ELECTRICAL TREEING PERFORMANCE OF SILICONE RUBBER FILLED WITH PLASMA-TREATED NANOPARTICLES

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Specially dedicated to

my late father and mother, Allahyarham Musa bin Dollah and Senah binti Jelani

my husband, Muhammad Ariff bin Taha

my siblings, Siti Farhana, Maslinda, Lukman Hakim and Azizul Hakim

and last but not least my families and also my in-laws family

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ABSTRACT

Nanocomposites have gained wide interests as insulating materials due to their excellent ability to resist electrical discharges such as corona discharges, partial discharges, electrical treeing and water treeing. However, surface incompatibility between polymer and nanoparticles is one of the main issues that may reduce their performances towards discharge resistances. Processing techniques of these nanoparticles such as coupling agent and intercalation methods showed excellent performance, but those techniques involved chemical processes. Recently, plasma treatment was introduced as an improved technique to enhance the dispersion of nanocomposites in electrical applications. However, electrical treeing studies on the electrical performance of plasma-treated nanocomposites are lacking. This study presents an investigation on the electrical tree growth performance as well as the effect of nanoparticles concentration of silicone rubber (SiR) filled with silicon dioxide (SiO_2) nanoparticles treated with Atmospheric Pressure Plasma (APP). The treatment of the SiO_2 nanoparticles' surfaces with APP is to enhance SiO_2 compatibility with SiR matrix. Besides, untreated and silane-treated nanocomposites were also studied for comparison purpose. Constant AC voltage was applied to these untreated, silane and plasma-treated nanocomposites with different nanoparticles concentration of 1, 3 and 5 wt% to investigate their electrical performances i.e. tree initiation time, tree propagation time, growth rate and tree breakdown time. Morphological analysis as well as chemical characterization of the nanoparticles were analyzed using Field Emission Scanning Electron Microscope (FESEM), Energy Dispersive X-ray spectroscopy (EDX) and X-ray Photoelectron Spectroscopy (XPS) while, the dispersion of the nanoparticles-polymer matrix were analyzed using FESEM. Results show that plasma-treated SiO_2 nanoparticles dispersed uniformly in the SiR polymer matrix. The plasma-treated nanocomposites were able to resist electrical treeing better than untreated and silane-treated nanocomposites. The increase in nanoparticles concentration in all three different treatments has enhanced the electrical tree performance of the nanocomposites. Overall, the result from this study reveals that the plasma-treated nanocomposites showed better efficacy in inhibiting electrical tree growth by as much as 64% as compared to silane-treated nanocomposites that showed an efficacy in electrical tree growth rate reduction by as much as 29%. This indicates that plasma treatment could be an alternative technique to improve surface incompatibility of nanocomposites, and hence, resisting electrical treeing growth.

ABSTRAK

Komposit-nano telah mendapat banyak perhatian sebagai bahan penebat kerana kemampuannya menghalang nyahcas elektrik seperti nyahcas korona, nyahcas separa, pepohon elektrik dan pepohon air. Walau bagaimanapun, ketidakserasian permukaan antara polimer dan partikel-nano telah dikenal pasti sebagai salah satu masalah utama yang boleh mengurangkan keupayaan komposit-nano ke arah menghalang nyahcas ini. Teknik pemprosesan partikel-nano itu sebagai ejen gandingan dan kaedah interkalasi telah digunakan secara meluas dan menunjukkan prestasi yang sangat baik, tetapi ianya melibatkan proses kimia. Baru-baru ini, rawatan plasma diperkenalkan sebagai teknik yang lebih baik untuk meningkatkan penyebaran komposit-nano dalam aplikasi elektrik. Tetapi, kajian mengenai prestasi rawatan plasma komposit-nano dalam pepohon elektrik masih kurang. Kajian ini membentangkan suatu penyiasatan ke atas prestasi pertumbuhan pepohon elektrik serta kesan kepekatan partikel-nano terhadap getah silikon (SiR) dipenuhi dengan partikel-nano dirawat dengan plasma tekanan atmosfera (APP). Rawatan permukaan silikon dioksida (SiO_2) partikel-nano menggunakan APP adalah untuk meningkatkan keserasian dengan matriks SiR. Selain itu, SiO_2 yang tidak dirawat dan rawatan silana juga dikaji untuk tujuan perbandingan. Komposit-nano dengan partikel-nano tidak dirawat, rawatan silana dan rawatan plasma dengan kepekatan partikel-nano 1, 3 dan 5 wt% telah digunakan untuk voltan AU yang berterusan untuk mengenal pasti prestasi elektrik mereka iaitu masa permulaan, masa pembiakan, kadar pertumbuhan dan masa kerosakan. Analisis morfologi serta pencirian kimia partikel-nano dianalisis menggunakan Mikroskop Imbasan Elektron Pancaran Medan (FESEM), Spektroskopi Sinar-X Sebaran Tenaga (EDX) dan Spektroskopi Fotoelektron Sinar-X (XPS) manakala penyebaran pengisi di dalam matriks polimer dianalisis menggunakan FESEM. Hasil menunjukkan bahawa SiO_2 partikel-nano rawatan plasma boleh bersurai seragam dalam polimer matriks SiR. Komposit-nano rawatan plasma dapat menahan pepohon elektrik lebih baik daripada komposit-nano tidak dirawat dan rawatan silana. Peningkatan kepekatan partikel-nano dalam ketiga-tiga rawatan yang berbeza telah meningkatkan persembahan pepohon elektrik daripada komposit-nano. Secara keseluruhan, hasil daripada kajian ini mendedahkan bahawa komposit-nano rawatan plasma menunjukkan keputusan cemerlang bagi menghalang pertumbuhan pepohon elektrik 64% berbanding rawatan silana yang menunjukkan pengurangan sebanyak 29%. Ini menunjukkan bahawa rawatan plasma boleh menjadi satu teknik alternatif untuk meningkatkan ketidakserasian permukaan komposit-nano, dan dengan itu menentang pertumbuhan pepohon elektrik.

