ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Effect of Surfactants on Electroless Ni-YSZ Composite Coating

[1]Nor Bahiyah Baba, [2]Rabiatul Adawiyah Ramli and [3]Muhamad Asyraf Mohd Amin

[1]*TATI University College (TATIUC), Faculty of Manufacturing Engineering Technology*, 24000 Kemaman, Terengganu, MALAYSIA
[2]*TATI University College (TATIUC), Faculty of Chemical Engineering Technology*, 24000 Kemaman, Terengganu, MALAYSIA
[3]*TATI University College (TATIUC), Centre of Preparatory and General Studies*, 24000 Kemaman, Terengganu, MALAYSIA

ARTICLE INFO

Article history:
Received 23 June 2015
Accepted 25 July 2015
Available online 30 August 2015

Keywords:
Electroless Nickel, yttria stabilised zirconia (YSZ), *composite, coating, surfactant*

ABSTRACT

Background: The effects of surfactants on electroless nickel (Ni) - yttria stabilised zirconia (YSZ) composite coating were evaluated in the study. Three types of surfactant were used in investigating the effect namely TRANS 2,3, SDS and HTAB. The aim is to determine the effect of these surfactant on Ni-YSZ composite coating thickness, porosity and surface roughness. Six sets of single parameter experiment were conducted with three replications each. The electroless Ni-YSZ composite coating parameters such as particle loading, surfactant volume and coating time were varied for high quantity and quality coating. SDS surfactant showed positive effect on coating thickness as particle loading of the YSZ particles were varied compared to the other types of surfactant. The highest and consistent porosity content was obtained for SDS surfactant and on the other hand, the lowest porosity obtained by HTAB surfactant indicating denser Ni-YSZ coating. Descending trends of coating thickness, porosity content and surface roughness were found as volume surfactant increase for both TRANS 2,3 and SDS surfactants. Linear relationship was obtained for coating time against coating thickness and surface roughness. The significant effect of surfactants on Ni-YSZ composite coating physical properties were by varying volume surfactant and coating time parameters.

To Cite This Article: Nor Bahiyah Baba, Rabiatul Adawiyah Ramli and Muhamad Asyraf Mohd Amin., Effect of surfactants on electroless Ni-YSZ composite coating. ***Aust. J. Basic & Appl. Sci.,*** *9(28): 12-17, 2015*

INTRODUCTION

Electroless coating of various metals such as copper, gold, nickel, cobalt, palladium, iron, silver and their alloys has been vastly used in many industries. Electroless coating is an in-situ catalytic reduction of a metallic ion from an aqueous solution without electrical energy which is a chemical reduction reaction (Balaraju *et al*. 1997, Panja and Sahoo, 2014). The reducing agent in electroless nickel solution is oxidized and Ni^{2+} ions are deposited on to the substrate surface as Ni metal and the first layer of deposited Ni acts as a catalyst for the continuous process (Khosroshahi *et al*. 2014).

Electroless coating becomes electroless composite coating by co-deposition of metalic ions and inert ceramic particles i.e. incorporation of diamond, silicon carbide, silicon nitride, silicon oxide, boron carbide, alumina, iron oxide, titanium oxide, ceria, yttria, zirconia and PTFE particles with varying the particulate sizes enables the production of a large range of composite materials with unique properties. Electroless nickel coating is controlled by parameters such as bath temperature, bath loading, bath pH, agitation methods and others (Agarwal *et al*. 2013).

Electroless composite coating involves combining variety of types of particles with different electrodeposited metals, thus the bath solution, substrate and particles should be compatible. Addition of surfactants acts as surface active agents which lowering the surface tension of a liquid for easy spreading and introducing less interfacial tension between two liquids.

