.011
23	2906.73	98.389	0.811	2933.73	2866.22	0.32	0.098
24	2964.59	93.238	6.061	3016.67	2933.73	0.951	0.732
25	3120.82	99.527	0.26	3147.83	3082.25	0.099	0.038
26	3238.48	98.766	0.953	3313.71	3147.83	0.551	0.353
27	3390.86	98.609	0.389	3408.22	3313.71	0.381	0.073
28	3444.87	98.659	0.402	3489.23	3431.36	0.191	0.032
29	3564.45	98.918	1.134	3581.81	3545.16	0.077	0.084
30	3618.46	96.629	2.531	3635.82	3581.81	0.391	0.257

Comment;

SR-C4

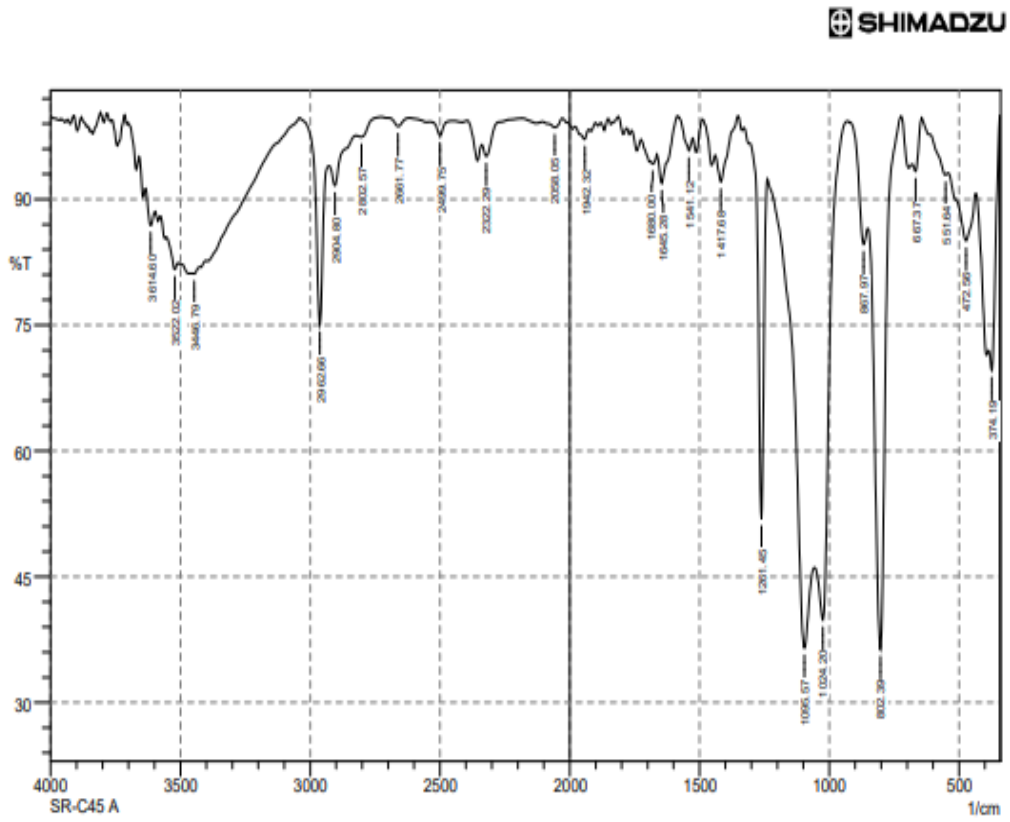
Date/Time; 3/13/2024 11:36:15 AM

No. of Scans;

Resolution;

Apodization;

c) *FTIR* setelah perlakuan korona



No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	374.19	69.621	8.873	383.83	345.26	3.772	0.999
2	472.56	85.07	6.443	540.07	435.91	5.539	1.692
3	551.64	92.91	0.854	611.43	542	1.57	0.137
4	667.37	93.328	2.871	680.87	644.22	0.747	0.244
5	802.39	36.356	55.225	850.61	723.31	18.37	14.403
6	867.97	84.633	4.845	918.12	852.54	2.586	0.506
7	1024.2	39.865	19.51	1055.06	931.62	20.729	4.084
8	1095.57	36.533	19.483	1236.37	1056.99	35.217	5.903
9	1261.45	51.921	41.936	1305.81	1238.3	6.727	5.053
10	1417.68	92.091	4.28	1438.9	1352.1	1.641	0.722
11	1541.12	95.793	2.15	1585.49	1525.69	0.614	0.242
12	1645.28	91.9	4.419	1662.64	1587.42	1.583	0.787
13	1680	94.236	1.563	1724.36	1664.57	1.298	0.29
14	1942.32	97.163	1.264	1978.97	1926.89	0.5	0.157
15	2058.05	98.576	0.719	2083.12	2029.11	0.258	0.097
16	2322.29	95.141	1.654	2337.72	2185.35	1.04	0.168
17	2499.75	97.602	1.671	2538.32	2445.74	0.474	0.184
18	2661.77	98.694	1.041	2727.35	2617.4	0.282	0.161
19	2802.57	97.431	0.641	2823.79	2727.35	0.568	0.016
20	2904.8	91.621	3.083	2926.01	2823.79	2.248	0.347
21	2962.66	75.031	20.701	3039.81	2927.94	4.161	2.609
22	3394.72	81.128	0.268	3456.44	3425.58	2.749	0.019
23	3522.02	81.656	1.578	3552.88	3510.45	3.393	0.148
24	3614.6	86.91	2.922	3633.89	3597.24	1.995	0.286

Comment;
SR-C45 A

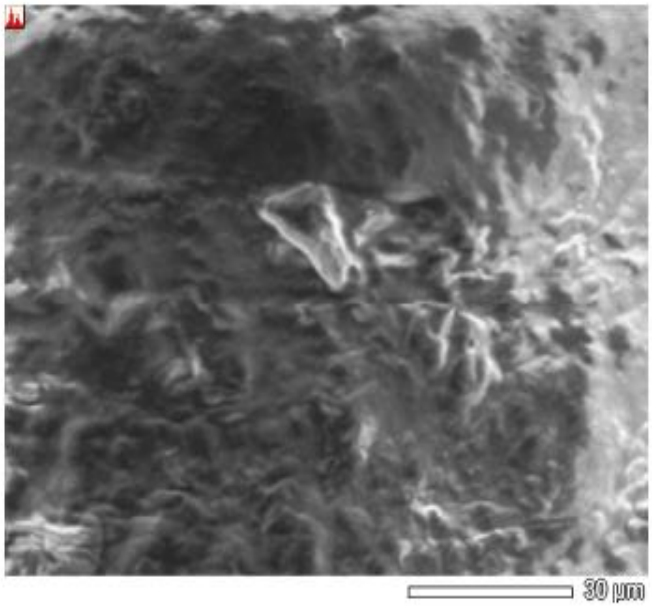
Date/Time; 3/18/2024 11:12:12 AM
No. of Scans;
Resolution;
Apodization;

Lampiran 9. Data hasil pengujian *EDS*

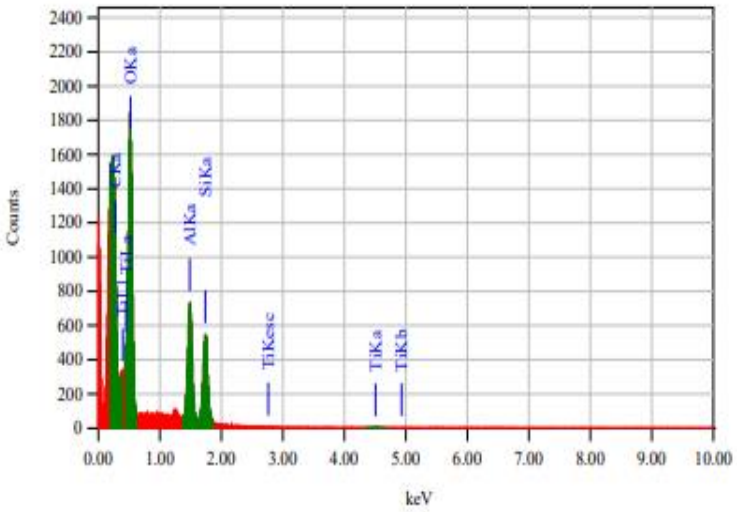
a) *EDS* murni

View008

JEOL 1/1



Title	: IMG1
Instrument	: JCM-6000PLUS
Volt	: 15.00 kV
Mag.	: x 1,000
Date	: 2023/10/25
Pixel	: 512 x 384



