EFFECT OF CURRENT DENSITY ON PROPERTIES OF NICKEL-SILICON CARBIDE COMPOSITES

Kailash Hamal, Armila Rajbhandari (Nyachhyon), Gobinda Gyawali and Soo Wohn Lee

Journal of Institute of Science and Technology
Volume 21, Issue 1, August 2016
ISSN: 2469-9062 (print), 2467-9240(e)

JIST, **21** (1), 82-85 (2016)

Published by:
Institute of Science and Technology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

JIST 2016, 21(1) : 82-85
ISSN: 2469-9062 (p), 2467-9240(e)

RESEARCH PAPER

EFFECT OF CURRENT DENSITY ON PROPERTIES OF NICKEL-SILICON CARBIDE COMPOSITES

Kailash Hamal[1], Armila Rajbhandari (Nyachhyon)[1,*], Gobinda Gyawali[2], and Soo Wohn Lee[2]
[1]*Central Department of Chemistry, Tribhuvan University, Kirtipur, Nepal*
[2]*Research Centre for Eco Multi-Functional Nano Materials, Global Research Laboratory,*
Sun Moon University, Republic of Korea
[*]*Corresponding email: armila3@yahoo.com*

ABSTRACT

Nickel-Silicon Carbide **(**Ni-SiC) composite coating has been prepared by two electrode electrochemical co-deposition technique in nickel sulfamate bath. The Cetyltrimethylammonium bromide (CTAB) was added in bath as cationic surfactant whereas saccharine as a grain modifier. The effect of current density during deposition was systematically studied and optimized to get homogeneous surface texture with utmost microhardness and deprived coefficient of friction. The result revealed that 60 mA/cm^2 current density was found to be the optimum current density which showed the highest microhardness of 590 ± 10 Hv and lowest coefficient of friction with regular surface morphology.

Keywords: Ni-SiC; Morphology, Microhardness, Coefficient of friction

INTRODUCTION

Surface modification of metallic body by coating has become an essential process to improve the surface properties such as wear, corrosion and oxidation. Different techniques have been utilized for depositing organic as well as inorganic material onto the substrate to achieve desired properties. Composite electroplating is one of the methods that involve incorporation of metallic, non-metallic or polymeric micro or nano sized second phase particles along with the growing metal matrix. Such incorporated particles improve the overall properties of the coatings such as adhesion, anti-corrosion, anti-friction, microhardness and the mechanical strength. In recent years, the nickel based composite has been studied frequently to overcome and improve the properties of coating. A large number of ceramics particles incorporated with nickel matrix have also been reported in literatures (Shi et al., 2005, Gyawali et al., 2010, Garcia-Lecina et al., 2012). Besides this, SiC particles have also been extensively studied due to the cost effectiveness and wider applications (Shi et al., 2005, Gyawali et al., 2010, Garcia-Lecina et al., 2012).

Nickel sulfamate is a commonly used electrolyte during the electroplating of nickel due to its high deposition rate and superior throwing power. Addition of additives like Saccharine and CTAB along with sulfamate electrolyte helps to form smooth surface morphology by grain modification and increases co-deposition of particles, respectively (Shi 2005). In addition to this, during electroplating, operating conditions like pH, temperature (Gyawali 2010, Hamal 2014), stirring rate (Hamal 2014, Garcia-Lecina 2012) and applied current has also played important role to obtain good quality deposit. In the previous study, we have presented the effects of additives on the SiC co-deposition into the nickel matrix. Different operating conditions like optimum temperature, stirring rate were also studied for the better surface texture, microhardness and tribological properties of the coatings (Gyawali et al., 2010, Hamal et al., 2014). In this study, Ni-SiC composite coatings have been prepared by using nickel sulfamate bath containing SiC nanoparticles, CTAB and saccharine as additives. The different current densities has been applied to find out the optimum current density, by keeping all other parameters such as pulse frequency and pulse duty cycle, constant. Thus prepared Ni-SiC coating samples were characterized and compared to get optimum current density.

