IOP Conf. Series: Materials Science and Engineering **226** (2017) 012167 doi:10.1088/1757-899X/226/1/012167

Morphology studies of hydrophobic silica on filter surface prepared via spray technique

Nazrul Shahfiq Zulkifli[1], Muhamad Zaini Yunos[1,2], Azlinnorazia Ahmad[1,2], Zawati Harun[1,2], Siti Hajar Mohd Akhair[1,2], Raja Adibah Raja Ahmad[1,2], Faiz Hafeez Azhar[1,2], Abdul Qaiyyum Abd Rashid[1,2], Al Emran Ismail[1]

[1]Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia

[2]Advanced Manufacturing and Materials Centre, Universiti Tun Hussein Onn Malaysia

Corresponding author: mzaini@uthm.edu.my, azlinnorazia@yahoo.com

Abstract. This study investigated the effect of the hydrophobic surface treatment effect of air filter performance by using silica aerogel powder as an additive by using spray coating techniques. The membrane characterization tests were carried out on a filter prepared from different additive concentration. Studies on the cross-section and the distribution of particles on the membrane were carried out using a scanning electron microscope (SEM), and the surface morphology was investigated by x-ray spectroscopy (EDS). The results are shown by SEM and EDS that the microstructure filter, especially in the upper layer and sub-layer has been changed. The results also show an increase of hydrophobicity due to the increased quantity of silica aerogel powder.

1. Introduction

In recent years, air filter membrane fabricated from fibrous materials has gain many attention due to the membrane capability to filtered solid particulate such as pollen, dust, old and bacteria contain in the air. Generally, chemically air filtered consists of catalyst or an absorbent. According to Irwin *et al.* in their study of nonwoven filter media, the applications of air filter was usually applied in HVAC systems, high-efficiency air filtration (HEA, HEPA, and ULPA), industrial air filtration, respirators and gas masks, turbine air filtration, and household air filtration such as vacuum, air purifiers, and cleaners [1].

Over the last decades, the air filter industry has change drastically with recent technology. The manufacturers have invented new product that able to improve the quality of air indoor and reduced the installation and operating equipment cost in commercial and institutional facilities. The industry also has successfully adopting the guideline and requirement that able to promote self-health by the quality of air being inhaled [2]–[4]. In addition, for maintenance, it will be focus on indoor air quality (IAQ) and its impact on their facilities and occupants. The manufacturer is providing them with more efficient high voltage alternative current (HVAC) systems and components, including air filters.

Air pollution is a control mechanism that supplies clean air realizes bright space through HEPA filter placed at the air supply terminal, which is the largest difference for cleaning air conditioner between the concept and general air conditioner [5]. The biggest problem in air filter media is leakage. However, sealing the leakage might not solve the problem effectively [6]–[10]. If this issue cannot address early, it will increase particle concentration or bacteria concentration on air filter media.

Theoretical interest in hydrophobic interactions and wetting has also been stimulated in several ways [11]. Chemical structure has a strong influence on the physical and mechanical properties of films [12]–[15]. Work on designing superhydrophobic surfaces has led to new interest in the theories of heterogeneous wetting due to Wenzel and Baxter [16]. Various surface reflectivity measurements have been interpreted as evidence for a layer (albeit thinner than the diameter of a water molecule) of depleted water density next to extended hydrophobic surfaces, and different techniques have been adopted to investigate the boundary conditions of flow next to both smooth and structured hydrophobic surfaces and the relationship to rewetting. M.khayet et al., (2005) had discussed the properties of hydrophobic/hydrophilic porous membrane and was proposed for application in this membrane distillation [17].

2. Experimental

2.1. Materials and procedure

The preparation process of hydrophobic silica aerogel with acetone and tetraethyl orthosilicate (TEOS) as the raw material. The process can be divided into two major step, including preparation of filter, synthesis of aerogel silica. For this experiment, we use a particular HEPA filter from company salutary avenue to make a hydrophobic treatment. The purpose of using this filter is because of this filter is very suitable for an environment with moisture contain and humidity. Silica aerogel will be obtained from Merogel Company [18].