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LIST OF ABBREVIATION

AC	-	Alternating current
Al_2O_3	-	Aluminum oxide
APG	-	Atmospheric pressure glow
APP	-	Atmospheric pressure plasma
BE	-	Binding energy
CNT	-	Carbon nanotubes
DBD	-	Dielectric barrier discharge
DMNC	-	Direct mixing nanocomposites
DMS	-	Dimethyl methylhydrogen siloxane
EDX	-	Energy dispersiveX-ray spectroscopy
ER	-	Epoxy resin
EVA	-	Ethylene-Vynil Acetate
FESEM	-	Field Emission Scanning Electron Microscope
HDPE	-	High Density Polyethene
LDPE	-	Low Density Polyethene
LPP	-	Low-pressure plasmas
MgO	-	Magnesium oxide
MMT	-	Montmorillonite

NaOH	-	Sodium hydroxide
NC	-	Nanocomposites
OMMT	-	Organo-Montmorillonite
PD	-	Partial Discharge
PE	-	Polyethylene
PILC	-	Paper Insulated Lead Covered
PTNC	-	Plasma-treated nanocomposites
PSR	-	Pure silicone rubber
RF	-	Radio frequency
SEM	-	Scanning Electron Microscopy
SiO_2	-	Silicon dioxide
SiR	-	Silicone rubber
STNC	-	Silane-treated nanocomposites
TiO_2	-	Titanium dioxide
UHV	-	Ultra High Vacuum
XLPE	-	Cross Linked Polyethylene
XPS	-	X-ray photoelectron spectroscopy
ZnO	-	Zinc oxide

LIST OF SYMBOLS

ε_0	-	Permittivity of the free space
ε_r	-	Permittivity of the dielectric
ΔG	-	Growth rate
BE	-	Binding energy
d	-	Gap distance
e	-	Electron charge
E	-	Magnitude of applied voltage
hv	-	Photon energy
KE	-	Kinetic energy or energy of electron measured
L_m	-	Final length of the first branch
l_x	-	Mean free path
p	-	Pressure
r	-	Needle tip radius
S	-	Mechanical stress in the dielectric
t	-	Time
t_1	-	Inception time for trees
T_b	-	Tree breakdown time
T_i	-	Tree initiation time

V	-	Applied voltage
V_b	-	Breakdown voltage
W	-	Energy gain
τ_e	-	Growth period of the trees
Φ	-	Work function of the instrument

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CHAPTER 1

INTRODUCTION

1.1 Background

Power cables are fabricated based on polymeric insulating material, namely cross-linked polyethylene. Polymeric insulation is being used throughout the world to replace paper insulated cable due to its excellent properties. Power cables consist of three main components, conductors, insulating materials and protective jackets. Insulating materials are the crucial components because they function as an outer layer protecting the cable from electrical and mechanical damages. However, if the insulator has served for a long time, it could be aged. Ageing is generally caused by environmental effects and electrical stress, which degrade the insulation performance and eventually lead to the insulation failure. One of the factors of failure in electrical insulation is electrical treeing.

Generally, electrical tree originates from the imperfection in the insulation such as impurities, voids, defects, or conducting projections that causing excessive electric field stress within a small vicinity of the insulation [1]. The growth of electrical tree results in the creation of a conductive path between the high voltage and grounded parts of the cable thus resulting in the breakdown. Insulation breakdown may result in the interruption of power, which can be costly, especially to the industry as well as the power utility company through cost of repairs.

Researchers have introduced many methods to improve the insulation performance, such as adding filler and modifying the insulation [2-4]. In addition, nanoparticles (nanofiller) have a high demand compare to microfiller due to its excellent electrical and mechanical properties as it improves the electrical treeing resistance [5, 6] when mixed with polymer base. Several techniques were introduced to enhance the performance of the insulation such as chemically modified. The silane coupling agent was used to modify the surface of the oxides filler [7, 8] while intercalation method was used to modify the surface of clay filler [9]. Recently, the plasma treatment was used for surface modification of the nanoparticles in the electrical application.

1.2 Problem Statement

Polymeric insulated cables are widely used in transmission and distribution system to replace paper-insulated cable due to its excellent performances. However, they are vulnerable to degradation process, namely electrical treeing. The electrical treeing is a pre-breakdown phenomenon in electrical insulation. Numerous methods have been proposed to increase the tree resistance of the insulating materials such as adding tree inhibitors, reinforcement and modifying the insulating material. In addition, results from the literature reported nanoparticles were superior in inhibition of electrical treeing in the polymeric insulating material compared to the micro-sized fillers.