Acquisition Parameter
Instrument : JCM-6000PLUS
Acc. Voltage : 15.0 kV
Probe Current: 1.00000 nA
PHA mode : T3
Real Time : 50.37 sec
Live Time : 50.00 sec
Dead Time : 0 %
Counting Rate: 1375 cps
Energy Range : 0 - 20 keV

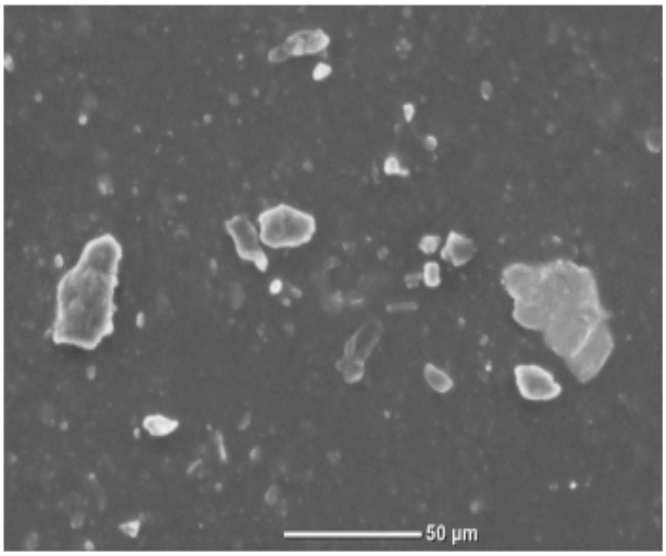
Thin Film Standardless Standardless Quantitative Analysis(Oxide)
Fitting Coefficient : 0.3972
Total Oxide : 24.0

Element	(keV)	Mass%	Counts	Sigma	Mol%	Compound	Mass%	Cation	K
C K*	0.277	14.17	924.61	0.33	51.38	C	14.17	0.00	3.2633
O		42.87					ND		
Al K (Ref.)	1.486	24.11	5134.05	1.00	19.46	Al2O3	45.55	8.00	1.0000
Si K	1.739	18.73	3888.48	1.03	29.05	SiO2	40.07	5.97	1.0258
Ti K	4.508	0.12	11.41	0.11	0.11	TiO2	0.21	0.02	2.3019
Total		100.00			100.00		100.00	14.00	

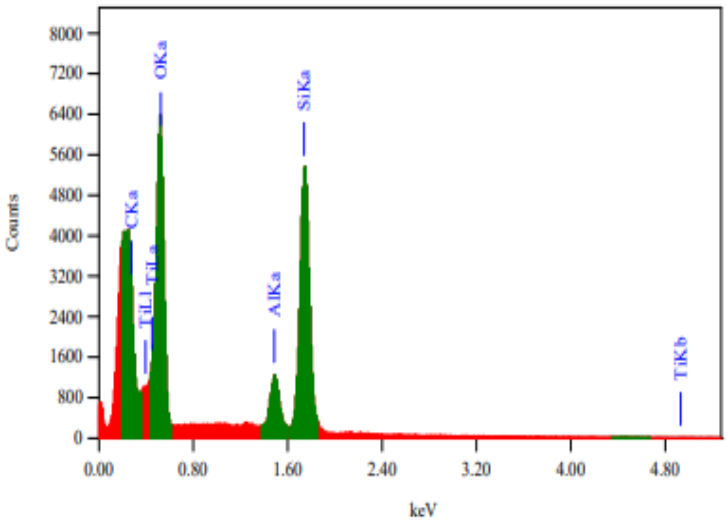
b) *EDS* setelah perlakuan korona

View012

JEOL 1/1



Title	: IMG1
Instrument	: JCM-6000PLUS
Volt	: 15.00 kV
Mag.	: x 1,000
Date	: 2024/03/13
Pixel	: 512 x 384



Acquisition Parameter
Instrument : JCM-6000PLUS
Acc. Voltage : 15.0 kV
Probe Current: 1.00000 nA
PHA mode : T3
Real Time : 50.68 sec
Live Time : 50.00 sec
Dead Time : 1 %
Counting Rate: 4561 cps
Energy Range : 0 - 20 keV

Thin Film Standardless Standardless Quantitative Analysis(Oxide)
Fitting Coefficient : 0.2219
Total Oxide : 24.0

Element	(keV)	Mass%	Counts	Sigma	Mol%	Compound	Mass%	Cation	K
C K	0.277	6.05	2016.51	0.10	25.52	C	6.05	0.00	3.1810
O		49.19					ND		
Al K	1.486	7.20	7827.65	0.25	6.76	Al2O3	13.60	2.08	0.9748
Si K (Ref.)	1.739	37.54	39795.22	0.63	67.71	SiO2	80.32	10.44	1.0000
Ti K	4.508	0.02	8.24	0.04	0.02	TiO2	0.03	0.00	2.2439
Total		100.00			100.00		100.00	12.52	

Lampiran 10. Data hasil pengujian *water diffusion*

a) Data resistivitas perlakuan difusi air

Table 1d. Resistivity Analysis After Perlakuan RTV683

Sample	Murni		Resistivity After Perlakuan					
			WD with RT		WD with 50 °C		WD with 70 °C	
	ρv(GΩ.m)	ρs(GΩ)	ρv(GΩ.m)	ρs(GΩ)	ρv(GΩ.m)	ρs(GΩ)	ρv(GΩ.m)	ρs(GΩ)
SR-ID	266.09	0.28	68.73	0.20	209.60	0.20	108.27	0.21
SR-NF	204.85	0.29	61.18	0.22	136.73	0.22	60.78	0.21
SR-A1	142.49	0.28	50.69	0.23	100.24	0.24	42.33	0.20
SR-A2	164.86	0.25	33.54	0.25	80.60	0.21	35.81	0.20
SR-A3	173.24	0.27	15.72	0.25	47.63	0.21	4.52	0.20
SR-A4	165.45	0.31	17.45	0.26	9.02	0.21	4.29	0.09
SR-B1	216.14	0.30	93.43	0.27	122.30	0.27	77.64	0.32
SR-B2	205.37	0.32	92.19	0.22	113.05	0.30	77.41	0.29
SR-B3	205.37	0.31	74.17	0.20	112.86	0.28	15.47	0.26
SR-B4	175.52	0.28	58.80	0.25	61.76	0.27	17.92	0.23
SR-C1	211.19	0.31	91.65	0.25	111.31	0.28	69.33	0.21
SR-C2	205.55	0.34	68.43	0.26	65.04	0.25	35.78	0.21
SR-C3	218.37	0.33	75.23	0.22	99.26	0.25	29.36	0.20
SR-C4	151.50	0.28	36.85	0.25	42.27	0.18	4.25	0.12
SR-D1	190.00	0.28	72.73	0.21	108.27	0.21	58.26	0.25
SR-D2	219.85	0.28	52.18	0.21	93.40	0.21	24.43	0.18
SR-D3	205.92	0.26	35.81	0.27	78.66	0.23	0.38	0.17
SR-D4	204.65	0.27	23.65	0.24	47.04	0.21	8.90	0.12

