Journal of Information Systems Engineering and Management
2025, 10(37s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

To Investigate the Hydrophobic Effect on Glass Slide using Aluminum Oxide as a Nonmaterial Coating with Ethanol, Polyvinyl Alcohol and Acetone as a Solvent using Dip Coating and Spray Coating Techniques

Gaurav Verma[1], Mohan Gupta[1*], Shweta Singh[1], Chitranjan Dwivedi[1], Sharad Chandra Srivastava[1], Pankaj Kumar Singh[1], Abhishek Kumar Singh[1]
[1] United College of Engineering and Research Naini, Prayagraj (U.P.)-211010, India
*Corresponding Authur (email: mohanguptaucer@gmail.com)

ARTICLE INFO

Received: 24 Dec 2024
Revised: 12 Feb 2025
Accepted: 26 Feb 2025

ABSTRACT

This study investigates the Al2O3 coatings' hydrophobic properties on glass slides utilizing a dip coating process and solvents containing acetone, polyvinyl alcohol (PVA), and ethanol in various compositions. The experimental design uses dip coating techniques to systematically apply Al2O3 coatings on glass slides. Coating on glass slide is done by mixing Al2O3 with a solution of firstly ethanol in different composition 5%, 10% and 15%. Secondly Al2O3 is mixed with ethanol along with polyvinyl alcohol in different composition 5%, 10% and 15%. Thirdly Al2O3 is mixed with ethanol, polyvinyl alcohol and acetone in different composition 5%, 10% and 15%. The hydrophobic property of based material Al2O3 enhanced and these enhancements is compared with different characterization of contact angle test, FTIR test and XRD analysis. Coating solution is prepared after weighing by analytical balance machine and mixing is done with help of magnetic stirrer and batch sonicator. Finally, sample is dried for 24 hrs and then heat treatment is done in Hot Air Oven between 250 -300-degree centigrade temperatures.
Keywords: Glass slides, hydrophobic, dip coating technique, spray coating technique, Ethanol, Polyvinyl alcohol and Acetone.

INTRODUCTION

Hydro phobicity also represents ability of surfaces to repel water, is an essential topic in a variety of fields, including biology and manufacturing. Due to its widespread use in this context, research efforts are concentrated on enhancing the hydrophobic characteristics of glass. [1]. Aluminum oxide (Al_2O_3) possesses distinct features for instance, chemical resistance and hardness, making it an interesting candidate for use as a hydrophobic coating. The researchers compare and contrast two popular coating techniques, dip and spray coating, using glass slides as a case study. [2]. It is essential to comprehend the effectiveness of these strategies, which have clear benefits, in order to develop targeted apps. Additionally, the study looks at solvents that are essential to the coating process, like ethanol, polyvinyl alcohol (PVA), and acetone [3]. The unique features of each solvent influence how the aluminum oxide layer interacts with the glass substrate. The purpose of this research is to improve glass surfaces for a variety of practical applications by providing insight into the complicated dynamics of hydrophobicity augmentation through a complete comparative investigation.[4]. Hydrophobicity, or a material's natural dislike to water, has become an important attribute in a variety of industries, including healthcare and manufacturing. The glass is used extensively in many different industries, and efforts to make it more hydrophobic are becoming more and more popular. In response, aluminum oxide has emerged as a potential coating material due to its hydrophobicity and ability to efficiently modify surface properties. This study's main objective is to look at the hydrophobic properties of aluminium oxide coatings on glass slides. This study compares the two most prevalent coating methods: dip and spray coating. [5]. Additionally, the study looks into how several solvents, including acetone, ethanol, and polyvinyl alcohol, impact the coated glass surfaces' hydrophobicity. [6]. The diversity of hydrophobic glass surfaces demonstrates their value. Making glass more hydrophobic has the ability to reduce stickiness and eliminate water stains in commercial settings, as well as make buildings easier to clean oneself. This study emphasizes on the complex interplay between coating processes, solvent selection, and the amount of aluminium oxide applied to glass