Nwosu et. al. 2011 found that the amphiphilic characteristics of anionic surfactant sodium dodecyl sulphate (SDS) enhanced dispersion of YSZ particles. Other study found SDS increase the wettability and dispersion of silicon carbide particles (Wu, *et al*. 2000). Necula *et al*. (2007) found that particles are having good dispersion stability in deionised water but not so in the EN solution. A study conducted on Ni-P coating show positive influenced of anionic and cationic surfactants SDS and cetyltrimethyl ammonium bromide (CTAB) (Elansezhian, *et al* .2009). Vaghefi, Saatchi *et al*. (2003) stated that high incorporation of boron carbide (B_4C) in hypophosphite-reduced EN solution

Corresponding Author: Nor Bahiyah Baba, TATI University College (TATIUC), Faculty of Manufacturing Engineering Technology, 24000 Kemaman, Terengganu, MALAYSIA.
Tel: +6098601000 E-mail: bahiyah@tatiuc.edu.my

with particle sizes ranging from 5 to 11 μm gave a maximum of 33 vol.% B_4C when wetted with surfactant.

Surface coating quantity and quality can be evaluated via its physical properties. The coating quantity can be determine by measuring its thickness. EN deposit is very well known for its ability to produce uniform thickness on complex geometries and shapes parts. The density of electroless nickel deposits is lower than pure nickel due to the presence of phosphorus as an alloying constituent (Kundu *et al*.2014). The quality of coating can evaluated by surface roughness. Electroless nickel deposition has reported to have excellent uniformity and dense deposition with thickness less than 10 μm (Das and Chin 1959). Electroless nickel coating has received widespread acceptance as it provides a uniform deposit on irregular surfaces, direct deposition on surface-activated nonconductors, formation of less porous deposits, and high hardness and excellent resistance to wear, abrasion, and corrosion [Sudagar et. al., 2012].

Experimental:

Electroless Ni-YSZ composite coating is an autocatalytic process. The addition of ceramic YSZ particles in the bath form a composite coating of metallic nickel matrix and ceramic YSZ reinforcement onto the substrate. In order to enhance the amount of Ni-YSZ composite coating, several electroless Ni-YSZ composite coating process parameters were chosen as listed in Table 1. Previous studies found that particle sizes of 2 micron and mechanical stirring agitation were the dominant parameters affected the amount of ceramic YSZ particle in the composite coating (Baba, Davidson & Muneer, 2011). In this study, the effect of surfactants on electroless Ni-YSZ composite coating was investigated and parameters such as particle loading, surfactant volume and coating time were selected for high quantity and quality coating.

Table 1: Experimental electroless Ni-YSZ composite coating parameters.

Parameters	*Variables*					
Particle Loading (g/L)	25	50	75	100	125	150
Surfactant Volume (g/L)	0.3	0.6	0.9	1.2	1.5	1.8
Coating TIme (min)	30	60	90	120	150	180

Electroless Ni-YSZ composite coating experimental procedure consist of pre-treatment of alumina substrate followed by electroless composite coating as described in details in the previous study (Baba 2012). Three types of surfactant namely 2,3-Dibromo-2-Butene-1,4-Diol (TRANS 2,3), Sodium dodecyl sulphate (SDS) and Hexadecyl Trimethyl Ammonium Bromide (HTAB) were used in the study.

Six sets of single parameter experiment were conducted with three replications each. The coating thickness was measured by digital micrometer Mitutoyo 293-340. Archimedes specific density determine the porosity fraction in the composite. The basic Archimedes principle states that the amount of displaced water volume is equal to the immersed object volume. The coating surface roughness was measured using Mitutoyo SJ-400 Surface Roughness Tester Profilometer Surftest.

RESULTS AND DISCUSSION

The study was conducted to investigate the effect of surfactant on the Ni-YSZ composite coating physical properties such as its thickness, porosity and surface roughness. The purpose of adding surfactant in the bath is to increase co-deposition of ceramic YSZ into the coating by reducing the liquid surface tension and increase wetability of the ceramic particles (Wu et. al. 2000,). The surfactant performance should not hinder the other common performance of the conventional composite coating. Hence, the effect of surfactant is investigated by varying the common parameters in electroless composite coating process such as particle loading, volume of surfactant and coating time against physical properties of the coating i.e. thickness, porosity and surface roughness.