b) Data *flashover* perlakuan difusi air

Table-1a. AC Flashover RTV683 With Water Diffusion

SAMPLE	FO Murni (kV)	FO After WD 25°C (kV)	FO After WD 50°C (kV)	FO After WD 70°C (kV)	IF Murni (mA)	IF After WD 25°C (mA)	IF After WD 50°C (mA)	IF After WD 70°C (mA)
SR-ID	16.18	23.66	23.76	18.27	42.00	21.80	20.00	10.00
SR-NF	21.26	19.28	29.47	19.24	33.00	18.80	24.00	10.00
SR-A1	16.78	20.58	36.03	20.71	39.00	13.70	36.00	8.00
SR-A2	20.25	20.89	21.16	14.22	56.00	3.30	8.00	2.00
SR-A3	20.60	20.30	19.64	12.34	33.00	9.20	2.00	4.00
SR-A4	23.00	18.99	20.56	19.35	51.00	10.80	2.00	22.00
SR-B1	21.53	26.41	20.86	16.08	70.00	10.70	10.00	6.00
SR-B2	22.70	25.31	21.97	13.79	120.00	20.00	8.00	2.00
SR-B3	17.56	25.10	18.67	8.65	54.00	22.00	2.00	2.00
SR-B4	20.62	22.41	18.45	12.72	37.00	41.40	2.00	2.00
SR-C1	22.05	20.63	24.84	20.46	134.00	7.80	30.00	17.00
SR-C2	18.55	20.74	14.56	10.10	63.00	20.00	2.00	6.00
SR-C3	17.55	20.82	23.45	10.50	33.00	13.80	6.00	2.00
SR-C4	19.64	25.96	15.25	13.44	58.00	48.40	2.00	2.00
SR-D1	21.76	20.59	27.96	15.44	25.00	13.70	30.00	2.00
SR-D2	18.82	31.90	23.14	12.02	42.00	22.00	4.00	2.00
SR-D3	17.84	23.32	21.42	7.12	81.00	28.20	4.00	6.00
SR-D4	21.70	20.98	20.98	8.33	58.00	15.20	4.00	10.00

Lampiran 11. Data hasil pengujian transfer hidrofobik

a) Data resistivitas perlakuan kontaminan

Table 2b. Data Resistivity RTV683

Sample	Virgin		After Treatement TH			
			Kaolin with RT		Kaolin with UVa	
	ρv(GΩ.m)	ρs(GΩ)	ρv(GΩ.m)	ρs(GΩ)	ρv(GΩ.m)	ρs(GΩ)
SR-ID	260.23	0.23	228.90	0.21	255.30	0.21
SR-NF	219.08	0.21	208.25	0.19	195.17	0.20
SR-A1	190.18	0.26	170.11	0.25	182.75	0.23
SR-A2	184.01	0.26	162.24	0.23	177.94	0.25
SR-A3	181.52	0.25	149.60	0.23	188.23	0.24
SR-A4	197.12	0.26	182.08	0.24	180.33	0.23
SR-B1	205.30	0.23	180.25	0.21	211.03	0.21
SR-B2	184.87	0.22	179.27	0.21	179.27	0.21
SR-B3	208.69	0.24	189.36	0.23	189.71	0.22
SR-B4	184.66	0.25	180.49	0.22	162.73	0.25
SR-C1	247.00	0.29	240.36	0.26	216.05	0.25
SR-C2	252.73	0.29	237.91	0.26	229.97	0.27
SR-C3	214.63	0.31	200.76	0.28	192.24	0.27
SR-C4	211.13	0.30	202.64	0.29	218.97	0.31
SR-D1	175.70	0.21	150.04	0.18	174.22	0.18
SR-D2	218.40	0.26	191.98	0.23	209.96	0.23
SR-D3	226.62	0.29	191.65	0.26	221.72	0.26
SR-D4	192.01	0.27	175.26	0.26	178.72	0.23

b) Data *flashover* perlakuan kontaminan

Table-1a. AC Flashover RTV683 With Transfer Hydrophobic

SAMPLE	BD Virgin (kV)	BD After TH-RT (kV)	BD After TH-UV (kV)	IB Virgin (mA)	IB After TH-RT (mA)	IB After-TH-UV (mA)
SR-ID	16.18	18.92	16.35	42.00	2.40	1.20
SR-NF	21.26	17.95	16.37	33.00	5.20	8.40
SR-A1	16.78	17.13	16.54	39.00	0.60	2.00
SR-A2	20.25	17.63	18.83	56.00	2.40	4.20
SR-A3	20.60	17.16	17.75	33.00	2.20	4.20
SR-A4	23.00	17.60	15.55	51.00	4.20	2.20
SR-B1	21.53	16.53	15.94	70.00	2.20	21.80
SR-B2	22.70	16.55	16.55	120.00	9.60	9.60
SR-B3	17.56	17.06	16.93	54.00	5.60	8.80
SR-B4	20.62	17.13	18.10	37.00	0.40	14.20
SR-C1	22.05	18.07	17.12	134.00	0.36	14.20
SR-C2	18.55	16.00	16.81	63.00	11.20	6.20
SR-C3	17.55	16.65	15.10	33.00	13.00	1.40
SR-C4	19.64	17.60	19.60	58.00	4.60	2.60
SR-D1	21.76	17.88	17.50	25.00	9.40	16.40
SR-D2	18.82	16.29	16.22	42.00	2.40	28.80
SR-D3	17.84	15.91	17.00	81.00	18.40	3.20
SR-D4	21.70	16.99	16.63	58.00	0.40	3.20

Lampiran 12. Data hasil pengujian korona

a) Data resistivitas perlakuan korona

Table-1a. Surface Resistivity RTV683 With Corona Treatement

TIME	SURFACE RESISTIVITY RTV683 ρs(GΩ) WITH CORONA TREATEMENT																	
(Day)	SR-ID	SR-NF	SR-A1	SR-A2	SR-A3	SR-A4	SR-B1	SR-B2	SR-B3	SR-B4	SR-C1	SR-C2	SR-C3	SR-C4	SR-D1	SR-D2	SR-D3	SR-D4
T-0	0.41	0.30	0.26	0.30	0.29	0.26	0.34	0.35	0.33	0.38	0.27	0.32	0.37	0.35	0.25	0.36	0.41	0.40
T-1	0.21	0.19	0.16	0.18	0.15	0.17	0.16	0.21	0.17	0.17	0.16	0.16	0.18	0.16	0.17	0.14	0.15	0.15
T-2	0.18	0.24	0.19	0.17	0.17	0.19	0.16	0.15	0.14	0.14	0.18	0.14	0.15	0.17	0.21	0.23	0.12	0.14
T-3	0.13	0.13	0.19	0.17	0.18	0.20	0.21	0.21	0.20	0.21	0.23	0.21	0.20	0.20	0.19	0.21	0.19	0.20
T-4	0.15	0.14	0.15	0.14	0.14	0.13	0.20	0.19	0.20	0.18	0.25	0.20	0.21	0.22	0.18	0.17	0.19	0.18
T-5	0.16	0.14	0.14	0.18	0.18	0.16	0.20	0.22	0.25	0.22	0.17	0.18	0.19	0.19	0.19	0.18	0.21	0.16
T-6	0.18	0.16	0.16	0.14	0.17	0.14	0.14	0.14	0.16	0.14	0.17	0.16	0.29	0.19	0.17	0.16	0.17	0.16
T-7	0.15	0.12	0.15	0.14	0.14	0.17	0.13	0.15	0.15	0.16	0.20	0.14	0.20	0.21	0.20	0.22	0.10	0.21
T-8	0.17	0.20	0.20	0.20	0.23	0.22	0.21	0.20	0.17	0.19	0.16	0.18	0.17	0.15	0.21	0.21	0.20	0.20
T-9	0.15	0.18	0.21	0.22	0.23	0.23	0.15	0.16	0.14	0.17	0.13	0.16	0.16	0.16	0.19	0.21	0.21	0.21
T-10	0.21	0.21	0.15	0.16	0.18	0.16	0.21	0.17	0.21	0.21	0.17	0.16	0.15	0.17	0.14	0.15	0.16	0.15