2.2. Spray coating

Basically, spray coating method is a process in which solvent solutions, molten powder and dispersions are atomized by the action of air, the pressure and inert gas of the solution itself and deposited on the substrate. The hydrophobic coating was prepared by using spray coating technique deposit on the company’s filter. The spray was set-up for static 90 degrees to get uniform spray coating like shown in Figure 1.

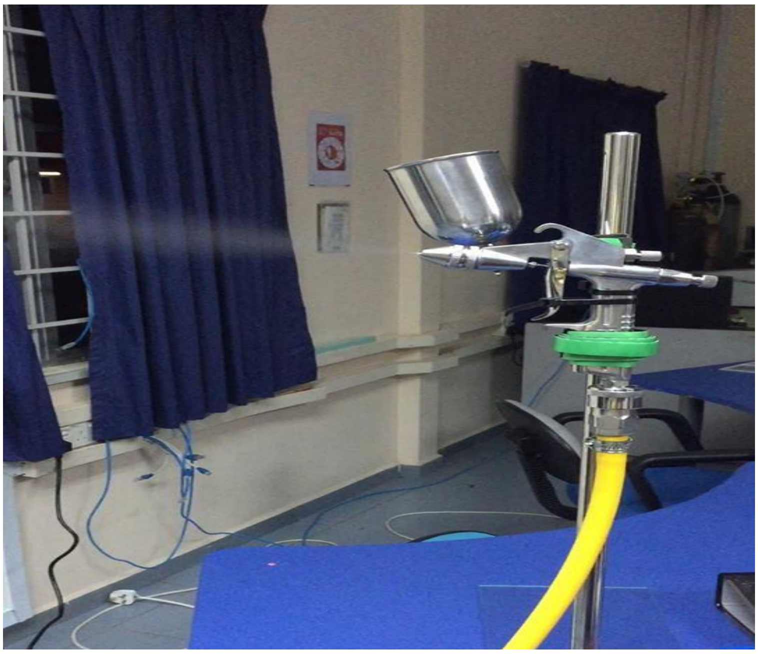

Figure 1: Spray Coating Technique

2.2.1. Parameter
The coating process has many types, but in this study hydrophobic coating was prepared via spraying method from 0 to 4 MPa. There are several parameters considered which is substrate aerogel silica and Tetraethyl orthosilicate (TEOS)/acetone, the speed of dipping and interval time between dipping.

2.3. Membrane Evaluation
The preparation of hydrophobic coating was characterized for surface morphology was studied by using SEM (JOEL JSM6380LA).

3. Result and Discussion

3.1. Scanning Electron Microscope (SEM)
Figure 2 (a-d) shows SEM micrographs of prepared filter with different weight percentage of aerogel silica additive. The addition of aerogel silica particles into the solution clearly shows a significant effect on filter morphology formation [19]–[23]. Figure 2 (a-d) shows the aerogel silica nanoparticle and their particle size at x500 magnification. From the observation, the aerogel silica was agglomerated in irregular shape particle. The sizes of aerogel silica particle from sample 1 until sample 4 are in range between 5.34µm and 7.86µm. The result was in line with Cui *et. al.* (2010), where the increased of silica in parameter formulation has increased the number of the particles at the filter surfaces. It is clearly observed that micro-void formation at the surface of sample filter increased with the increase of aerogel silica particles in coated filter compared to uncoated filter by sample 1.