Journal of Information Systems Engineering and Management
2025, 10(37s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

surfaces in order to obtain optimal hydrophobic properties. [7]. It is essential to compare dip and spray techniques in-depth in order to fill in the information gaps. Although each technique has benefits, understanding how each one functions with different solvents is essential to making an informed choice in practical situations. [8]. Along with the materials and techniques employed in the investigation, it also incorporates the features of the time and place. In order to produce hydrophobic glass surfaces, the next chapters will provide a thorough assessment of the comparative analysis, illuminating the complex interactions between solvent choices, coating procedures, and aluminium oxide coatings. [9].

To determine how much more effective dip coating is than spray coating in making glass surfaces hydrophobic. The goal is to investigate the effect of various solvents on the hydrophobic characteristics of aluminium oxide-coated glass slides, with a focus on acetone, polyvinyl alcohol (PVA), and ethanol. [10]. Determine the best coating technique and solvent for enhancing glass surfaces' hydrophobic characteristics. The goal is to shed light on the complex interplay between coating techniques, solvent selection, and aluminium oxide coatings so that useful information may be shared across multiple sectors. [11]. Together, these goals make sure that, regardless of the method or solvent used, we learn as much as possible about how aluminium oxide coatings affect glass slides' hydrophobicity. This study may provide valuable insights for researchers, engineers, and practitioners that aim to customize hydrophobic properties on glass surfaces for specific purposes.

METHODS

Before beginning any glass slide preparation, the standard glass slide used in the experiment lab is selected, verified, and cleared to provide a uniform surface. Aluminium oxide was dissolved in a range of solvents, such as acetone, polyvinyl alcohol (PVA), and ethanol, to form the experimental solution. This solution was then employed as a coating material on the surface of a glass slide. [12]. Two distinct coating procedures that have been used in practice are dip coating and spray coating. In the dip coating process, the glass slides were dipped into the aluminium oxide solution and progressively taken out to achieve a nominal coating thickness. [13]. Furthermore, a glass slide is coated utilising a spray coating method with the help of a spray gun and a compressor, which provide a thin layer of an aluminium oxide solution sprayed at the proper distance. The experimental design systematically installs Al_2O_3 coatings on glass slides using dip coating techniques. Coating on glass slide is done by mixing Al_2O_3 with a solution of firstly ethanol in different composition 5%, 10% and 15% .Secondly Al_2O_3 is mixed with ethanol along with polyvinyl alcohol in different composition 5%, 10% and 15%. Thirdly Al_2O_3 is mixed with ethanol, polyvinyl alcohol and acetone in different composition 5%, 10% and 15%. Using a contact angle goniometer, the hydrophobicity of coated and untreated glass slides was assessed by determining the contact angle that the water droplets formed on the surfaces. The surface energy estimates were later built using the contact angle data. Based material Al_2O_3's hydrophobic property was improved, and this improvement was compared to other characterizations using FTIR, XRD, and contact angle tests on a glass slide setup.

1. Glass Slide Preparation

To provide a consistent and clean surface for the subsequent coating techniques, glass slide preparation is a crucial first step. The regular glass slides are selected for their uniform size, and any imperfections or abnormalities are closely inspected. Its non-porous characteristic causes it to reject water. Usually, the surface of a glass slide is hydrophobic, which means that water droplets bead up and roll off since it has no attraction for water. Making ensuring the initial surface is homogeneous and free of contaminants that could adhere to the glass slide surface is the goal. Following the observation, the glass slides are meticulously cleaned. [17]. Fig. 1 demonstrates how to prepare glass slides for coating. A appropriate solvent is typically employed as part of the

Journal of Information Systems Engineering and Management
2025, 10(37s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

multi-step process to remove any contaminants or leftover oils. After that, they could utilize ultrasonic cleaning or another method to get rid of any last traces of dirt on the slides to ensure they are immaculate. The contact angle of a particle with good wetting capabilities should be near 0 degrees. This shows that the liquid spreads out rather than beads up, effectively wetting the surface. Good wetting is indicated by a modest contact angle, which indicates a strong attraction between the liquid and the surface. It is important to closely monitor the glass slide preparation procedure prior to applying aluminium oxide coatings. The uniformity of coating adhesion, and the ability to replicate consistently and reliably.