Table-2a. Volume Resistivity RTV683 With Corona Treatement

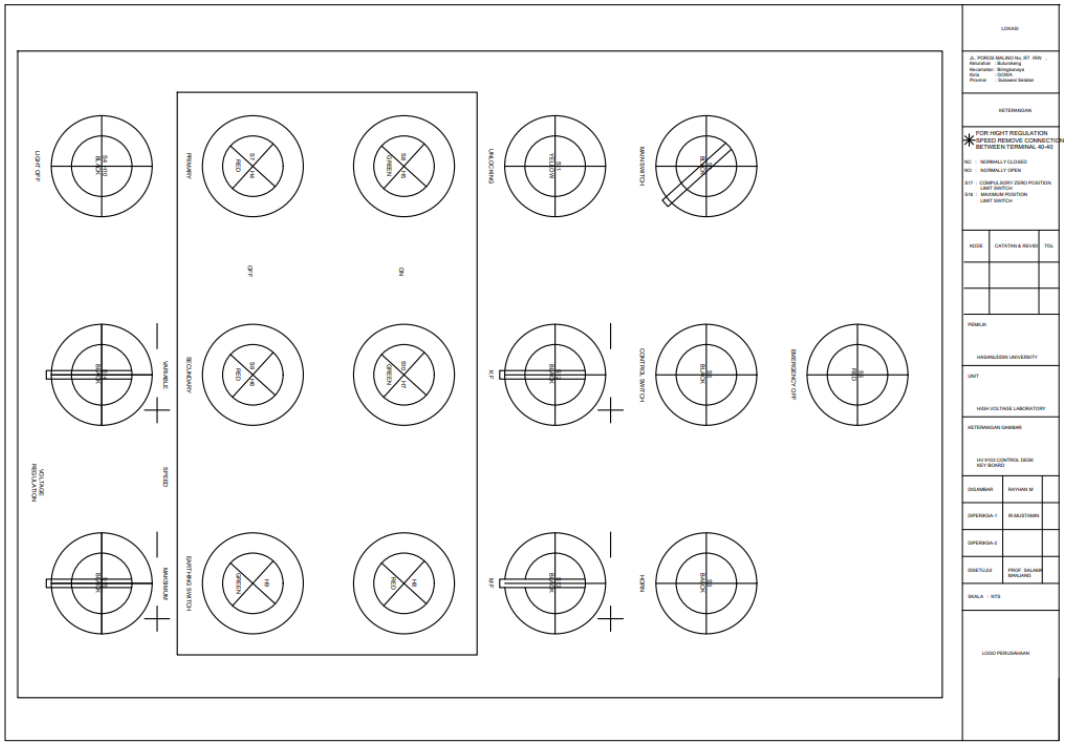
TIME	VOLUME RESISTIVITY RTV683 ρv(GΩ.m) WITH CORONA TREATEMENT																	
(Day)	SR-ID	SR-NF	SR-A1	SR-A2	SR-A3	SR-A4	SR-B1	SR-B2	SR-B3	SR-B4	SR-C1	SR-C2	SR-C3	SR-C4	SR-D1	SR-D2	SR-D3	SR-D4
T-0	261.59	177.30	141.72	185.11	154.69	116.06	157.09	152.75	259.85	185.09	178.08	184.59	203.98	203.64	193.25	154.83	230.02	233.00
T-1	81.25	67.22	65.78	74.14	57.58	64.20	65.90	71.75	57.64	64.82	58.78	57.52	54.64	65.86	47.66	47.33	47.50	59.97
T-2	61.55	49.68	47.40	60.21	47.82	32.10	42.88	48.42	39.07	40.36	48.84	50.66	44.52	43.23	40.73	34.90	50.50	51.12
T-3	71.40	49.68	64.33	67.67	66.85	53.50	68.61	61.19	77.17	66.04	81.26	60.10	70.42	80.00	59.36	49.74	60.00	62.43
T-4	17.23	33.12	60.95	61.21	59.04	50.62	72.22	66.47	60.57	67.68	78.23	70.40	76.49	80.81	64.13	58.16	70.01	74.22
T-5	17.23	56.50	38.21	47.77	54.16	36.22	66.81	47.54	60.08	57.08	54.89	62.68	57.07	57.78	34.23	42.92	52.00	54.56
T-6	17.85	51.15	44.98	41.30	39.53	37.45	48.75	42.26	54.22	53.81	41.49	42.93	37.24	57.38	44.20	40.91	66.51	52.10
T-7	66.48	39.94	59.49	76.63	75.64	56.38	18.06	24.65	24.42	20.79	33.71	23.18	24.69	26.26	50.26	54.55	68.51	60.95
T-8	27.08	39.45	50.30	66.68	63.92	51.44	35.66	40.06	42.98	46.07	42.36	43.36	27.52	37.98	32.50	47.73	46.00	64.89
T-9	25.85	48.22	53.21	66.18	59.04	60.09	50.56	56.35	53.73	55.85	49.27	55.38	49.78	44.85	47.23	48.13	59.50	58.99
T-10	45.55	48.71	70.62	68.67	63.92	60.91	32.50	36.10	44.94	33.02	32.42	35.20	37.64	40.81	50.70	61.37	72.51	75.21