However, the problem related with these nanoparticles is that they tend to agglomerate because of surface incompatibility between the fillers and the polymer matrices. As a result, the insulation performance of these nanocomposites is often significantly degraded. Several processing techniques such as intercalation and coupling agent have been introduced, but such techniques use chemical substances (which are toxic) and the process is complicated and costly. Recently, atmospheric pressure plasma treatment was introduced to treat nanoparticles that able to enhance the compatibility and maintaining excellent dispersion uniformity. Plasma is environmentally friendly and easy to generate. Though this technique has shown good results, however, glow discharges were used which are difficult to generate and thus not suitable for mass production. In addition, a comprehensive study on the electrical performance of the plasma-treated composites to electrical treeing is lacking.

1.3 Objectives of Study

1. To assess the performance of surface modification of the nanoparticles treated with atmospheric pressure plasma
2. To investigate the electrical tree growth performance of polymer-based nanocomposites filled with untreated, silane-treated and plasma-treated of nanoparticles with different filler concentrations
3. To conduct instrumental analysis of with untreated, silane-treated and plasma-treated of the nanoparticles as well as the nanocomposites

1.4 Scope of Study

This research was conducted with the following scope:

1. Silicon dioxide nanoparticles is treated with filamentary atmospheric pressure plasma and also chemically modified using silane coupling agent
2. Silicone rubber is used as base material and silicon dioxide as nanoparticles with 1, 3 and 5 wt% concentration using direct mixing, silane coupling and plasma treatment
3. The instrumental analysis of the nanoparticles is conducted using FESEM, EDX and XPS while the morphological analysis of nanocomposites is conducted using FESEM

1.5 Significance/Contribution of Study

The contribution of this research is as follows:

1. The performance of filamentary discharge of atmospheric pressure plasma for surface modification of the nanoparticles
2. Comprehensive study on the electrical treeing performance of silicone rubber mixed with plasma-treated nanoparticles
3. Improvement of electrical treeing resistance in the nanocomposites using an environmentally friendly technique (does not use any chemicals).

1.6 Thesis Organization

The thesis is organized as follows:

Chapter 2 presents a review of the electrical treeing phenomena in polymeric insulation. The reviews of various types of polymer nanocomposites used to study the electrical treeing are presented. In addition, the traditional processing techniques of the nanoparticles are described in details. Atmospheric pressure plasma to treat the surface of nanoparticles, which includes its fundamental theory, applications in high voltage and previous application of this surface modification technique are reviewed.

Chapter 3 describes the research methodology employed in this study. Also, it includes schematic diagrams and necessary pictures that explain the findings. The experimental set-up includes a detailed description of the electrical tree studies. The data collection procedure used for electrical tree analysis and morphological analysis were explained in more details.

Chapter 4 describes the use of atmospheric pressure plasma treatment on the nanoparticles. In addition, the morphological analysis of the treated nanoparticles is presented. Also, this chapter describes the electrical tree in plasma-treated silicone rubber nanocomposites. Results of the electrical treeing performance of the silicone rubber based nanocomposites vis-à-vis different filler concentrations of the plasma-treated nanoparticles are presented and analyzed. The morphology of the nanocomposites is discussed in details.

Chapter 5 concludes the findings of the study and presents some recommendations. This chapter also offers suggestions for future study in the area.

REFERENCES

1. Auckland, D. and Varlow, B. (1995). Electrical treeing in solid polymeric insulation. *Engineering Science & Education Journal*. 4(1): 11-16.
2. Cooper, J. (1988).The effect of barriers on electrical treeing. *Dielectric Materials, Measurements and Applications, 1988., Fifth International Conference on*. IET.
3. Patsch, R. (1979). On tree-inhibition in polyethylene. *Electrical Insulation, IEEE Transactions on*, (4): 200-206.
4. Zheng, X. and Chen, G. (2008). Propagation mechanism of electrical tree in XLPE cable insulation by investigating a double electrical tree structure. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 15(3): 800-807.
5. Iizuka, T. and Tanaka, T. (2010). Effects of nano silica filler size on treeing breakdown of epoxy nanocomposites. *IEEJ Transactions on Fundamentals and Materials*. 130: 837-842.
6. Danikas, M.G. and Tanaka, T. (2009). Nanocomposites-a review of electrical treeing and breakdown. *Electrical Insulation Magazine, IEEE*. 25(4): 19-25.
7. Iizuka, T., Ohki, Y., and Tanaka, T. (2008).Effects of coupling agent and filler dispersion on Vt characteristics of epoxy/silica nanocomposites. *Electrical Insulating Materials, 2008.(ISEIM 2008). International Symposium on*. IEEE.
8. Zhou, W. and Yu, D. (2011). Effect of coupling agents on the dielectric properties of aluminum particles reinforced epoxy resin composites. *Journal of composite materials*. 45(19): 1981-1989.
9. Guastavino, F., Dardano, A., Montanari, G., Deorsola, F., and Testa, L. (2006).Electrical tree growth in EVA-layered silicate nanocomposites. *Electrical Insulation and Dielectric Phenomena, 2006 IEEE Conference on*. IEEE.
10. Dissado, L.A. and Fothergill, J.C. (1992). Electrical degradation and breakdown in polymers. IET.
11. Tanaka, T. and Greenwood, A. (1978). Effects of charge injection and extraction on tree initiation in polyethylene. *Power Apparatus and Systems, IEEE Transactions on*, (5): 1749-1759.
12. Bamji, S.S. (1999). Electrical trees, physical mechanisms and experimental techniques. *Wiley Encyclopedia of Electrical and Electronics Engineering*.
13. Artbauer, J. (1996). Electric strength of polymers. *Journal of Physics D: Applied Physics*. 29(2): 446.