The first parameter to be discussed is the effect of surfactants on the coating by varying the particle loading. Particle loading is the amount of powder YSZ particles in a litre solution. The relationship between coating thickness and YSZ particle loading for various types of surfactant is presented in Figure 1. TRANS 2,3 surfactant showed significant increase in coating thickness upto 75 g/L but further addition of particle loading did not show significant change. Decreasing trend on coating thickness with particle loading was shown for SDS surfactant. Generally, the coating thickness decreasing as the particle loading increases though at 100 g/L particle loading there was an increase in coating thickness. The highest thickness obtained was 64 μm at 25 g/L. There was no direct relationship between the coating thickness and particle loading for HTAB surfactant. High value of coating thickness was obtained at particle loading of 75 g/L (38 μm) and 150 g/L (36 μm).

In comparison, SDS surfactant had higher value of thickness whereas HTAB gave the least coating thickness. The thickness of all the three batch surfactants did not show consistence values. This might be due to the fluctuating bath temperature during coating leading to inconsistency of coating thickness. These results follow a similar trend as reported by earlier researchers Hanna *et al*. (2003).

However, the thickness for SDS surfactant were all higher at all range of particle loading compared to the other types of surfactant.

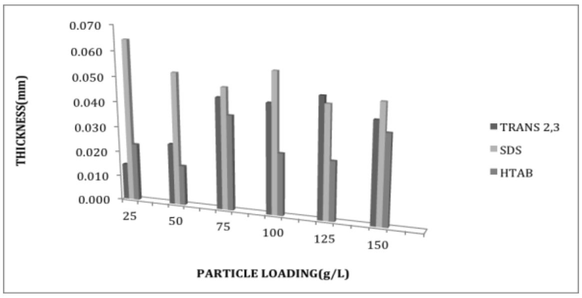

Fig. 1: Coating Thickness against particle loading for various surfactants.

Porosity is also an indication of the composite coating density. The effect of surfactant on porosity content in the composite coating by varying the particle loading was investigated. The correlation between porosity and particle loading for various types of surfactant is shown in Figure 2. It was found that porosity increases uniformly as the particle loading increases for trans 2,3 surfactant. Thus it indicates that TRANS 2,3 surfactant reduces the density of the coating with increasing particle loading. For SDS surfactant, the highest porosity (45.31%) obtained at 125 g/L followed closely 44.72% porosity obtained at 25 g/L particle loading but decrease drastically at 150 g/L (15.34%). Thus, it concludes SDS surfactant did not give significant effect on the density of Ni-YSZ composite coating. The porosity percent obtained for HTAB surfactant at all point of particle loading did not exceed 40%. This means HTAB surfactant produce more dense Ni-YSZ composite coating than the other two surfactants.

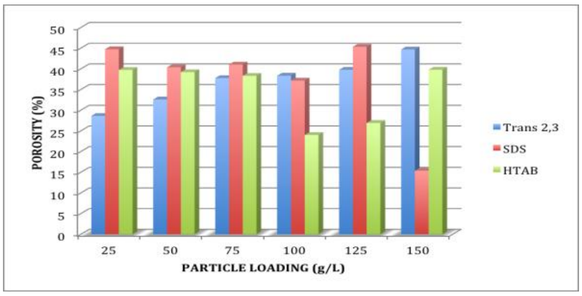

Fig. 2: Porosity against particle loading for various surfactants.

Comparing the porosity content for all 3 surfactants, the highest and constant porosity content was obtained when SDS surfactant was used. The lowest porosity obtained indicating denser Ni-YSZ coating was achieved when HTAB surfactant was used. The best particle loading for high porosity content to all 3 surfactants was at 75 g/L.

Second parameter to be discussed is the volume of surfactant. In this set of experiments, only 2 types of surfactant were compared. The relationship between Ni-YSZ composite coating thickness against surfactant volume (Figure 3). The relationship of surfactant volume and coating thickness for the two surfactant TRANS 2,3 and SDS showed a similar trend. Increasing surfactant volume caused decreasing in coating thickness. The optimum surfactant volume for both surfactants was in the range between 0.3–1.5 g/L, above which cause tremendous reduction in coating thickness. Janczuk *et al*. (1996) studied the surface free energy of fluorite in the presence of SDS and reported that as the concentration of surfactant increases, SDS molecules at the solid or solution interface are adsorbed forming a stable monolayer which then reduce the action of the surfactant on the surface.