MATERIALS AND METHODS

All chemical reagents were of analytical grade and obtained from Duksan Pure Chemicals Co. Ltd. Korea. These reagents were prepared in de-ionized water. Nickel sulfamate electroplating bath was formulated by taking 300 g/L of $Ni(NH_2SO_3)_2$, 10 g/L of $NiCl_2$, and 40 g/L of boric acid. In the bath, 0.2

g/L of CTAB was used as cationic surfactant while 2 g/L saccharine has been used as a grain modifier. Similarly, 20 g/L of SiC particle (~270 nm) was also added into the bath. Then, nickel balls inside a titanium basket was taken as anode whereas SUS304 stainless steel of exposed area 6 cm^2, was used as cathode. The co-deposition process was then carried out at pH 4.2, temperature 50˚C, 25% duty cycle, and 100 Hz of pulse frequency. In order to investigate the effect ofcurrent density during deposition, three different samples namely, S-20, S-60, S-100 were prepared at 20 mA/cm^2, 60 mA/cm^2 and 100 mA/cm^2 current densities, respectively. The electrolytic bath was continuously stirred by using teflon coated magnetic stirrer at 250 rpm.

Scanning Electron Microscopy (Mini-SEM, Nanoeye) was used to examine the surface morphology and microstructure of the coatings, X-ray diffraction (XRD, Rigaku DMAX 2200, X-ray diffractometer Japan) with Cu-K α wave length of 1.5 Å was used to determine the crystallinity and phase present in the electrodeposited Ni-SiC coatings. XRD measurement was performed at the 2θ range of 10-100 degrees with the scan rate of 4^0/min. The hardness of the composite coating was measured by Vickers microhardness tester (Buehler Ltd. USA) by applying 100g load for 10 seconds. Coefficient of friction of the prepared samples were recorded by ball on disc method using Tribometer (CSM Swiss) without using any lubricants in unidirectional sliding wear for 10 min under 2 N applied load.

RESULTS

Surface Morphology

Surface morphology of Ni-SiC composite coatings prepared at different current densities are shown in **Fig.1**.

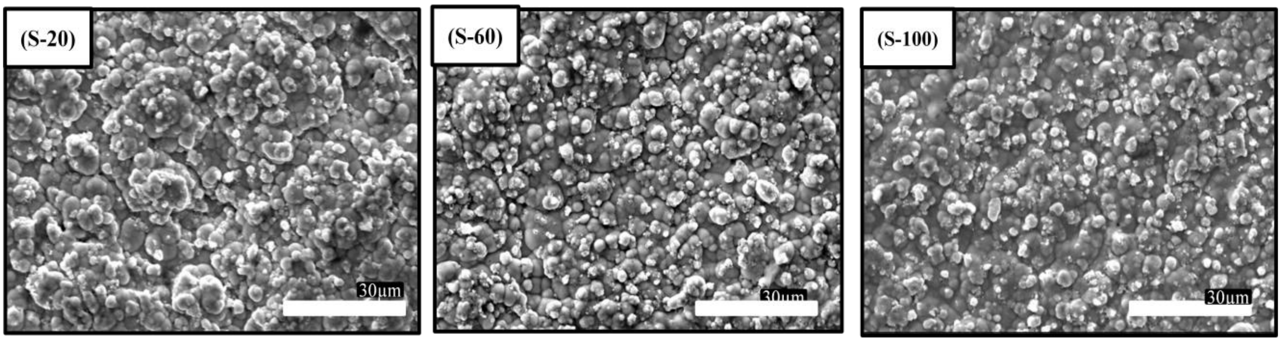

Fig.1. Surface morphology of Ni-SiC composite coatings prepared at different current density: sample (S-20) prepared at 20 mA/cm^2, sample (S-60) prepared at 60 $mA/cm^2$and sample (S-100) prepared at 100mA/cm^2.

X-ray Diffraction (XRD) studies

X-ray diffraction patterns of the Ni-SiC composite coatings are shown in **Fig. 2**.

Microhardness

Hardness is one of the important properties of the coating that affects the application of the coatings in engineering purposes. Hence, the Vicker's microhardness of the Ni-SiC composite coatings were investigated for the samples prepared at different current densities. **Fig. 3** shows the Vicker's microhardness plot of prepared samples.

Coefficient of Friction

Coefficient of friction was measured by unidirectional sliding wear in absence of lubricants for 10 min under the load of 2N. The variation of the coefficient of friction of Ni-SiC coatings prepared at different current densities is presented in **Fig. 4**.