14. Mason, J.H. (1951). The deterioration and breakdown of dielectrics resulting from internal discharges. *Proceedings of the IEE-Part I: General*. 98(109): 44-59.
15. Densley, R. (1979). An investigation into the growth of electrical trees in XLPE cable insulation. *Electrical Insulation, IEEE Transactions on*, (3): 148-158.
16. Alapati, S. and Thomas, M.J. (2012). Influence of nano-fillers on electrical treeing in epoxy insulation. *IET Science, Measurement & Technology*. 6(1): 21-28.
17. Tanaka, T. (2005). Dielectric nanocomposites with insulating properties. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 12(5): 914-928.
18. Tanaka, T., Montanari, G., and Mulhaupt, R. (2004). Polymer nanocomposites as dielectrics and electrical insulation-perspectives for processing technologies, material characterization and future applications. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 11(5): 763-784.
19. Andritsch, T. (2010). Epoxy based nanocomposites for high voltage DC applications- synthesis, dielectric properties and space charge dynamics., Delft University of Technology
20. Gangopadhyay, R. and De, A. (2000). Conducting polymer nanocomposites: a brief overview. *Chemistry of Materials*. 12(3): 608-622.
21. Jordan, J., Jacob, K.I., Tannenbaum, R., Sharaf, M.A., and Jasiuk, I. (2005). Experimental trends in polymer nanocomposites—a review. *Materials science and engineering: A*. 393(1): 1-11.
22. Crosby, A.J. and Lee, J.Y. (2007). Polymer nanocomposites: the "nano" effect on mechanical properties. *Polymer reviews*. 47(2): 217-229.
23. Hussain, F., Hojjati, M., Okamoto, M., and Gorga, R.E. (2006). Review article: polymer-matrix nanocomposites, processing, manufacturing, and application: an overview. *Journal of composite materials*. 40(17): 1511-1575.
24. Groover, M.P. (2007). Fundamentals of modern manufacturing: materials processes, and systems. John Wiley & Sons.
25. Nelson, J.K. (2010). Dielectric polymer nanocomposites. Springer.
26. Roberts, J.D. and Caserio, M.C. (1977). Basic principles of organic chemistry. WA Benjamin, Inc.
27. Du, B., Ma, Z., and Gao, Y. (2009).Phenomena and mechanism of electrical tree in silicone rubber. *Properties and Applications of Dielectric Materials, 2009. ICPADM 2009. IEEE 9th International Conference on the*. IEEE.
28. Hosier, I., Freebody, N., Vaughan, A., Swingler, S., and Moss, G. (2011). Electrical Treeing in Silicone Rubber. *7th International Symposium on High Voltage Engineering, Hannover, Germany*.
29. Imai, T., Komiya, G., Murayama, K., Ozaki, T., Sawa, F., Shimizu, T., Harada, M., Ochi, M., Ohki, Y., and Tanaka, T. (2008).Improving epoxy-based insulating materials with nano-fillers toward practical application. *Electrical Insulation, 2008. ISEI 2008. Conference Record of the 2008 IEEE International Symposium on*. IEEE.
30. Schadler, L., Brinson, L., and Sawyer, W. (2007). Polymer nanocomposites: a small part of the story. *Jom*. 59(3): 53-60.