The effect of surfactants on composite coating porosity content by varying the surfactant volume is shown in Figure 4. The descending trend of porosity content with increasing surfactant volume for both surfactants; TRANS 2,3 and SDS were observed. The porosity content decreases as the surfactant volume increases. TRANS 2,3 surfactant achieved the highest porosity content of 40% at 0.3 g/L surfactant volume, then gradually drop as the surfactant volume increasing. For SDS surfactant, the results of porosity was lower than 40%. The recommended porosity content should not more than 40 vol.% as the greater amount will reduce the mechanical properties of the coating. Thus, an adequate amount of porosity and reasonable mechanical properties should be balance. It is known that electroless nickel deposition has excellent uniformity and dense deposition with thickness less than 10 µm (Das and Chin 1959). Therefore, in many cases, a minimum thickness of 25 µm is recommended or obtaining a coating with the least amount of pores and highest corrosion and wear resistance [Deng and Hong, 1993].

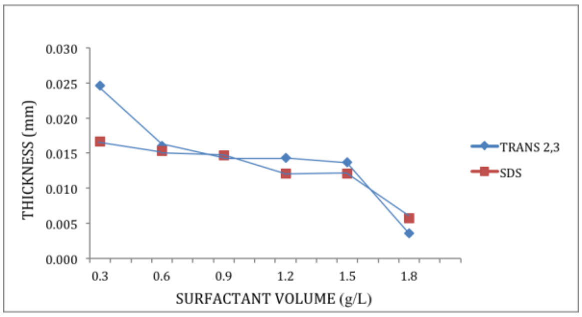

Fig. 3: Coating Thickness against surfactant volume for various surfactants.

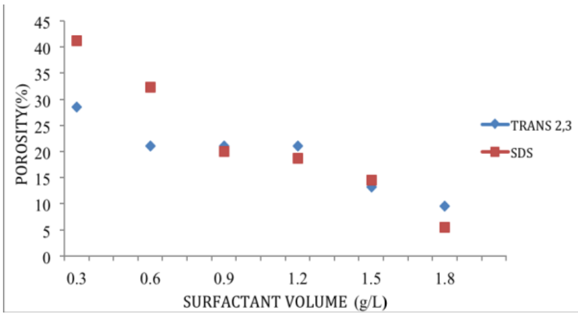

Fig. 4: Porosity against surfactant volume for various surfactants.

The variation of Ni-YSZ composite coating surface roughness against the surfactant volume for both TRANS 2,3 and SDS is in Figure 5. Similar decreasing trend was observed as the surfactant volume increases. The surface roughness for trans 2,3 surfactant showed small decrease from 0.71 to 0.63 µm whereas the SDS surfactant show significant decrease starting from 0.80 to 055 µm. Further increase in surfactant volume did not influence the surface roughness values much.

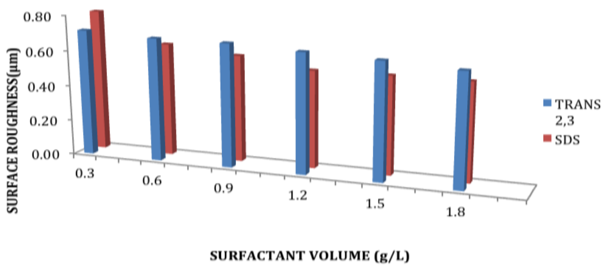

Fig. 5: Surface roughness against surfactant volume for various surfactants.

Varying surfactant volume parameter in general showed negative effect on the physical properties of Ni-YSZ composite coating. The coating thickness, porosity content and surface roughness of the Ni-YSZ composite coating reduces as the surfactant volume increases. This trends are consistence for both types of surfactants; TRANS 2,3 and SDS.

The last but not least investigated parameter was the coating time. This set of experiment was conducted with only one type of surfactant that was the TRANS 2,3. Based on the analysis shown in Figure 6, the thickness of coating increasing rapidly due to the increasing of coating time. Thus, when the coating time increase, the thickness of coating also increases. This is expected since increasing the coating time induces more metallic Ni matrix to be deposited on to the alumina substrate and thus increase the coating thickness. It can be concluded that Ni-YSZ composite coating thickness is directly proportional to the coating time.