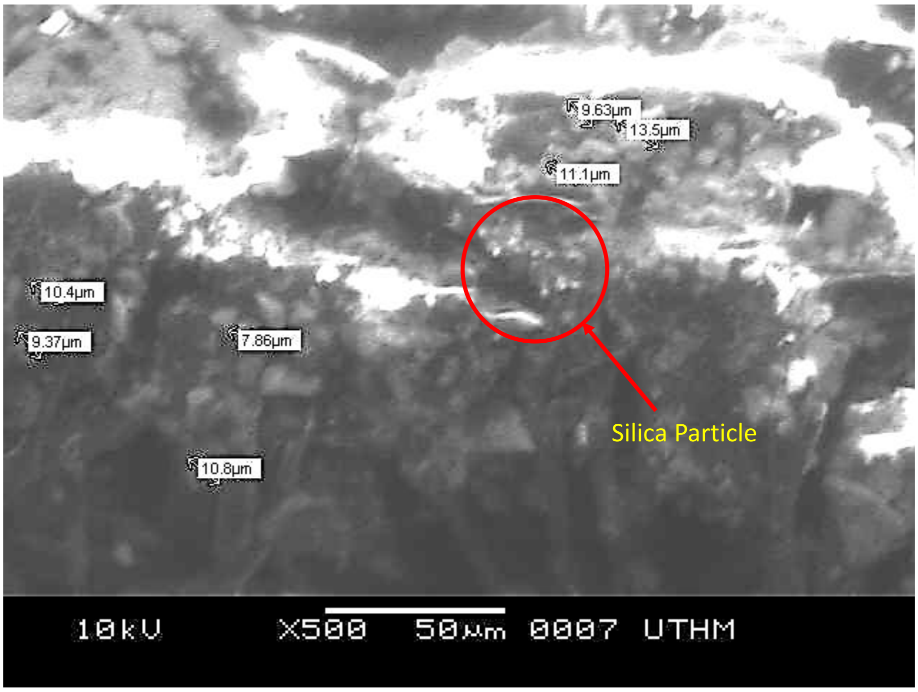

Figure 2 (a): Sample 1 (0 wt. % of silica aerogel)

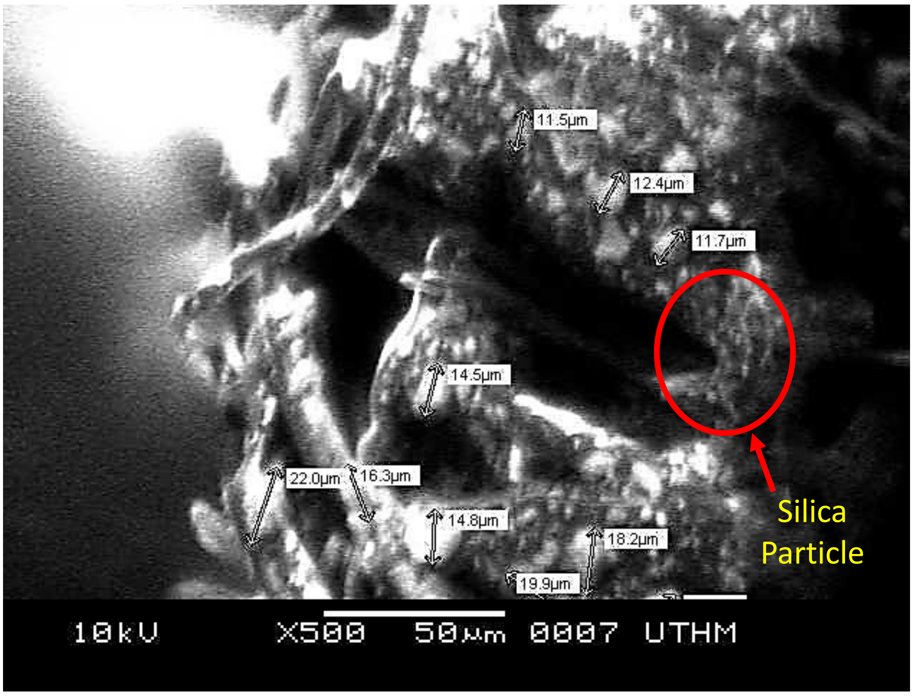

Figure 2 (b): Sample 1 (3 wt. % of silica aerogel)