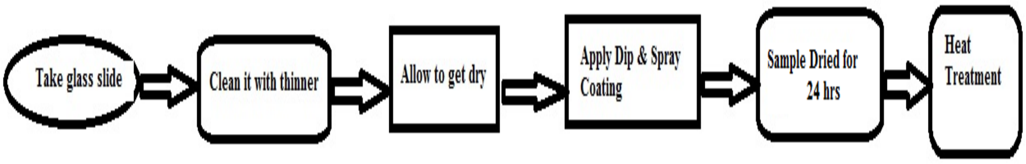

Fig. 1. Glass Slide Preparation for coating.

2. Coating using Aluminium Oxide:

A. Dip Coating Technique:

The glass slides that have been made are submerged in a solution that contains dissolved aluminium oxide in the dip coating process. Precise management of the immersion is necessary to obtain a uniform and consistent coating on the glass's surface [18]. Both the speed of removal and the length of immersion are significant determinants of the coating's thickness and quality. With this method, homogeneous coatings on intricate geometries are easier to achieve than ever before.

B. Spray Coating Technique:

Using the spray coating method, an aluminium oxide solution is applied to the glass slides in the form of a fine mist or spray. A significant benefit of this technology is its potential for large-scale, high-speed applications. To obtain the appropriate coating thickness, the spray system is fine-tuned and the nozzle's distance from the glass surface is adjusted to scatter the coating material evenly. [19]. Spray coating is the best option for surfaces with several dimensions or those that are complex.

C. Solvent Selection:

The solvent used in aluminium oxide coating has an impact on several aspects of the process. These include the viscosity of the solvent, the evaporation rate, and the interaction of the coating material with the glass substrate. Three distinct solvents were examined in this investigation:

i. Ethanol:

Ethanol is a versatile solvent that evaporates slowly, making it a popular choice for many applications. Its choice was influenced by its controlled and consistent coating qualities as well as its effectiveness at dissolving aluminium oxide.

ii. Polyvinyl Alcohol (PVA):

Additional solvents include polyvinyl alcohol, a water-soluble polymer. The exceptional film-forming properties are just one of the unique features that set PVA apart. PVA is utilised to examine the impact on the aluminium oxide coating, adding innovative solvent chemistry to the mixture.

Journal of Information Systems Engineering and Management
2025, 10(37s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

iii. Acetone:

Acetone dissolves aluminium oxide quickly, making it a useful solvent for this purpose. Acetone is utilised to introduce a solvent with a specific volatility profile in order to compare its effect on the coating process.We intend to learn more about the various effects on the aluminium oxide coating by considering the characteristics of each solvent and its interactions with the glass substrate. Fig. 3 displays glass slides that are hydrophobic. This comprehensive approach provides a full understanding of how different solvents alter the hydrophobic properties of coated glass slide.