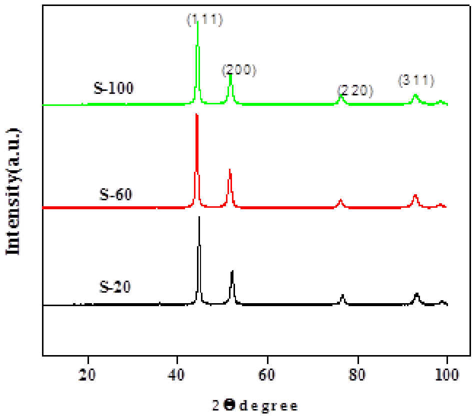

Fig.2: XRD patterns of Ni-SiC composite coatings prepared at different current density: (S-20) prepared at 20 mA/cm^2, (S-40) prepared at 40 mA/cm^2 and (S-100) prepared at 100 mA/cm^2.

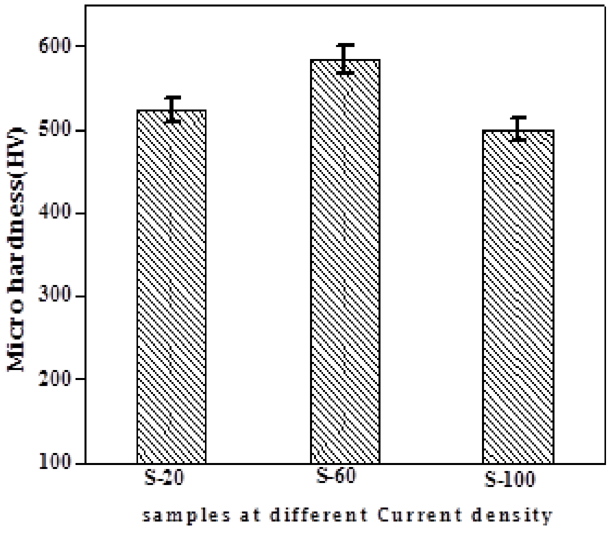

Fig.3: Vickers Microhardness of Ni-SiC composite coatings prepared at different current density: (S-20) prepared at 20 mA/cm^2, (S-60) prepared at 60 mA/cm^2 and (S-100) prepared at 100 mA/cm^2.

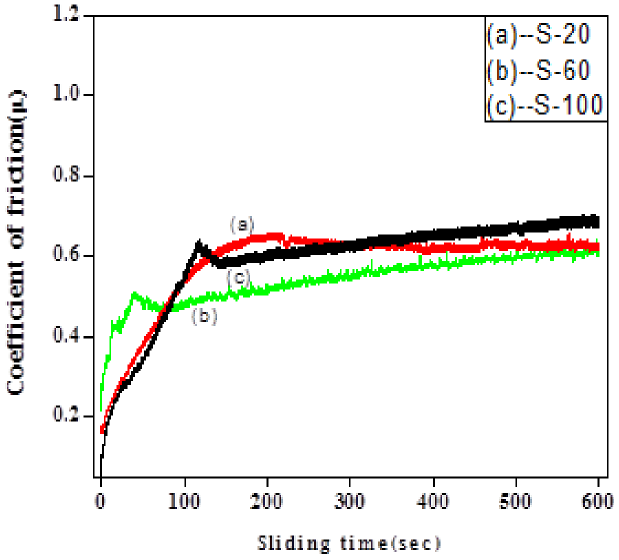

Fig.4: Coefficient of friction as function of time of Ni-SiC composite coatings prepared at different current density: (S-20) prepared at 20 mA/cm^2, (S-60) prepared at 60 mA/cm^2 and (S-100) prepared at 100 mA/cm^2.

DISCUSSION

The study of morphology of the Ni-SiC coatings (**Fig. 1**) showed that at the lower current density, the Ni-SiC coatings possessed the larger grains at its surface and the grains were not uniformly distributed. On the other hand, the regular and homogeneous surface morphology was observed when the current density was set to higher. This result is attributed due to the faster deposition rate of Ni at the cathode and the increased co-deposition of second phase SiC particles onto the growing nickel matrix. The co-deposition of SiC particles lead to the breakage of the regular nickel grain and hence the alternative nucleation takes place. Thus, the process ultimately turned into the regular and homogeneous surface morphology at higher current densities.