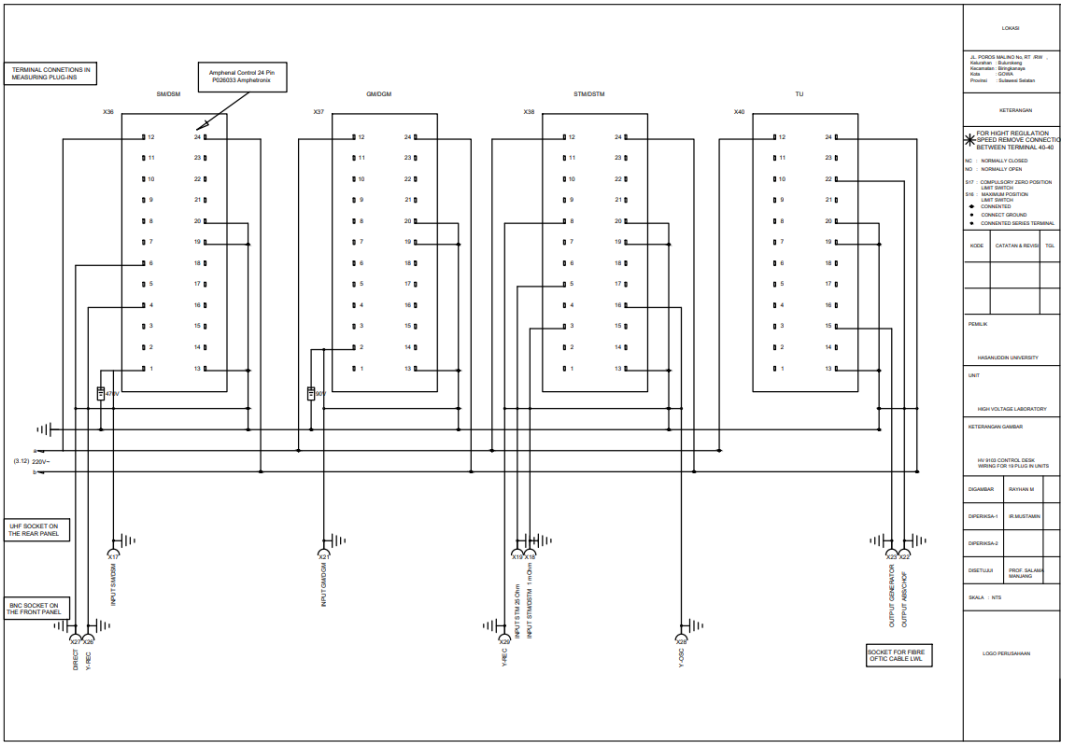
b) Data *flashover* perlakuan korona

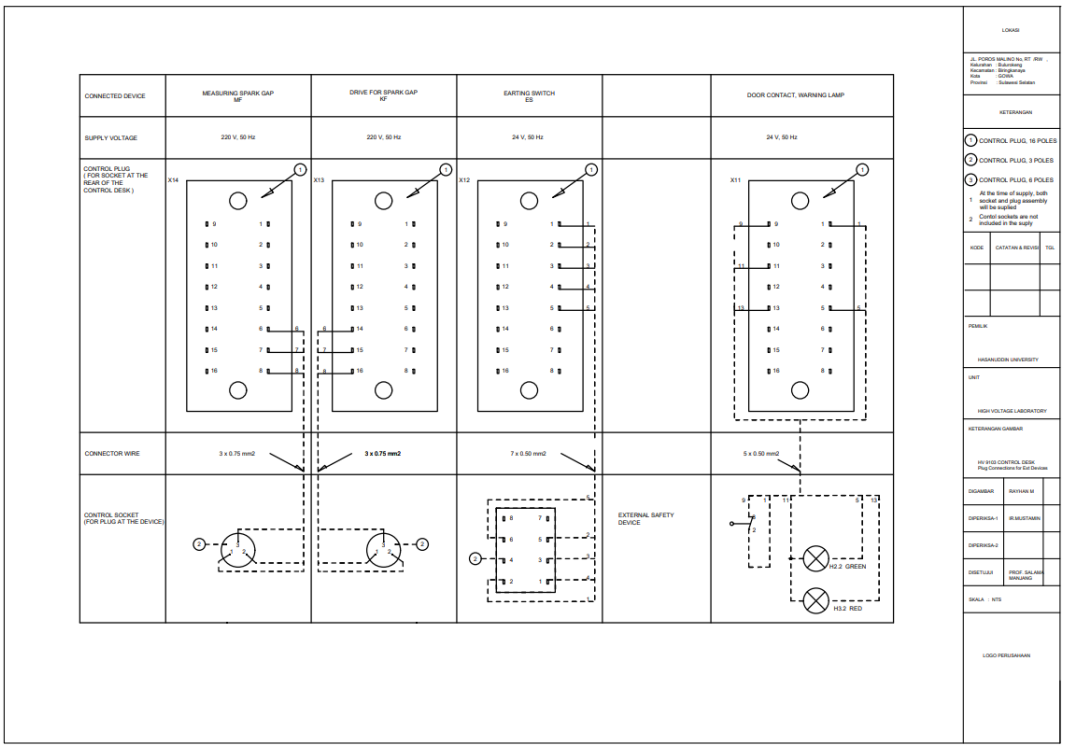
Table-1a. AC Flashover RTV683 With Corona Discharge

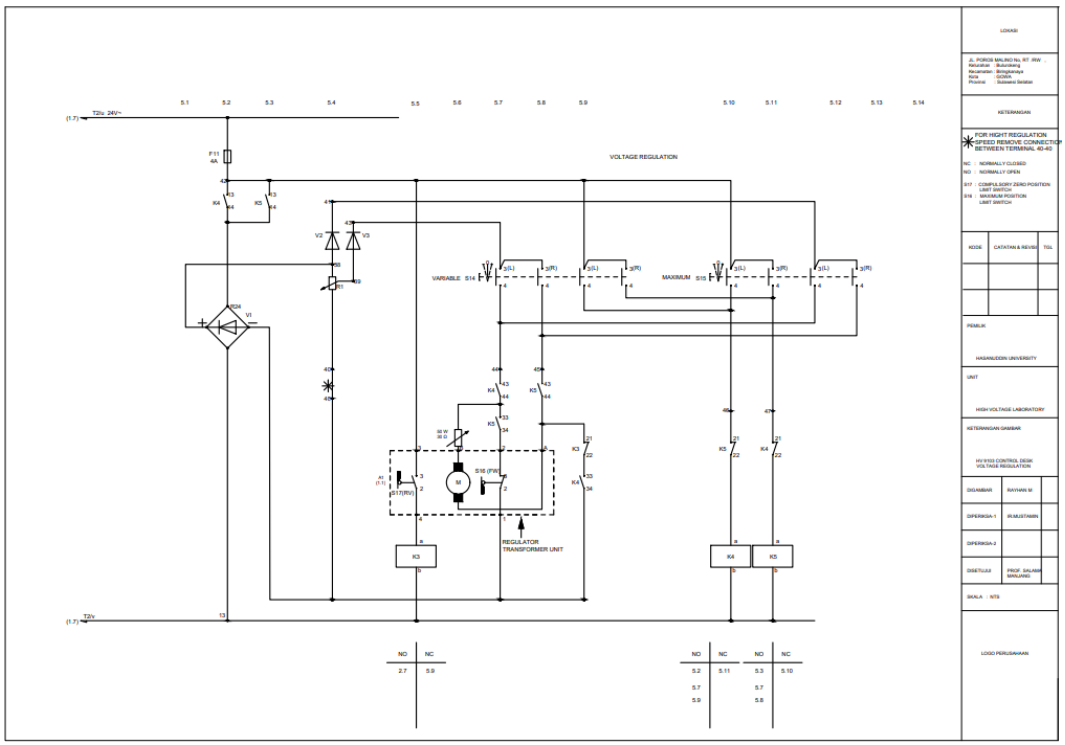
SAMPLE	FO Before (kV)	FO After (kV)	IF Before (mA)	IF After (mA)
SR-ID	16.18	19.18	42.00	31.00
SR-NF	21.26	20.46	33.00	24.00
SR-A1	16.78	21.19	39.00	42.00
SR-A2	20.25	18.98	56.00	12.80
SR-A3	20.60	19.02	33.00	24.30
SR-A4	23.00	17.90	51.00	14.80
SR-B1	21.53	18.07	70.00	45.00
SR-B2	22.70	17.82	120.00	62.00
SR-B3	17.56	20.24	54.00	75.00
SR-B4	20.62	21.95	37.00	87.00
SR-C1	22.05	19.34	134.00	54.00
SR-C2	18.55	19.63	63.00	19.00
SR-C3	22.55	19.96	33.00	32.00
SR-C4	19.64	21.31	58.00	26.00
SR-D1	21.76	21.10	25.00	71.00
SR-D2	18.82	18.33	42.00	39.00
SR-D3	17.84	19.16	81.00	21.00
SR-D4	21.70	19.72	58.00	17.00

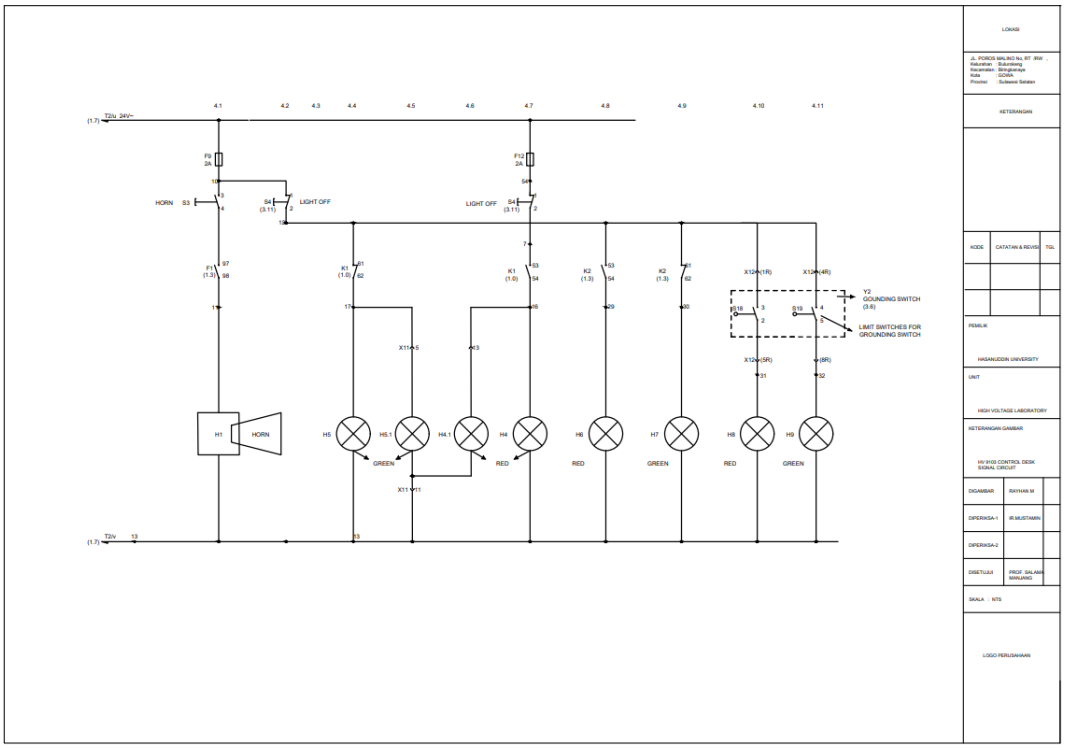
Lampiran 13. Data modul tegangan tinggi *existing*