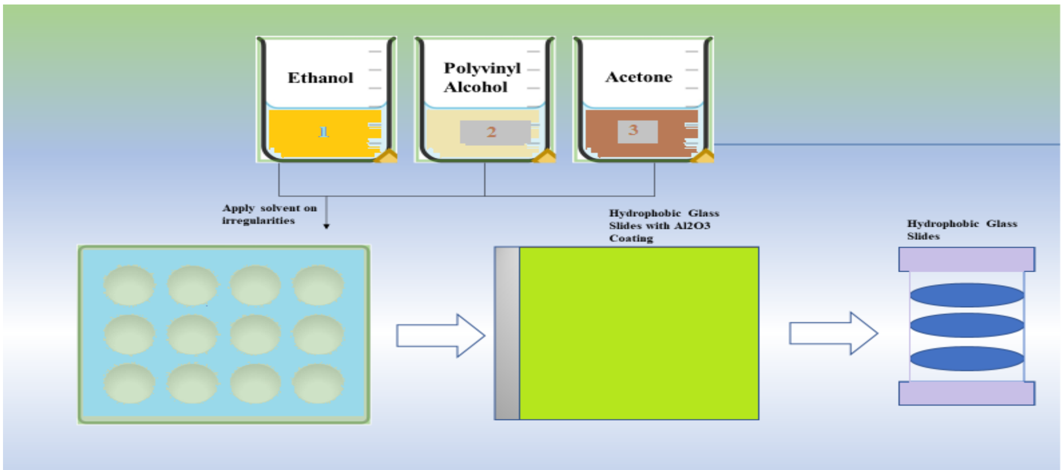

Fig. 2. Hydrophobic glass slides

RESULTS AND DISCUSSION

Calculation of data

For calculation of hydrophobicity three solution of Ethanol, Polyvinyl alcohol and Acetone aa solvent using dip coating and spray coating techniques along with aluminium oxide as coating material

Standard Data:

Density of Ethanol = 0.78929 g/ml

Density of Polyvinyl alcohol (PVA) = 1.269 g/ml

Density of Acetone = 0.7900 g/ml

Case I- Standard solution is prepared by taking 50 ml of Ethanol along with aluminium oxide

ρ= mass / volume

Mass of ethanol = 0.78929 * 50 = 39.46 kg

5% of Ethanol = 1.97 g

10% of Ethanol = 3.946 g

15 % of Ethanol = 5.919 g

Journal of Information Systems Engineering and Management
2025, 10(37s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

Case II- Standard solution is prepared by taking 50 ml of Ethanol and Polyvinyl alcohol along with aluminium oxide.

ρ= mass / volume

Mass of PVA = 1.269 * 50 = 63.45 kg

5% of PVA = 3.1725 g

10% of PVA = 6.345 g

15% of PVA = 9.51 g

Case III - Standard solution is prepared by taking 50 ml of Acetone and Polyvinyl alcohol along with aluminium oxide.

ρ= mass / volume

Mass of Acetone = 0.7990 * 50 = 39.95 g

5% of Acetone = 1.99 g

10% of Acetone = 3.995 g

15 % of Acetone = 5.992 g

Table 1. Represent solvent with different composition with its density.

Solvent	***Density***	***5%***	***10%***	***15%***
Ethanol	*0.78929*	*1.97 g*	*3.946 g*	*5.919 g*
Polyvinyl alcohol (PVA) +Ethanol	*1.269*	*5.1425 g*	*10.291 g*	*15.429 g*
Acetone + (PVA)	*0.7900*	*5.1625 g*	*10.34 g*	*15.502 g*

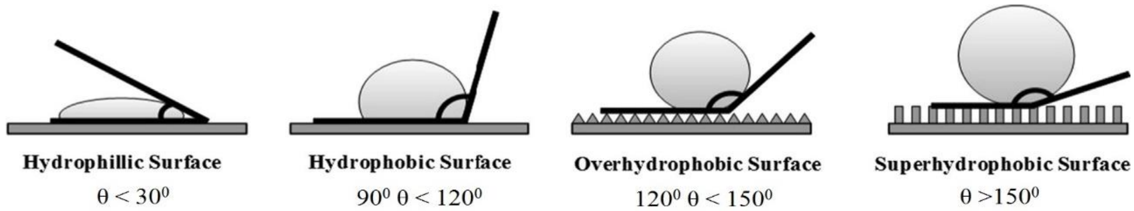

Fig. 3. Contact angles of hydrophobicity.

Table 2. Represent solvent with different composition with its contact angle.