31. Schadler, L.S. (2003). Polymer-Based and Polymer-Filled Nanocomposites. Wiley Online Library.
32. Sinha Ray, S. and Okamoto, M. (2003). Polymer/layered silicate nanocomposites: a review from preparation to processing. *Progress in polymer science*. 28(11): 1539-1641.
33. Izzati, W.A., Arief, Y.Z., Adzis, Z., and Shafanizam, M. (2014). Partial Discharge Characteristics of Polymer Nanocomposite Materials in Electrical Insulation: A Review of Sample Preparation Techniques, Analysis Methods, Potential Applications, and Future Trends. *The Scientific World Journal*. 2014.
34. Moniruzzaman, M. and Winey, K.I. (2006). Polymer nanocomposites containing carbon nanotubes. *Macromolecules*. 39(16): 5194-5205.
35. Breuer, O. and Sundararaj, U. (2004). Big returns from small fibers: a review of polymer/carbon nanotube composites. *Polymer composites*. 25(6): 630-645.
36. Lewis, T. (2004). Interfaces are the dominant feature of dielectrics at the nanometric level. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 11(5): 739-753.
37. Lewis, T. (2005). Interfaces: nanometric dielectrics. *Journal of Physics D: Applied Physics*. 38(2): 202.
38. Tanaka, T., Kozako, M., Fuse, N., and Ohki, Y. (2005). Proposal of a multi-core model for polymer nanocomposite dielectrics. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 12(4): 669-681.
39. Chen, G. (2011). Applications of nanotechnology in high voltage power equipment-Nanodielectrics (invited talk). *The nineteenth Annual International Conference on Composites or Nano Engineering, Shanghai, China*.
40. Fang, Z., Xie, X., Li, J., Yang, H., Qiu, Y., and Kuffel, E. (2009). Comparison of surface modification of polypropylene film by filamentary DBD at atmospheric pressure and homogeneous DBD at medium pressure in air. *Journal of Physics D: Applied Physics*. 42(8): 085204.
41. Hall, J.F. (1993). History and bibliography of polymeric insulators for outdoor applications. *Power Delivery, IEEE Transactions on*. 8(1): 376-385.
42. Winey, K.I. and Vaia, R.A. (2007). Polymer Nanocomposites. *MRS Bulletin*. 32(04): 314-322.
43. Raetzke, S., Ohki, Y., Imai, T., Tanaka, T., and Kindersberger, J. (2009). Tree initiation characteristics of epoxy resin and epoxy/clay nanocomoposite. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 16(5): 1473-1480.
44. Chen, Y., Imai, T., Ohki, Y., and Tanaka, T. (2010). Tree initiation phenomena in nanostructured epoxy composites. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 17(5): 1509-1515.
45. Kurnianto, R., Murakami, Y., Hozumi, N., and Nagao, M. (2007). Characterization of tree growth in filled epoxy resin: the effect of filler and moisture contents. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 14(2): 427-435.
46. Nagao, M., Oda, K., Nishioka, K., Muramoto, Y., and Hozumi, N. (2002).Effect of moisture on treeing phenomenon in epoxy resin with filler

under ac voltage. *Electrical Insulation and Dielectric Phenomena, 2002 Annual Report Conference on*. IEEE.

47. Ding, H.-Z. and Varlow, B. (2004).Effect of nano-fillers on electrical treeing in epoxy resin subjected to AC voltage. *Electrical Insulation and Dielectric Phenomena, 2004. CEIDP'04. 2004 Annual Report Conference on*. IEEE.
48. Nagao, M., Oda, K., Nishioka, K., Muramoto, Y., and Hozumi, N. (2001).Effect of filler on treeing phenomenon in epoxy resin under AC voltage. *Electrical Insulating Materials, 2001.(ISEIM 2001). Proceedings of 2001 International Symposium on*. IEEE.
49. Sridhar, A. and Thomas, M.J. (2010).Electrical treeing in polyethylene: effect of nano fillers on tree inception and growth. *High Voltage Engineering and Application (ICHVE), 2010 International Conference on*. IEEE.
50. Tiemblo, P., Hoyos, M., Gómez-Elvira, J.M., Guzmán, J., García, N., Dardano, A., and Guastavino, F. (2008). The development of electrical treeing in LDPE and its nanocomposites with spherical silica and fibrous and laminar silicates. *Journal of Physics D: Applied Physics*. 41(12): 125208.
51. Kurnianto, R., Murakami, Y., Hozumi, N., Nagao, M., and Murata, Y. (2006).Some fundamentals on treeing breakdown in inorganic-filler/LDPE nano-composite material. *Electrical Insulation and Dielectric Phenomena, 2006 IEEE Conference on*. IEEE.
52. Guastavino, F., Dardano, A., Squarcia, S., Tiemblo, P., Guzman, J., Benito, E., and Garcia, N. (2009).Electrical treeing in LDPE nanocomposite materials. *Electrical Insulation and Dielectric Phenomena, 2009. CEIDP'09. IEEE Conference on*. IEEE.
53. Chen, G. and Tham, C. (2009). Electrical treeing characteristics in XLPE power cable insulation in frequency range between 20 and 500 Hz. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 16(1): 179-188.
54. Guastavino, F., Coletti, G., Dardano, A., Montanari, G., Deorsola, F., and Di Lorenzo Del Casale, M. (2005).Electrical treeing in EVA-layered silicate nanocomposites. *Electrical Insulation and Dielectric Phenomena, 2005. CEIDP'05. 2005 Annual Report Conference on*. IEEE.
55. Guastavino, F., Dardano, A., Montanari, G., Testa, L., and Bellucci, F. (2009).Electrical treeing in EVA-boehmite and EVA-montmorillonite nanocomposites. *Electrical Insulation Conference, 2009. EIC 2009. IEEE*. IEEE.
56. Du, B., Ma, Z., Gao, Y., Han, T., and Xia, Y. (2011).Effects of nano filler on treeing phenomena of silicone rubber nanocomposites. *Electrical Insulation and Dielectric Phenomena (CEIDP), 2011 Annual Report Conference on*. IEEE.
57. Yuan-xiang, Z., Rui, L., Fei, H., Wen-bin, X., and Xu, Z. (2012).Effect of silica particles on electrical treeing initiation in silicone rubber. *Electrical Insulation and Dielectric Phenomena (CEIDP), 2012 Annual Report Conference on*. IEEE.
58. Ahmad, M., Ahmad, H., Bashir, N., Jamil, A., Piah, M., Malek, Z., and Dodd, S. (2012).Electrical treeing in silicone rubber/organo-montmorillonite. *Electrical Insulation and Dielectric Phenomena (CEIDP), 2012 Annual Report Conference on*. IEEE.