On the basis of XRD pattern (**Fig. 2**), all the coatings exhibited a single phase on Ni matrix with FCC structure according to the JCPDS no. 04-0850. The relative peak intensity of (111), (220), and (311) peaks have been found to be increased by increasing the current densities up to 60 mA/cm2. However, at 100 mA/cm^2, a slight decreased intensity of these peaks were observed. The elevation of these peaks correspond to the mixed [211] orientation of nickel crystallites favored in presence of incorporated SiC particles (Gyawali et al., 2010). Meanwhile, the decreased peak intensity of (200) reflection peak suggests the less preferred [100] texture orientation of Nickel. Hence, at higher current densities XRD analysis showed that, , there is mixed orientation of nickel deposits. It indicates the higher incorporation of second phase SiC nanoparticles.

Similarly, it was found that the sample S-60 prepared at 60 mA/cm^2 showed the highest value of Vickers microhardness ~590 Hv than the other two samples. Sample S-20 and sample S-100 showed relatively low value of Vicker's microhardness.

The outcome was explained on the basis of incorporation of SiC nanoparticles, grain modification and the textural orientation of nickel crystallites. The presence of well dispersed SiC nanoparticles in the nickel matrix enhances the load bearing capacity and restricted the propagation of slip planes. In addition, it is well known that the microhardness is also related to the grain size of the matrix. As the matrix grain size decreases, the microhardness increases. Similarly, [211] texture orientation was relatively harder in comparison to the preferred [100] orientation of the matrix. Therefore under the optimum condition, the electro-deposition of Ni-SiC composite coating, favored by all the mentioned factors, collectively contributed to the enhancement of microhardness of the coatings.

The coefficient of friction shows the significant variations depending on both the sliding time and samples. Coefficient of friction of all the samples increased at the initial 2 min and reached to the steady state. It has been observed that the coefficient of friction of the samples S-20 and S-100 were higher in comparison to the S-60 sample. The reduced coefficient of friction of S-60 sample is due to the well compact fine surface, higher microhardness value and the increased co-deposition of SiC nanoparticles at this particular current density in comparison to the other samples. On the other hand, uniform dispersion of SiC nanoparticles in the nickel matrix may obstruct the ploughing out of larger flakes during the sliding wear. The formation of larger flakes due to the slippage of planes not only increases the frictional force but also cause to severe wear of the coating. Hence, the dispersed SiC nano particles might block the motion of dislocation and crack propagation in the soft matrix there by reduced the coefficient of friction of S-60 sample

CONCLUSION

In this investigation, the effect of variable current densities on the properties of Ni-SiC composite coating was carried out. It has been found that the Ni-SiC composite coating prepared at 60 mA/cm^2 exhibited the regular and smooth surface morphology. Similarly, the enhanced Vickers microhardness and the lower coefficient of friction were observed in the sample. Hence, from the morphological, microstructural, mechanical and tribological characterizations, the optimum current density was found at 60 mA/cm^2.

ACKNOWLEDGEMENTS

Kailash Hamal thanks the University Grants Commission (UGC) Nepal for partial financial support and Research Centre for Eco Multifunctional Nano Materials, Global Research Laboratory, Sun Moon University, Korea for providing all laboratory facilities and financial support as well.

REFERENCES

Garcia-Lecina, E., Garcia-Urrutia, I., Diez, J. A., Morgiel, J., Indyka, P., 2012. A comparative study of the effect of mechanical and ultrasound agitation on the properties of electrodeposited Ni/Al_2O_3 nanocomposite coatings. *Surface and Coatings Technology*, **206:** 2998-3005.

Gyawali, G., Cho, S. H., Woo, D., Lee, S. W., 2010. Electrodeposition of Ni-SiC Nano Composite in Presence of Ultrasound. *Materials Science Forum,* **658**: 424-427.

Gyawali, G., Hamal, K., Joshi, B., Rajbhandari, A., Lee S.W. 2014. Microstructural and electrochemical analysis of Ni–SiC composite coatings prepared in presence of additives. *Materials letters,* **126**: 228-231

Hamal, K., Gyawali, G., Rajbhandari, A., Lee S.W. 2014. Effect of Bath Temperature on Electrochemical Codeposition of Nickel Silicon Carbide composite. *International Journal Chemistry and Pharmaceutical Sciences,* **2(4)**: 658-663.

Hamal, K., Rajbhandari, A., Gyawali, G., Lee S.W. 2014. Effect of stirring rate on electrochemical codeposition of Ni-SiC composite. *Scientific World* **12**: 30-33.

Shi L., Sun C.F., Zhou F., Liu W.M., 2005. Electrodeposited nickel–cobalt composite coating containing nano-sized Si_3N_4. *Materials Science and Engineering A*, **397**: 190-194.