Solvent	***% Composition***	***Contact Angle***
Al_2O_3 + Ethanol	*5*	*97.6*
	10	*98.7*
	15	*99.8*
Al_2O_3 + Ethanol + PVA	*5*	*99.6*
	10	*102.7*
	15	*103.8*
	5	*101.6*

Journal of Information Systems Engineering and Management
2025, 10(37s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Al_2O_3 + Acetone + PVA	*10*	*103.7*
	15	*103.8*

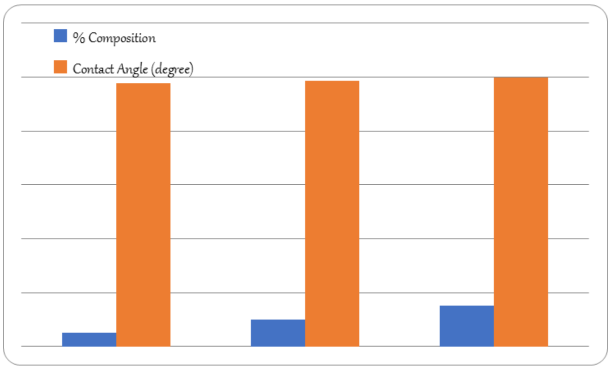

Fig. 4. Represent graphical representation of Al_2O_3 + Ethanol in different composition with contact angle.

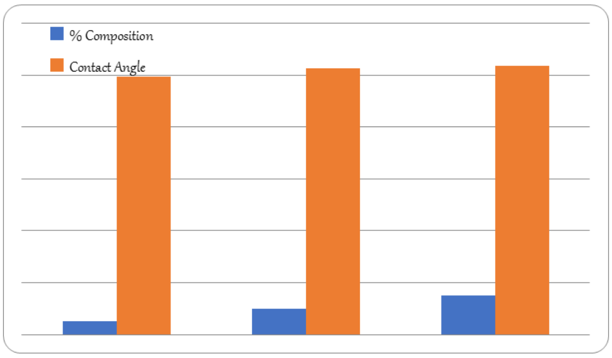

Fig. 5. Represent graphical representation of Al_2O_3 + Ethanol +PVA in different composition with contact angle.

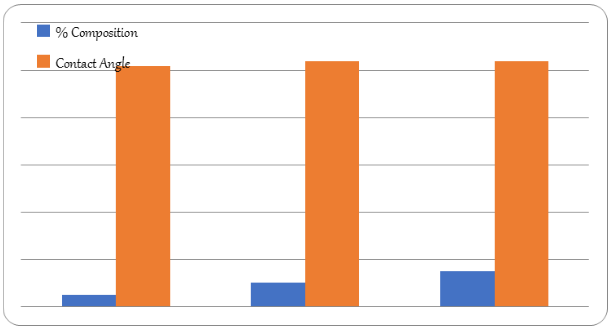

Fig. 6. Represent graphical representation of Al_2O_3 + Acetone +PVA in different composition with contact angle.

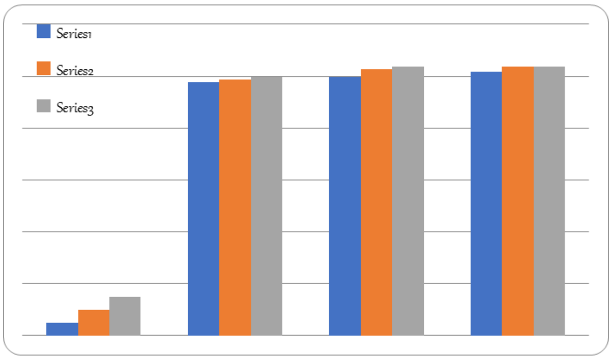

Fig. 7. Represent graphical representation of Al_2O_3 + Ethanol +Acetone +PVA in different composition with contact angle.

Glass slide XRD

On hydrophobic glass slides coated with Al_2O_3, we examined the Dip and spray coating processes employ ethanol, polyvinyl alcohol (PVA), and acetone as solvents. Our initial goal was to use X-ray diffraction (XRD) analysis to comprehend the structural characteristics of the coated glass slides. The experimental procedure started with hydrophobic coating of glass slides and proceeded to dip and spray Al_2O_3 applications. Three solvents were chosen to transfer the Al_2O_3 layer: acetone, polyvinyl alcohol, and ethanol. Using XRD analysis, the coated samples' crystalline structures were further investigated. The XRD signals showed clear differences in the crystalline structures on surface of material. The peak positions along with intensities XRD spectra were seen to be strongly influenced by the coating material.