59. Jamil, A., Ahmad, M., Arief, Y., Kamarol, M., Mariatti, M., Bashir, N., and Piah, M. (2013). Electrical Tree Growth in Silicone Rubber/Organo-Montmorillonite Nanocomposites under AC Ramp Voltage. *Jurnal Teknologi*. 64(4).
60. Jamil, A., Bashir, N., Ahmad, M., Arief, Y., Kamarol, M., and Mariatti, M. (2013).Electrical treeing initiation and propagation in silicone rubber nanocomposites. *Electrical Insulation and Dielectric Phenomena (CEIDP), 2013 IEEE Conference on*. IEEE.
61. Jamil, A., Kamarol, M., Mariatti, M., Bashir, N., Ahmad, M., Arief, Y., and Muhamad, N. (2012).Organo-montmorillonite as an electrical treeing retardant for polymeric insulating materials. *2012 IEEE International Conference on Condition Monitoring and Diagnosis*.
62. Rong, M., Zhang, M., and Ruan, W. (2006). Surface modification of nanoscale fillers for improving properties of polymer nanocomposites: a review. *Materials science and technology*. 22(7): 787-796.
63. Xianyou, Z., Xiaohong, Z., and Yong, S. (1994).Interface between inorganic fillers and polymers. *Properties and Applications of Dielectric Materials, 1994., Proceedings of the 4th International Conference on*. IEEE.
64. Tanaka, T. (2010). Interface properties and surface erosion resistance, in Dielectric Polymer Nanocomposites. Springer. 229-258.
65. Imai, T., Komiya, G., Murayama, K., Ozaki, T., Sawa, F., Shimizu, T., Harada, M., Ochi, M., Ohki, Y., and Tanaka, T. (2008).Nano-and micro-filler combination enabling practical use of nanocomposite insulating materials. *Electrical Insulating Materials, 2008.(ISEIM 2008). International Symposium on*. IEEE.
66. Musa, M., Arief, Y., Abdul-Malek, Z., Ahmad, M., and Jamil, A. (2013).Influence of nano-titanium dioxide (TiO 2) on electrical tree characteristics in silicone rubber based nanocomposite. *Electrical Insulation and Dielectric Phenomena (CEIDP), 2013 IEEE Conference on*. IEEE.
67. Imai, T., Sawa, F., Nakano, T., Ozaki, T., Shimizu, T., Kozako, M., and Tanaka, T. (2006). Effects of nano-and micro-filler mixture on electrical insulation properties of epoxy based composites. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 13(2): 319-326.
68. Ahmad, M., Bashir, N., Ahmad, H., Jamil, A.A., and Suleiman, A. (2014). An Overview of Electrical Tree Growth in Solid Insulating Material with Emphasis of Influencing Factors, Mathematical Models and Tree Suppression. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 12(8).
69. Alexandre, M. and Dubois, P. (2000). Polymer-layered silicate nanocomposites: preparation, properties and uses of a new class of materials. *Materials Science and Engineering: R: Reports*. 28(1–2): 1-63.
70. Guastavino, F., Dardano, A., Montanari, G., Deorsola, F., and del Casale, M.D.L. (2006).A study about electrical treeing in different EVA-layered silicate nanostructured compounds. *Electrical Insulation, 2006. Conference Record of the 2006 IEEE International Symposium*. IEEE.
71. Imai, T., Sawa, F., Yoshimitsu, T., Ozaki, T., and Shimizu, T. (2004).Preparation and insulation properties of epoxy-layered silicate nanocomposite [insulating material applications]. *Electrical Insulation and Dielectric Phenomena, 2004. CEIDP'04. 2004 Annual Report Conference on*. IEEE.