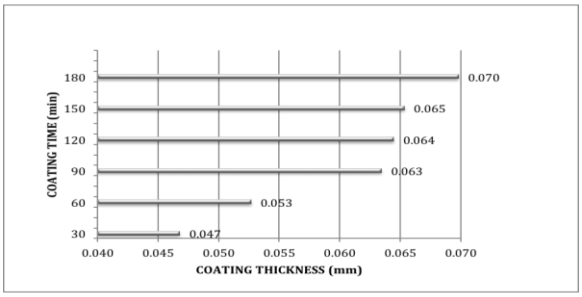

Fig. 6: Coating thickness against coating time.

The effect of TRANS 2,3 surfactant on the amount of porosity in the Ni-YSZ composite coating by varying coating time was described in Figure 7. TRANS 2,3 surfactant showed positive effect on porosity content in the Ni-YSZ composite coating for particle loading parameter (Figure 2). The porosity content increases as coating time increases for the first 120 min and drop slightly after. The highest porosity content obtained was 51.99% at 120 min coating time. This is supported by Das and Chin (1959) that reported electroless nickel deposition has excellent uniformity and dense deposition with thickness less than 10 μm. Since the coating thickness is directly proportional to the coating time, thus the porosity content. The most dense Ni-YSZ composite coating was achieved at 30 min coating time.

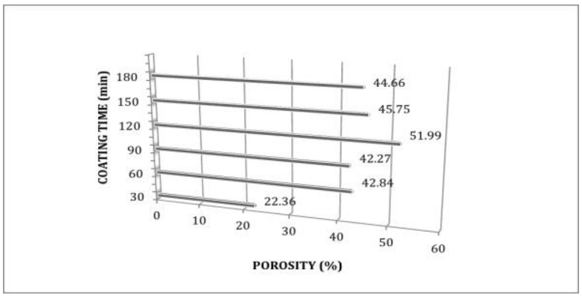

Fig. 7: Porosity against coating time.

Figure 7 shows the relationship between surface roughness and coating time. The surface roughness of the Ni-YSZ composite coating increases with increasing coating time. Coating time showed linear relationship with surface roughness as expected. Furthermore, agglomeration of surfactant takes place over the electroless Ni–P matrix and this leads to increased in surface roughness [Dhinakaran et. al., 2013].

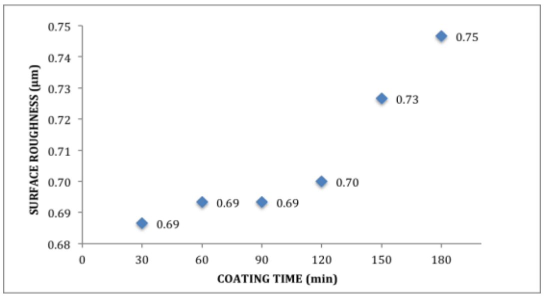

Fig. 8: Surface roughness against coating time.

Conclusions:

The study investigate the effect of three types of surfactant namely TRANS 2,3, SDS and HTAB on the physical porperties of Ni-YSZ composite coating. The physical properties involved were coating thickness, porosity content and surface roughness. Three parameters such as particle loading, volume of surfactant and coating time were varied in this study. It was found that increasing the particle loading does not show positive effect on coating thickness for all types of surfactant, however the results indicated that SDS surfactant gives positive effect on the electroless Ni-YSZ composite coating thickness. In the case of porosity content, the highest and constant porosity content was obtained for SDS surfactant. The lowest porosity obtained indicating denser Ni-YSZ coating was achieved when using HTAB surfactant. Increasing the volume surfactant from 0-1.8g/L decreasing the coating thickness, porosity content as well as surface roughness of the Ni-YSZ composite coating as the surfactant volume increases. This trends are consistence for both types of surfactants, TRANS 2,3 and SDS. Coating time show linear relationship with coating thickness and surface roughness as expected and most dense Ni-YSZ composite coating was achieved at 30 min coating time. The effect of surfactants on Ni-YSZ composite coating physical properties were significant for volume surfactant and coating time parameters.

ACKNOWLEDGMENT

The author acknowledges the support of Ministry of Higher Education Malaysia for the financial fund under Fundamental Research Grant Scheme (FRGS/1/2012/TK07/TATID2/1).