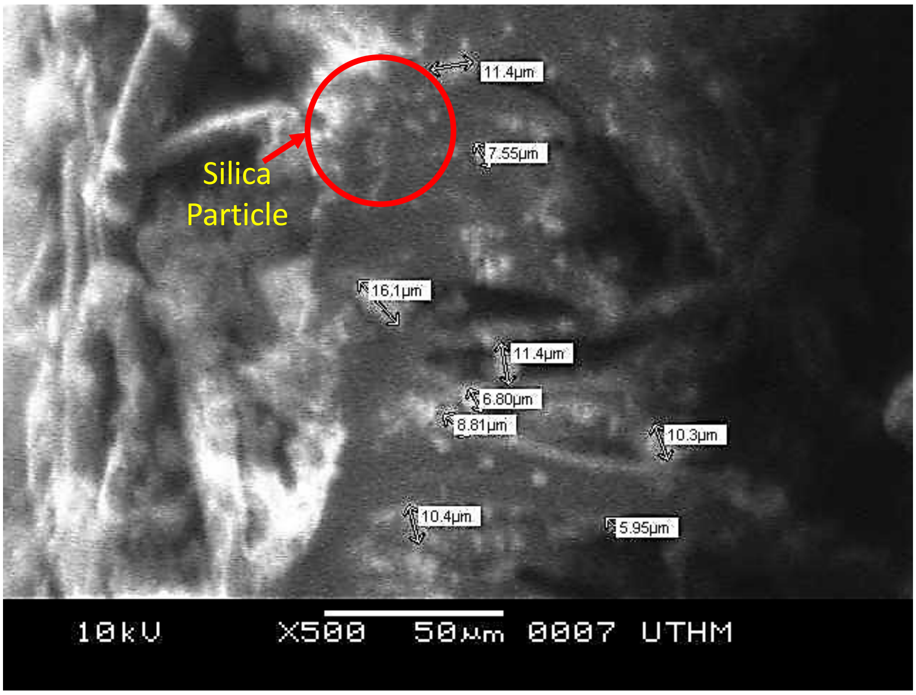

Figure 2 (c): Sample 2 (4 wt. % of silica aerogel)

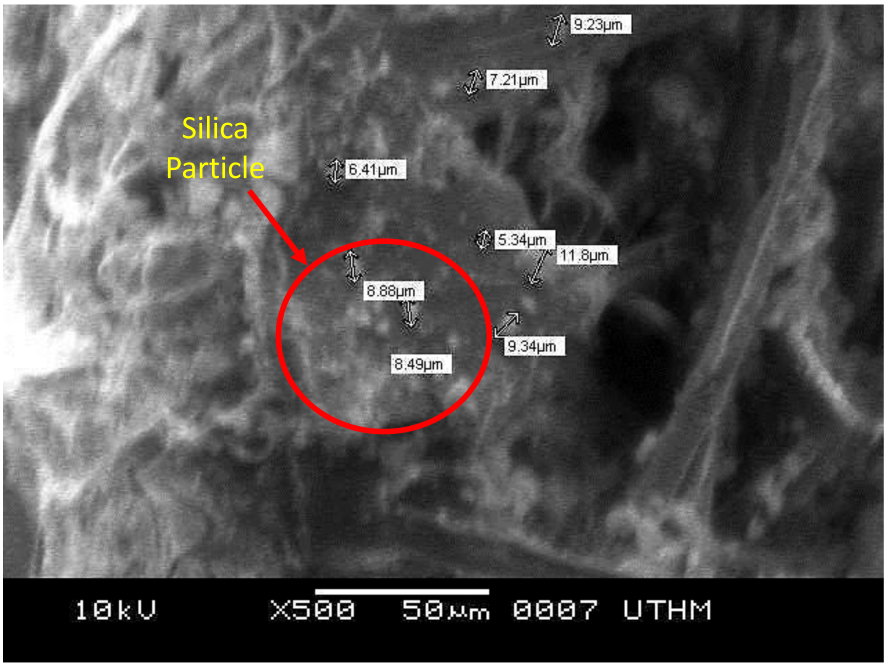

Figure 2 (d): Sample 4 (5 wt. % of silica aerogel)

3.2. Energy Dispersive X-Ray Analyzer (EDX)

The concentration of silica on filter surface was measured using X-ray energy dispersion spectroscopic (EDS). The results indicate that silica concentration on filter surface decreases as percentage silica aerogel increases. 5 wt% of silica aerogel shows the lowest concentration of silica in filter surface with the value of 9.03%. This phenomenon happened due to the tendency of aggregation or agglomeration of silica aerogel particles during the spraying process. As the concentration of aerogel silica increased, the tendency of silica to attract or agglomerate is high. Another reason related to this phenomenon was due to high solvent viscosity [24]–[29]. The increase in viscosity could affects the spray process although the pressure and spray time was constant for all samples [30]–[32]. When highly viscous solution being spray, the transportation of liquid from the tank to nozzle was slow, and it was affected the amount of silica concentration on the filter surface.