72. Imai, T., Sawa, F., Ozaki, T., Shimizu, T., Kido, R., Kozako, M., and Tanaka, T. (2006). Influence of temperature on mechanical and insulation properties of epoxy-layered silicate nanocomposite. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 13(2): 445-452.
73. Shimizu, T., Ozaki, T., Hirano, Y., Imai, T., and Yoshimitsu, T. (2004). Properties of epoxy-layered silocate nanocomposites. *CIGRE Paris*.
74. Saheb, D.N. and Jog, J. (1999). Natural fiber polymer composites: a review. *Advances in polymer technology*. 18(4): 351-363.
75. Kaplan, S.L. (2003).Cold Gas Plasma and Silanes. *Fourth International Symposium on Silanes and Other Coupling Agents, June*.
76. Todd, M.G. and Shi, F.G. (2003). Characterizing the interphase dielectric constant of polymer composite materials: Effect of chemical coupling agents. *Journal of Applied Physics*. 94(7): 4551-4557.
77. Kurnianto, R., Murakami, Y., Nagao, M., and Hozumi, N. (2008). Investigation of filler effect on treeing phenomenon in epoxy resin under ac voltage. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 15(4): 1112-1119.
78. Tendero, C., Tixier, C., Tristant, P., Desmaison, J., and Leprince, P. (2006). Atmospheric pressure plasmas: A review. *Spectrochimica Acta Part B: Atomic Spectroscopy*. 61(1): 2-30.
79. Mishra, L.N., Shibata, K., Ito, H., Yugami, N., and Nishida, Y. (2007). Characterization of pulsed discharge plasma at atmospheric pressure. *Surface and Coatings Technology*. 201(13): 6101-6104.
80. Friedrich, J., Rohrer, P., Saur, W., Gross, T., Lippitz, A., and Unger, W. (1993). Improvement in polymer adhesivity by low and normal pressure plasma surface modification. *Surface and Coatings Technology*. 59(1): 371-378.
81. Rossi, F., Kylián, O., and Hasiwa, M. (2006). Decontamination of surfaces by low pressure plasma discharges. *Plasma Processes and Polymers*. 3(6-7): 431-442.
82. Schutze, A., Jeong, J.Y., Babayan, S.E., Park, J., Selwyn, G.S., and Hicks, R.F. (1998). The atmospheric-pressure plasma jet: a review and comparison to other plasma sources. *Plasma Science, IEEE Transactions on*. 26(6): 1685-1694.
83. Shenton, M. and Stevens, G. (2001). Surface modification of polymer surfaces: atmospheric plasma versus vacuum plasma treatments. *Journal of Physics D: Applied Physics*. 34(18): 2761.
84. Napartovich, A. (2001). Overview of atmospheric pressure discharges producing nonthermal plasma. *Plasmas and Polymers*. 6(1-2): 1-14.
85. Foest, R., Kindel, E., Ohl, A., Stieber, M., and Weltmann, K.-D. (2005). Non-thermal atmospheric pressure discharges for surface modification. *Plasma physics and controlled fusion*. 47(12B): B525-B536.
86. Kogelschatz, U. (2004). Atmospheric-pressure plasma technology. *Plasma Physics and Controlled Fusion*. 46(12B): B63.
87. Fridman, A., Chirokov, A., and Gutsol, A. (2005). Non-thermal atmospheric pressure discharges. *Journal of Physics D: Applied Physics*. 38(2): R1.
88. Chirokov, A., Gutsol, A., and Fridman, A. (2005). Atmospheric pressure plasma of dielectric barrier discharges. *Pure and applied chemistry*. 77(2): 487-495.

89. Kogelschatz, U. (2003). Dielectric-barrier discharges: their history, discharge physics, and industrial applications. *Plasma chemistry and plasma processing*. 23(1): 1-46.
90. Tyata, R., Subedi, D., and Wong, C. (2010). Comparison of dielectric barrier discharge in air, nitrogen and argon at atmospheric pressure. *Kathmandu University Journal of Science, Engineering and Technology*. 6(2): 6-12.
91. Kim, Y.H., Cha, M.S., Shin, W.H., and Song, Y.H. (2003). Characteristics of dielectric barrier Glow Discharges with a low-frequency generator in nitrogen. *Journal of the Korean Physical Society*.
92. Kogelschatz, U. (2000).Fundamentals and applications of dielectric barrier discharges. *HAKONE VII Int. Symp. On High Pressure Low Temperature Plasma Chemistry, Greifswald*.
93. Kanazawa, S., Kogoma, M., Moriwaki, T., and Okazaki, S. (1988). Stable glow plasma at atmospheric pressure. *Journal of Physics D: Applied Physics*. 21(5): 838.
94. Borcia, G., Anderson, C., and Brown, N. (2005). Using a nitrogen dielectric barrier discharge for surface treatment. *Plasma Sources Science and Technology*. 14(2): 259.
95. Pearlman, N.W., Stiegmann, G.V., Vance, V., Norton, L.W., Bell, R.C., Staerkel, R., Van Way, C.W., and Bartle, E.J. (1991). A prospective study of incisional time, blood loss, pain, and healing with carbon dioxide laser, scalpel, and electrosurgery. *Archives of surgery*. 126(8): 1018-1020.
96. Chinpairoj, S., Feldman, M.D., Saunders, J.C., and Thaler, E.R. (2001). A comparison of monopolar electrosurgery to a new multipolar electrosurgical system in a rat model. *The Laryngoscope*. 111(2): 213-217.
97. Fridman, G., Friedman, G., Gutsol, A., Shekhter, A.B., Vasilets, V.N., and Fridman, A. (2008). Applied plasma medicine. *Plasma Processes and Polymers*. 5(6): 503-533.
98. Heinlin, J., Isbary, G., Stolz, W., Morfill, G., Landthaler, M., Shimizu, T., Steffes, B., Nosenko, T., Zimmermann, J., and Karrer, S. (2011). Plasma applications in medicine with a special focus on dermatology. *Journal of the European Academy of Dermatology and Venereology*. 25(1): 1-11.
99. Heinlin, J., Morfill, G., Landthaler, M., Stolz, W., Isbary, G., Zimmermann, J.L., Shimizu, T., and Karrer, S. (2010). Plasma medicine: possible applications in dermatology. *JDDG: Journal der Deutschen Dermatologischen Gesellschaft*. 8(12): 968-976.
100. Kogelschatz, U. (2002). Industrial innovation based on fundamental physics. *Plasma Sources Science and Technology*. 11(3A): A1.
101. Am Water Works Res, F., Langlais, B., Reckhow, D.A., and Brink, D.R. (1991). Ozone in water treatment: application and engineering. CRC press.
102. Kim, J.-G., Yousef, A.E., and Khadre, M.A. (2003). Ozone and its current and future application in the food industry, in Advances in Food and Nutrition Research. Academic Press. 167-218.
103. Sharma, R., Biris, A.S., and Mazumder, M.K. (2011).Plasma surface modification of TiO 2 nanoparticles for Dye-Sensitized Solar cell (DSSC) application. *Industry Applications Society Annual Meeting (IAS), 2011 IEEE*. IEEE.