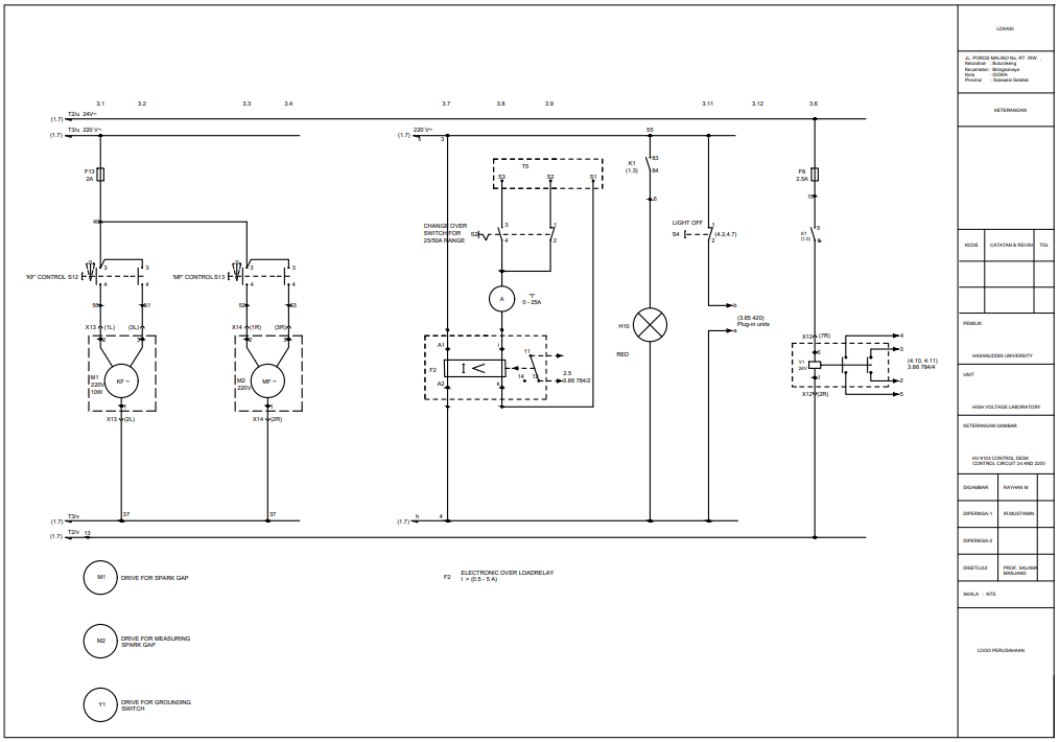


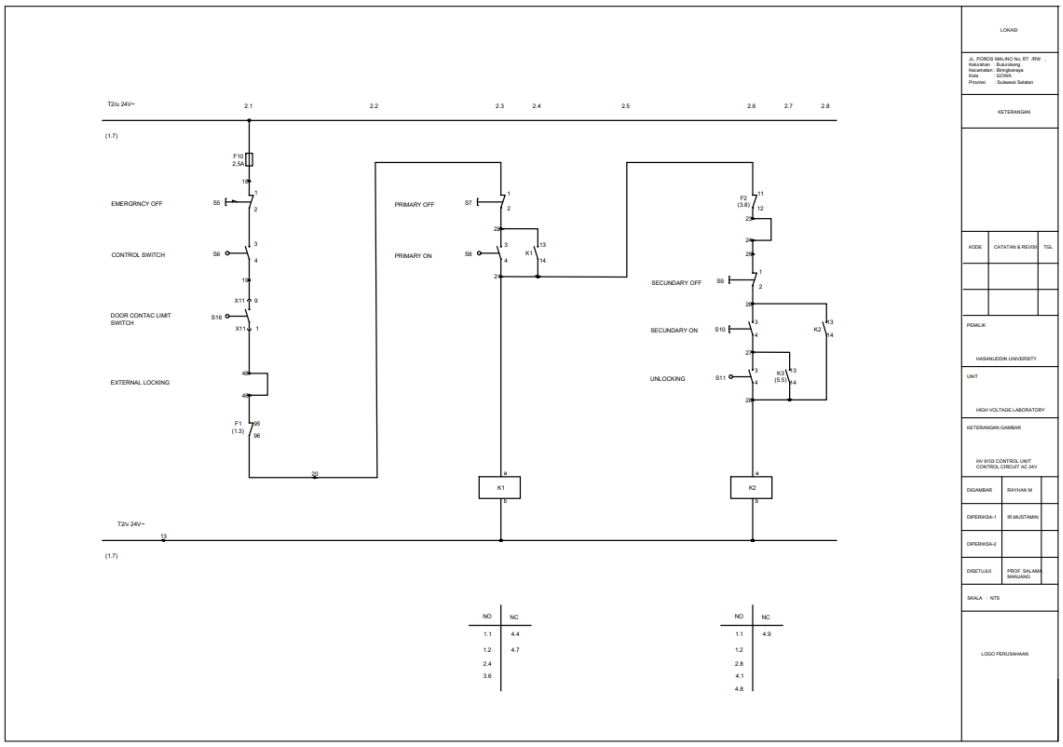


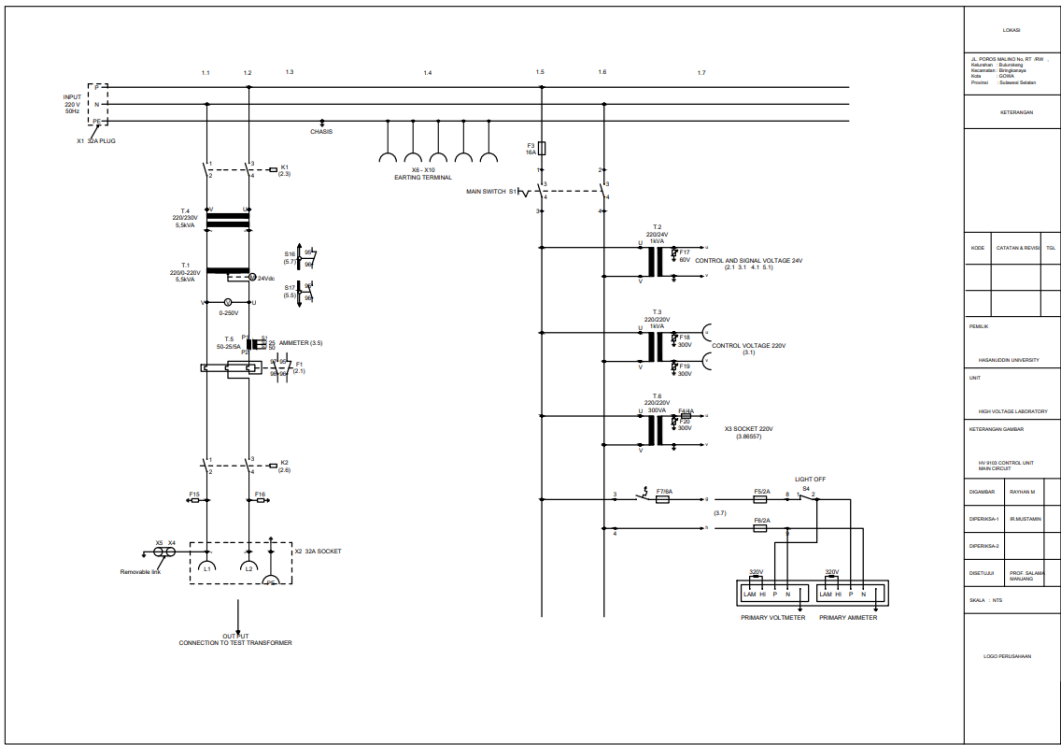

CONNECTED DEVICE
MEASURING SPARK GAP MF
DRIVE FOR SPARK GAP KF
EARTING SWITCH ES
DOOR CONTACT, WARNING LAMP
SUPPLY VOLTAGE
220 V, 50 Hz
220 V, 50 Hz
24 V, 50 Hz
24 V, 50 Hz
CONTROL PLUG (FOR SOCKET AT THE REAR OF THE CONTROL DESK)
X14
X13
X12
X11
CONNECTOR WIRE
3 x 0.75 mm2
3 x 0.75 mm2
7 x 0.50 mm2
5 x 0.50 mm2
CONTROL SOCKET (FOR PLUG AT THE DEVICE)
EXTERNAL SAFETY DEVICE
H2.2 GREEN
H3.2 RED
LOKASI
KETERANGAN
1 CONTROL PLUG, 16 POLES
2 CONTROL PLUG, 3 POLES
3 CONTROL PLUG, 6 POLES
1 At the time of supply, both socket and plug assembly will be supplied
2 Contol sockets are not included in the suply
KODE
CATATAN & REVISI
TGL
PEMILIK
HASANUDDIN UNIVERSITY
UNIT
HIGH VOLTAGE LABORATORY
KETERANGAN GAMBAR
HV 9103 CONTROL DESK Plug Connections for Ext Devices
DIGAMBAR
RAYHAN M
DIPERIKSA-1
IR MUSTAMIN
DIPERIKSA-2
DISETUJUI
PROF. SALAM MANJANG
SKALA : NTS
LOGO PERUSAHAAN