REFERENCES

Agarwal Amrita, Murali Pujari, R. Uppalurin, A. Verma, 2014. Optimal Electroless Plating Rate Enhancement Techniques For The Fabrication Of Low Cost Dense Nickel/Ceramic Composite Membranes. Original Research Article Ceramics International, 40(1A): 691-697.

Balaraju, J.N., S.K. Seshadri, 1997. Synthesis and Characterization of Electroless Nickel-High Phosphorus Coatings. Metal Finishing, 97(7): 8-10-12-13.

Das, L. and D.T. Chin, 1959. Electrochemical Porosity Measurement of EN Coating. Plating and Surface Finishing, 84: 66-68.

Deng, H. and P. Moller, 1993. Effect of the Substrate Surface Morphology on the Porosity of Electroless Nickel Coatings. Trans. Inst. Metal Finish, 71: 142-148.

Elansezhian, R., B. Ramamoorthy and P.K. Nair, 2009. The Influence of SDS and CTAB Surfactants on the Surface Morphology and Surface Topography of Electroless Ni-P Deposits. Journal of Materials Processing Technology, 209(1): 33-240.

Hanna, F., Z. Abdel Hamid and A. Abdel Aal, 2003. Controlling factors affecting the stability and rate of electroless copper plating. Materials Letters, 58(1-2): 104–109.

Jańczuk, B., M.L. González-martín and J.M. Bruque, 1996. Wettability of fluorite in the presence of an anionic and a non-ionic surfactant. Canadian Metallurgical Quarterly, 35(1): 17–21.

Khosroshahi, N., Beigi, Khosroshahi R. Azari, Mousavian R. Taherzadeh, D. Brabazon, 2014. Effect of Electroless Coating Parameters and Ceramic Particle Size on Fabrication of a Uniform Ni–P Coating On Sic Particles. Original Research Article Ceramics International, 40(8A): 12149-12159.

Kundu Sanjip, Kalyan Das Suman, Sahoo Prasanta, 2014. Properties of Electroless Nickel at Elevated Temperature. A Review,Original Research Article Procedia Engineering, 97: 1698-1706.

Necula, B.S., I. Apachitei, 2007. Stability of nano-/microsized particles in deionized water and electroless nickel solutions. Journal of Colloid and Interface Science, 314: 514–522.

Nwosu, N.O., Davidson, A.M. Colin, S. Hindle, 2011. Effect of Sodium Dodecyl Sulphate on the Composition of Electroless Nickel—Yttria Stabilized Zirconia Coatings. Advances in Chemical Engineering and Science, 1: 118-124.

Baba, N., Bahiyah, Alan Davidson, Tariq Muneer, 2011. YSZ-reinforced Ni-P deposit: An effective condition for high particles incorporation and porosity level. Advanced Materials Research, 214: 412-417.

Baba, N., Bahiyah, 2012. YSZ Reinforced Ni-P Composite by Electroless Nickel Co-Deposition, Book Chapter in Composite Materials Book 1, Intech Publication, ISBN, 980-953-307-269-7.

Panja Bikash, Sahoo Prasanta, 2014. Friction Performance of Electroless Ni-P Coatings in Alkaline Medium and Optimization of Coating Parameters. Original Research Article Procedia Engineering, 97: 47-55.

Dhinakaran, R., Rasu Elansezhian and Arunachalam Arumugam Lalitha, 2013. Effect of Nanoadditives with Surfactant on the Surface Characteristics of Electroless Nickel Coating on Magnesium-Based Composites Reinforced with MWCNT. Advances in Tribology, Hindawi Publishing Corporation, 10.

Sudagar, J., J. Lian and W. Sha, 2013. Electroless Nickel Alloy, Composite and Nano Coatings – A Critical Review. Journal of Alloy and Compound, 571: 183-204.

Vaghefi, S.M.M., A. Saatchi, 2003. Deposition and properties of electroless Ni-P-B4C composite coatings. Surface and Coatings Technology, 168: 259-262.

Wu, Y.C., G.H., Li, L. Zhang and B. Yan, 2000. Study on Constitution and Wear Resistance of Nickel Phosphorus Alloy-Silicon Carbide Composite Coatings. Materials Research and Advanced Techniques, 91: 788-793.