104. Ritts, A.C., Yu, Q., Li, H., Lombardo, S.J., Han, X., Xia, Z., and Lian, J. (2011). Plasma treated multi-walled carbon nanotubes (MWCNTs) for epoxy nanocomposites. *Polymers*. 3(4): 2142-2155.
105. Yan, W., Han, Z.J., Phung, B.T., and Ostrikov, K. (2012). Silica Nanoparticles Treated by Cold Atmospheric-Pressure Plasmas Improve the Dielectric Performance of Organic–Inorganic Nanocomposites. *ACS applied materials & interfaces*. 4(5): 2637-2642.
106. Noto, F., Yoshimura, N., and Ohta, T. (1977). Tree initiation in polyethylene by application of dc and impulse voltage. *Electrical Insulation, IEEE Transactions on*, (1): 26-30.
107. Fukuzawa, M. and Iwamoto, M. (1998). Study of the relationship between space charge field and electrical treeing in low density polyethylene under a needle-plane electrode system. *Japanese journal of applied physics*. 37(7R): 4016.
108. Niedernhuber, J. and Kindersberger, J. (2013).Electrical treeing in insulating resins with silica nanofillers. *Solid Dielectrics (ICSD), 2013 IEEE International Conference on*. IEEE.
109. Huuva, R., Englund, V., Gubanski, S.M., and Hjertberg, T. (2009). A versatile method to study electrical treeing in polymeric materials. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 16(1): 171-178.
110. Hozumi, N., Okamoto, T., and Fukagawa, H. (1988).TEM observation of electrical tree paths and micro-structures in polyethylene. *Electrical Insulation, 1988., Conference Record of the 1988 IEEE International Symposium on*. IEEE.
111. Kurnianto, R., Murakami, Y., Hozumi, N., and Nagao, M. (2005).Electrical tree propagation in epoxy resin under different characteristics. *Electrical Insulating Materials, 2005.(ISEIM 2005). Proceedings of 2005 International Symposium on*. IEEE.
112. Ahmad, M., Ahmad, H., Bashir, N., Arief, Y., Kurnianto, R., Yusof, F., Abdul-Malek, Z., and Darus, A. (2011). A New Statistical Ranking of Tree Inception Voltage Distribution of Silicone Rubber and Epoxy Resin Under AC Voltage Excitation. *International Review of Electrical Engineering*. 6(4).
113. Yan, W., Phung, B., Han, Z., and Ostrikov, K. (2012).Plasma functionalization of SiO 2 nanoparticles for the synthesis of polymer nano-dielectrics. *Properties and Applications of Dielectric Materials (ICPADM), 2012 IEEE 10th International Conference on the*. IEEE.
114. Witucki, G.L. (1993). A silane primer: chemistry and applications of alkoxy silanes. *Journal of coatings technology*. 65: 57-57.
115. Lee, C.H., Park, S.H., Chung, W., Kim, J.Y., and Kim, S.H. (2011). Preparation and characterization of surface modified silica nanoparticles with organo-silane compounds. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*. 384(1): 318-322.
116. Buntat, Z., Harry, J., and Smith, I. (2007). Generation of a homogenous glow discharge in air at atmospheric pressure. *Elektrika*. 9(2): 60-65.
117. Fang, Z., Qiu, Y., Zhang, C., and Kuffel, E. (2007). Factors influencing the existence of the homogeneous dielectric barrier discharge in air at atmospheric pressure. *Journal of Physics D: Applied Physics*. 40(5): 1401.

118. Chan, C.-M., Ko, T.-M., and Hiraoka, H. (1996). Polymer surface modification by plasmas and photons. *Surface science reports*. 24(1): 1-54.

119. Yan, W., Phung, B., Han, Z.J., and Ostrikov, K. (2014). Plasma polymer-coated on nanoparticles to improve dielectric and electrical insulation properties of nanocomposites. *Dielectrics and Electrical Insulation, IEEE Transactions on*. 21(2): 548-555.

120. Ahmad, M., Ahmad, H., Bashir, N., Dolmat, M., Arief, Y., Malek, Z., and Jamil, A. (2012).Effects of oil palm empty fruit bunch filler on electrical tree propagation in Epoxy resin. *High Voltage Engineering and Application (ICHVE), 2012 International Conference on*. IEEE.