T2/u 24V~
T2/v
VOLTAGE REGULATION
VARIABLE S14
MAXIMUM S15
REGULATOR TRANSFORMER UNIT
S16 (FW)
K3
K4
K5
NO NC
2.7 5.9
5.2 5.11 5.3 5.10
5.7 5.7
5.9 5.8
LOKASI
KETERANGAN
FOR HIGHT REGULATION SPEED REMOVE CONNECTION BETWEEN TERMINAL 40-46
NC : NORMALLY CLOSED
NO : NORMALLY OPEN
S17 : COMPULSORY ZERO POSITION LIMIT SWITCH
S18 : MAXIMUM POSITION LIMIT SWITCH
KODE
CATATAN & REVISI
TGL
PEMILIK
HASANUDDIN UNIVERSITY
UNIT
HIGH VOLTAGE LABORATORY
KETERANGAN GAMBAR
HV 9103 CONTROL DESK VOLTAGE REGULATION
DIGAMBAR
RAYHAN M
DIPERIKSA-1
IR MUSTAMIN
DIPERIKSA-2
DISETUJUI
PROF. SALAM MANJANG
SKALA : NTS
LOGO PERUSAHAAN

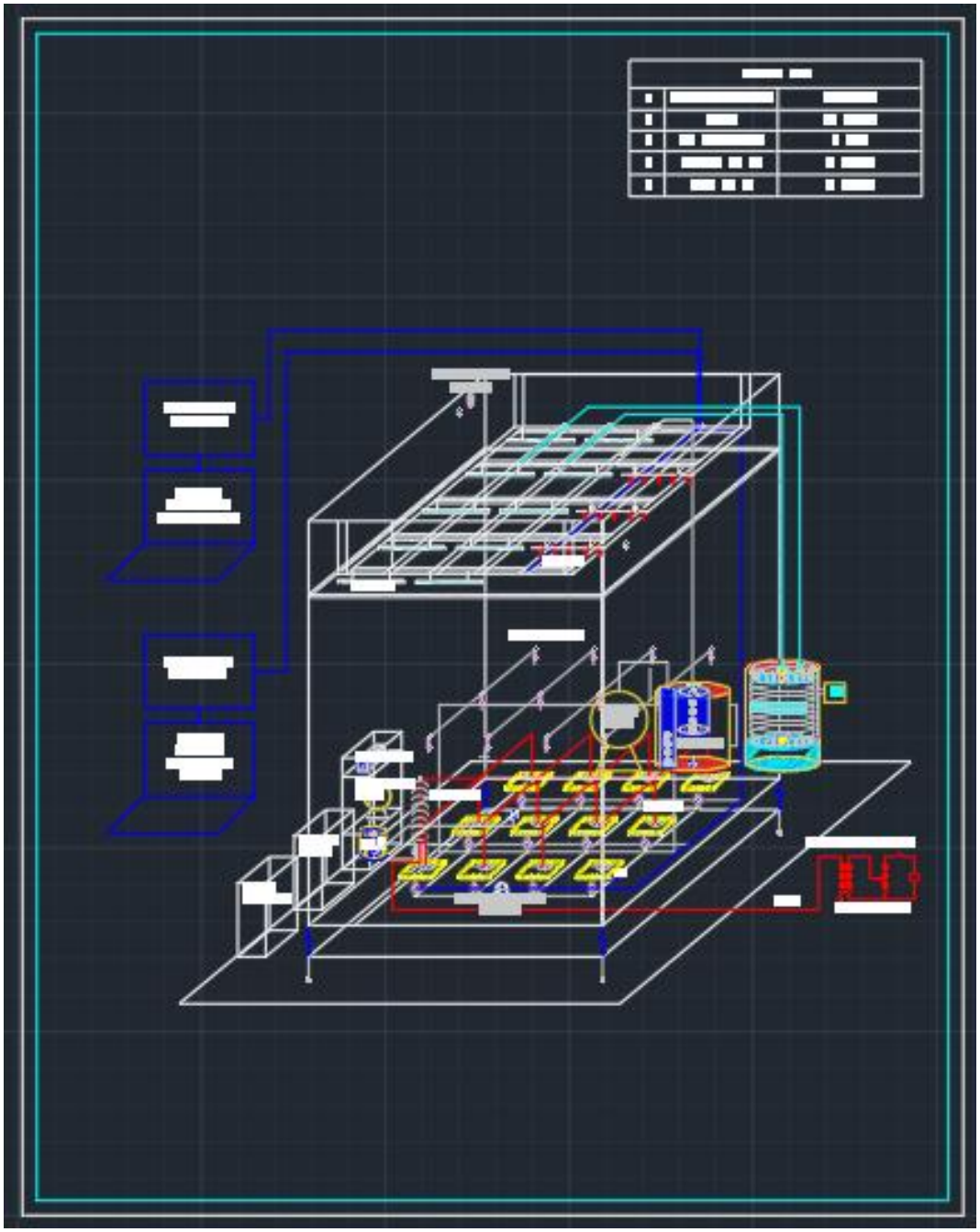

T2lv 24V~
F9 2A
F12 2A
HORN S3
S4 (3.11) LIGHT OFF
LIGHT OFF S4 (3.11)
F11 (1.3)
K1 (1.0)
K2 (1.3)
X12A(1R)
X12A(4R)
Y2 GROUNDING SWITCH (3.6)
B18
B19
LIMIT SWITCHES FOR GROUNDING SWITCH
X12A(5R)
(6R)
X11A 5
X3
H1 HORN
H5
H5.1
H4.1
H4
H6
H7
H8
H9
GREEN
RED
X11 11
T2lv 13
LOKASI
KETERANGAN
KODE
CATATAN & REVISI
TGL
PEMILIK
HASANUDDIN UNIVERSITY
UNIT
HIGH VOLTAGE LABORATORY
KETERANGAN GAMBAR
HV 9103 CONTROL DESK SIGNAL CIRCUIT
DIGAMBAR
RAYHAN M
DIPERIKSA-1
IR.MUSTAMIN
DIPERIKSA-2
DISETUJUI
PROF. SALAMI MANJANG
SKALA : NTS
LOGO PERUSAHAAN


T2lv 24V~
T3lv 220 V~
220 V~
F10 2A
'KF' CONTROL S12
'MF' CONTROLS13
X13 (1L) (3L)
X14 (1R) (3R)
M1 220V 10W
KF ~
MF ~
X13 (2L)
X14 (2R)
T5
CHANGE OVER SWITCH FOR 25/50A RANGE S5
'I' 0 - 25A
F2
I <
2.5 3.86 784Ω
K1 (1.3)
LIGHT OFF S4 (4.2,4.7)
H10
RED
(3.85 420) Plug-in units
F8 2.5A
K1 (1.6)
X12A (7R)
X12A (2R)
(4.10, 4.11) 3.86 784Ω
M1 DRIVE FOR SPARK GAP
M2 DRIVE FOR MEASURING SPARK GAP
Y1 DRIVE FOR GROUNDING SWITCH
F2 ELECTRONIC OVER LOADRELAY I = (0.5 - 5 A)
LOKASI
KETERANGAN
KODE
CATATAN & REVISI
TGL
PEMILIK
HASANUDDIN UNIVERSITY
UNIT
HIGH VOLTAGE LABORATORY
KETERANGAN GAMBAR
HV 9103 CONTROL DESK CONTROL CIRCUIT 2A AND 220V
DIGAMBAR
RAYHAN M
DIPERIKSA-1
IR.MUSTAMIN
DIPERIKSA-2
DISETUJUI
PROF. SALAMI MANJANG
SKALA : NTS
LOGO PERUSAHAAN