The final crystal formations varied as a result of the diverse ways that several solvents, including Acetone, ethanol, and PVA all reacted with the Al_2O_3 coating. Lastly, this comparative XRD investigation illustrates the intricate interactions that occur between Al_2O_3 - coated hydrophobic glass slides' structural characteristics and coating methods and solvents. The outcomes highlight how crucial it is to properly choose the coating method and solvent to achieve the required crystallographic characteristics, which helps optimize hydrophobic coatings for a variety of applications.

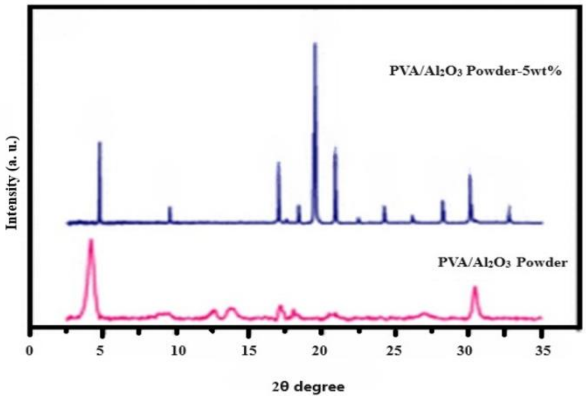

Fig. 8. XRD analysis of Glass Slide with Al_2O_3.

CONCLUSION

- In this paper we have discuss hydrophobic behavior of aluminium oxide by mixing with different solvent such as ethanol, acetone and polyvinyl alcohol in different composition 5%,10% and 15% with its density in solution of aluminum oxide along with respective solvent.
- Result depicts as we increase the % concentration from 5% to 15% in each different solvent solution of aluminum oxide the contact angle shows increase which predicts increase in hydrophobic behavior of aluminum oxide.
- In solution of Al_2O_3 + Ethanol contact angle increases from 97.6 ^{o} to 99.8 ^{o}, Similarly in solution of Al_2O_3 + Ethanol + PVA contact angle increases from 99.6^o to 103.8^o.Likewise in solution of Al_2O_3 + Ethanol +PVA contact angle increases from 101.6^o to 103.8^o.From above result we can predict that contact angle increase shows hydrophobic behavior increase.
- Also, the peak obtained in XRD graph shows increase in hydrophobic behavior of aluminium oxide.
- Different concentration changes show variation in analysis of XRD graph which is a clear indication of hydrophobic behavior increase.

REFRENCES

[1] K. Sobolev, H. Tabatabai, J. Zhao, M.F.-V.I. Oliva, R. Rivero, S. Muzenski, R. Rauf, (2013). Super hydrophobic Engineered Cementations Composites for Highway Applications: Phase I, No. CFIRE 04-09, 2013.

[2] S. Muzenski, I. Flores-Vivian, K. Sobolev, (2019). Ultra-high strength cement-based composites designed with aluminum oxide nano-fibers, Constr. Build. Mater, 220, 177–186.

[3] K. Sobolev, V. Batrakov, (2007) . Effect of a polyethylhydrosiloxane admixture on the durability of concrete with supplementary cementitious materials. J. Mater. Civ. Eng., 19(10), 809–819.

[4] X.M. Bao, J.F. Cui, H.X. Sun, W.D. Liang, Z.Q. Zhu, J. An, B.P. Yang, P.Q. La, A. Li, (2014). Facile preparation of super-hydrophobic surfaces based on metal oxide nanoparticles, Appl. Surf. Sci., 303, 473480.

[5] N. Agrawal, S. Munjal, M.Z. Ansari, N. Khare, (2017). Super-hydrophobic palmitic acid modified ZnO nanoparticles. Ceram. Int., 43, 14271–14276.