4. Conclusion

This aim of this study is to identify the effects of silica aerogel added to the filter. Four filter composition were produced including three filter with additive concentration. The properties of the filter were improved by the present of silica aerogel powder on the filter. The surface morphology for all samples have been observed using SEM and the presence of silica on the surface of the filter through experimental spectroscopic X-ray energy dispersion (EDX). EDX tests have shown the distribution of silica was decrease with the increase of aerogel silica due viscosity and agglomeration of the additive. However, the addition of silica aerogel powder additives has changed and improved the performance of the filter.

Acknowledgement

The authors would like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for funding this research under IGSP and STG grant Vot no. U244 and U125 and also Ministry of Higher Education (MOHE), Malaysia.

References

[1] I. M. Hutten, *Chapter 8 - Air Filter Applications*. 2016.
[2] A. R. Ainuddin and N. A. Aziz, "Thermal post-treatment of TiO2 films via sol-gel for

enhanced corrosion resistance," *ARPN J. Eng. Appl. Sci.*, vol. 11, no. 14, pp. 8698–8703, 2016.
[3] N. S. Zulkiflee *et al.*, "Characterization of TiO2 , ZnO , and TiO2 / ZnO Thin Films Prepared by Sol-Gel Method," vol. 11, no. 12, pp. 7633–7637, 2016.
[4] R. Hussin, K.-L. Choy, and X. Hou, "Enhancement of crystallinity and optical properties of bilayer TiO2/ZnO thin films prepared by atomic layer deposition.," *J. Nanosci. Nanotechnol.*, vol. 11, no. 9, pp. 8143–7, 2011.
[5] S. A. Ibrahim, N. S. Ridhuan, S. Sreekantan, A. M. Hashim, and V. K. Arora, "Degradation of Methyl Orange using TiO2 as Photocatalyst," *AIP Conf. Proc.*, vol. 127, pp. 123–127, 2011.
[6] M. Zaini, Z. Harun, H. Basri, M. Fikri, M. Riduan, and S. Hassan, "Effect of Zinc Oxide on Performance of Ultrafiltration Membrane for Humic Acid Separation," *J. Teknol. (Sciences Eng.*, vol. 65, no. 4, pp. 117–120, 2013.
[7] M. Z. Yunos, Z. Harun, H. Basri, H. Taib, and A. F. Ismail, "Fouling Characterization of Polysulfone-Grafted-Methyl Methacrylate Membrane," *Appl. Mech. Mater.*, vol. 465–466, pp. 819–823, 2013.
[8] R. Hussin, K. L. Choy, and X. Hou, "Deposited Tio 2 Thin Films By Atomic Layer Deposition (Ald) for Optical Properties," vol. X, no. X, pp. 7529–7533, 2015.
[9] R. Hussin, K. L. Choy, and X. H. Hou, "Fabrication of Multilayer ZnO/TiO2/ZnO Thin Films with Enhancement of Optical Properties by Atomic Layer Deposition (ALD)," *4th Mech. Manuf. Eng. Pts 1 2*, vol. 465–466, pp. 916–921, 2014.
[10] R. Hussin, X. H. Hou, and K. L. Choy, "Growth of ZnO Thin Films on Silicon Substrates by Atomic Layer Deposition," *Defect Diffus. Forum*, vol. 329, no. August, pp. 159–164, 2012.
[11] P. J. Rossky, "Exploring nanoscale hydrophobic hydration.," *Faraday Discuss.*, vol. 146, pp. 13-18-101, 395–401, 2010.
[12] A. R. Ainuddin, N. Hakiri, H. Muto, and A. Matsuda, "Micropatterning of non-crystalline methylsilsesquioxane-titania hybrid films based on their structural changes with UV irradiation," *Phys. Status Solidi*, vol. 209, no. 10, pp. 2034–2040, 2012.
[13] A. Rahmahwati, N. Hakiri, and H. Muto, "Mechanical properties comparison of phenylsilsesquioxane – methylsilsesquioxane hybrid films by indentation," *J. Ceram. Soc. Japan*, pp. 6–9, 2011.
[14] A. R. Ainuddin, T. Ishigaki, N. Hakiri, and H. Muto, "Influence of UV irradiation on mechanical properties and structures of sol – gel-derived vinylsilsesquioxane films," *J. Ceram. Soc. Japan*, vol. 120, no. 1406, pp. 10–13, 2012.
[15] A. R. Ainuddin and W. N. A. M. Idris, "Growth of ZnO nanostructures with different alkaline precursor solution," *ARPN J. Eng. Appl. Sci.*, vol. 11, no. 12, pp. 7612–7616, 2016.
[16] B. D. Cassie, A. B. D. Cassie, and S. Baxter, "Of porous surfaces," *Trans. Faraday Soc.*, vol. 40, no. 5, pp. 546–551, 1944.
[17] M. Khayet, J. I. Mengual, and T. Matsuura, "Porous hydrophobic/hydrophilic composite membranes: Application in desalination using direct contact membrane distillation," *J. Memb. Sci.*, vol. 252, no. 1–2, pp. 101–113, 2005.
[18] The University of Oslo, "Sol-Gel methods," *KJM5100_Sol_Gel_Method*, 2006.
[19] M. R. Jamalludin, Z. Harun, H. Basri, M. Z. Yunos, and M. F. Shohur, *Performance studies of polysulfone-based membrane: Effect of silica morphology*, vol. 372. 2013.
[20] M. Z. Yunos, Z. Harun, H. Basri, and A. F. Ismail, "Studies on fouling by natural organic matter (NOM) on polysulfone membranes: Effect of polyethylene glycol (PEG)," *Desalination*, vol. 333, no. 1, pp. 36–44, 2014.
[21] S. A. Ibrahim and S. Sreekantan, "Effect of annealing atmosphere towards Ti02 nanoparticles on their Photocatalytic Performance in Aquoues Phase," pp. 3–4, 2010.
[22] S. A. Ibrahim and M. N. Ahmid, "Influence of Calcination Temperature towards Fe-TiO2 for Visible-Driven Photocatalyst," *Mater. Sci. Forum*, vol. 888, pp. 435–440, 2017.
[23] S. A. Ibrahim and S. Sreekantan, "Effect of pH on TiO2 Nanoparticles via Sol-Gel Method," *Adv. Mater. Res.*, vol. 173, pp. 184–189, 2010.