T2lu 24V~
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
(1.7)
F10
2.5A
EMERGRNCY OFF
S5
CONTROL SWITCH
S6
DOOR CONTAC LIMIT SWITCH
S16
EXTERNAL LOCKING
F1
(1.3)
PRIMARY OFF
S7
PRIMARY ON
S8
K1
SECUNDARY OFF
S9
SECUNDARY ON
S10
UNLOCKING
S11
K3
F2
(3.8)
K2
T2lv 24V~
NO
NC
1.1
4.4
1.2
4.7
2.4
3.6
2.8
4.1
4.8
LOKASI
JL. POROS MALINO No. RT. /RW :
Kelurahan : Bulurokeng
Kecamatan : Bonigunaya
Kota : GOWA
Provinsi : Sulawesi Selatan
KETERANGAN
KODE
CATATAN & REVISI
TGL
PEMILIK
HASANUDDIN UNIVERSITY
UNIT
HIGH VOLTAGE LABORATORY
KETERANGAN GAMBAR
HV 9103 CONTROL UNIT
CONTROL CIRCUIT AC 24V
DIGAMBAR
RAYHAN M
DIPERIKSA-1
IR MUSTAMIN
DIPERIKSA-2
DISETUJUI
PROF. SALAMA MANJANG
SKALA : NTS
LOGO PERUSAHAAN


1.1
1.2
1.3
1.4
1.5
1.6
1.7
INPUT
220 V
50Hz
X1 32A PLUG
CHASIS
X8 - X10
EARTING TERMINAL
F3
16A
MAIN SWITCH S1
K1
(2.3)
T.4
220/230V
5.5kVA
T.1
220/0-220V
5.5kVA
24Vac
0-250V
S16
(5.7)
S17
(5.8)
T.5
55-25/5A
AMMETER (3.5)
F1
(2.1)
K2
(2.6)
F15
F16
X5 X4
Removable link
K2 32A SOCKET
OUTPUT
CONNECTION TO TEST TRANSFORMER
T.2
220/24V
160VA
F17
60V
CONTROL AND SIGNAL VOLTAGE 24V
(2.1 3.1 4.1 5.1)
T.3
220/220V
160VA
F18
300V
F19
300V
CONTROL VOLTAGE 220V
(3.1)
T.6
220/220V
320VA
F20
300V
X3 SOCKET 220V
(3.86557)
F7/6A
F5/2A
F6/2A
S4
LIGHT OFF
(3.7)
500V
LAM Hi P N
PRIMARY VOLTMETER
PRIMARY AMMETER
LOKASI
JL. POROS MALINO No. RT. /RW :
Kelurahan : Bulurokeng
Kecamatan : Bonigunaya
Kota : GOWA
Provinsi : Sulawesi Selatan
KETERANGAN
KODE
CATATAN & REVISI
TGL
PEMILIK
HASANUDDIN UNIVERSITY
UNIT
HIGH VOLTAGE LABORATORY
KETERANGAN GAMBAR
HV 9103 CONTROL UNIT
MAIN CIRCUIT
DIGAMBAR
RAYHAN M
DIPERIKSA-1
IR MUSTAMIN
DIPERIKSA-2
DISETUJUI
PROF. SALAMA MANJANG
SKALA : NTS
LOGO PERUSAHAAN

Lampiran 14. Data kontrol dan instrument pengujian



Lampiran 15. Dokumentasi dan foto-foto kegiatan

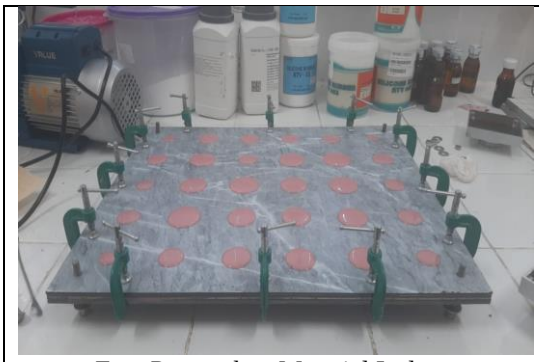


Foto Pencetakan Material Isolator

Foto Peralatan Vacum & Mixer

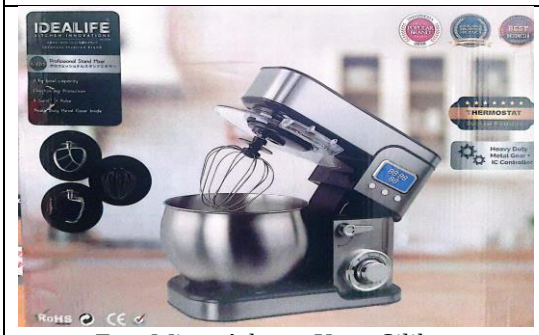


Foto Mixer Adonan Karet Silikon

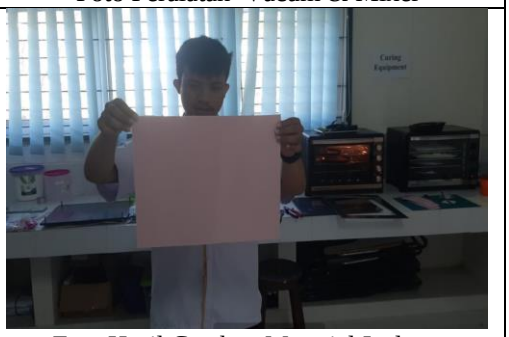


Foto Hasil Cetakan Material Isolator

Foto *Treatment* Difusi Air

Foto *Treatment* Kontaminan Suhu Kamar

Foto *Treatment* Kontaminan UVa

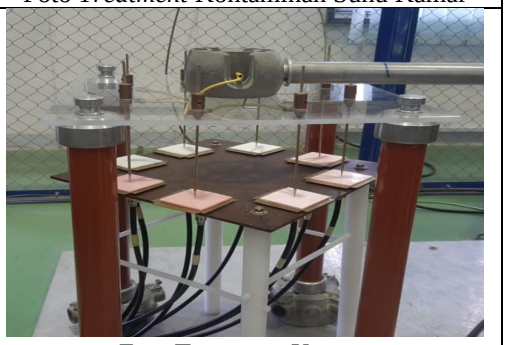


Foto Treatment Korona

Foto Uji *Breakdown* dan *Flashover*

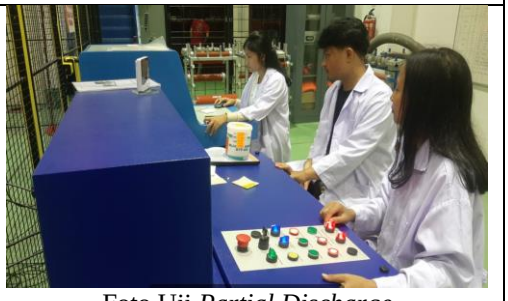


Foto Uji *Partial Discharge*

Lampiran 16. Daftar arti lambang dan singkatan

DAFTAR ARTI LAMBANG DAN SINGKATAN

Lambang/Singkatan		Arti dan keterangan
R_v	=	Resitansi volume
R_s	=	Resistansi permukaan
ρ_v	=	Resitivitas volume
ρ_s	=	Resistivitas permukaan
ε_r	=	Permitivitas relativ
ε_r	=	Permitivitas relatif
Ω	=	Ohm
Θ	=	Sudut kontak
λ	=	Panjang gelombang
ν	=	Bilangan gelombang
c	=	Kecepatan cahaya
°	=	Derajat
h	=	Konstanta Planck
Vrms	=	Tegangan efektif
BD	=	Tegangan tembus
PD	=	Peluahan sebagian
pC	=	Piko Coulomb
LC	=	Arus bocor
f	=	Frekuensi
σ	=	Kekuatan tarik
ρ	=	Massa jenis
ε	=	Elongasi
R_v	=	Resitansi volume
R_s	=	Resistansi permukaan