[6] Z.T. Li, B. Lin, L.W. Jiang, E.C. Lin, J. Chen, S.J. Zhang, Y.W. Tang, F.A. He, D.H. Li, (2018). Effective Preparation of magnetic super-hydrophobic Fe_3O_4/PU sponge for oil water separation. Appl. Surf. Sci., 427, 56–64.

[7] D. Hill, H. Attia, A.R. Barron, S. Alexander, (2019). Size and morphology dependent surface wetting based on hydrocarbon functionalized nanoparticles. J. Colloid Interface Sci., 543, 328–334.

[8] I.S. Bayer, K.G. Krishnan, R. Robison, E. Loth, D.H. Berry, T.E. Farrell, J.D. Crouch, (2016). Thermal Alternating Polymer Nanocomposite (TAPNC) coating designed to prevent aerodynamic insect fouling. Sci. Rep., 6, 38459–38472.

[9] Y. Lu, S. Sathasivam, J. Song, C.R. Crick, C.J. Carmalt, I.P. Parkin, (2015). Robust self cleaning surfaces that function when exposed to either air or oil. Science, 347, 1132–1135

Journal of Information Systems Engineering and Management
2025, 10(37s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

[10] J. Prakash, J.C. Pivin, H.C. Swart, (2015). Noble metal nanoparticles embedding into polymeric materials: from fundamentals to applications. Adv. Colloid Interface Sci., 226, 187–202.
[11] R. Gordon, (2015). Thermal interface materials: opportunities and challenges for developers. Transl. Mater. Res., 2(2), 020301.
[12] J.W. Zha, Y.H. Zhu, W.K. Li, J. Bai, Z.M. Dang, (2012). Low dielectric permittivity and high thermal conductivity silicone rubber composites with micro-nano-sized particles. Appl. Phys. Lett., 101(6).
[13] A. Farzaneh, Z. Ahmad, M. Can, S. Okur, O. Mermer, A.K. Havare, (2015). The role of hydrophobicity in the development of aluminum and copper alloys for industrial applications, New Trends Alloy Dev. Charact. Appl.
[14] Rachmat Subagyo, Dedy Muliadi, (2017). Kaji Eksperimental Hidrofobisitas Daun Dengan Varias Volume dan Bahan Droplet. sjme KINEMATIKA, 2(1), 113-125.
[15] Wahyudi, R. Subagyo, F. Gapsari, (2019). Physical and chemical mechanisms of hydrophobicity of nanoparticle membranes ($Mg+Al_2O_3$). Journal of Achievements in Materials and Manufacturing Engineering, 96(2).
[16] Lisa Ditscherlein, Jörg Fritzsche, Urs Alexander Peuker, (2016). Study of nanobubbles on hydrophilic and hydrophobic alumina surfaces, Colloids and Surfaces A: Physicochem. Eng. Aspects, 497, 242–250.
[17] E. Khalili, M. Sarafbidabad, (2017). Combination of laser patterning and nano PTFE sputtering for the creation of a super-hydrophobic surface on 304 stainless steel in medical applications. Surfaces and Interfaces, 8, 219–224.
[18] Y. He, W.T. Sun, S.C. Wang, P.A.S. Reed, F.C. Walsh, (2017). An electrodeposited Ni-P- WS2 coating with combined super-hydrophobicity and self-lubricating properties. Electrochimica Acta., 245, 872–882.
[19] Iaiche, S., Djelloul, A., (2015). $ZnO/ZnAl_2O_4$ nanocomposite films studied by X-ray diffraction, FTIR, and X-ray photoelectron spectroscopy. Journal of Spectroscopy.
[20] Deon, S.b., Deher, J., Lam, B., Crini, N., Crini, G., Fievet, P., (2017). Remediation of solutions containing oxyanions of selenium by ultrafiltration: study of rejection performances with and without chitosan addition. Ind. Eng. Chem. Res., 56, 10461-10471.