[24] M. Z. Yunos *et al.*, "Influence of inorganic additives on the performance of polysulfone ultrafiltration membrane," *J. Teknol. (Sciences Eng.*, vol. 65, no. 4, 2013.
[25] S. A. Ibrahim and S. Sreekantan, "Fe-TiO Nanoparticles by Hydrothermal Treatment with Photocatalytic Activity Enhancement," *Adv. Mater. Res.*, vol. 1024, pp. 39–43, 2014.
[26] M. N. M. Hatta, F. Xu, Y. De Xia, and Y. Q. Zhu, "Growth of Bamboo-Shaped Carbon Nanostructures on Carbon Fibre by Chemical Vapor Deposition," *Appl. Mech. Mater.*, vol. 465–466, pp. 927–931, 2013.
[27] M. N. M. Hatta and F. Xu, "Deposition of iron catalyst on carbon fibre," *ARPN J. Eng. Appl. Sci.*, vol. 11, no. 24, pp. 14065–14069, 2016.
[28] Z. Kamdi, C. Y. Phang, and H. Ahmad, "Corrosion behavior of WC-Co cermet coatings," *Int. Conf. Funct. Mater. Metall. ICoFM 2014*, vol. 819, pp. 87–90, 2015.
[29] Z. Kamdi and K. T. Voisey, "Corrosion mechanism of tungsten carbide-based coatings in different aqueous media," *Key Eng. Mater.*, vol. 694, pp. 167–171, 2016.
[30] Z. Kamdi, P. H. Shipway, and K. T. Voisey, "Micro-Scale Abrasion of WC-Based Coatings with Different Abrasive Type," *Appl. Mech. Mater.*, vol. 465–466, pp. 65–69, 2013.
[31] Z. Kamdi, P. H. Shipway, and K. T. Voisey, "A Modified Micro-Scale Abrasion for Large Hard Phase Cermet," *Appl. Mech. Mater.*, vol. 393, pp. 888–892, 2013.
[32] Z. Kamdi, P. H. Shipway, K. T. Voisey, and A. J. Sturgeon, "Abrasive wear behaviour of conventional and large-particle tungsten carbide-based cermet coatings as a function of abrasive size and type," *Wear*, vol. 271, no. 9–10, pp. 1264–1272, 2011.