

Electrophoretic deposition of Ni nanoparticles on Ni-plate

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1. Introduction

Ni-63, a beta radiation source, prepared by electrophoretic deposition (EPD), is widely used in the shaping and coating when preparing uniform ceramic films with various thickness and assembling charged particles on electrodes with various morphologies [1]. This process shows a higher deposition rate of the nanoparticles with electroactive ions than those of conventional electroplating. Since the discovery of a repairing pit using an EPD method, well-dispersed metal nanoparticles in the suspension are applied to the self-repairing pit on the metal surface [2]. The main advantages of EPD are a short processing time, process simplicity, easier composition control, low cost, and selective deposition of a uniform film [3]. Electrophoretic deposition consists of two processes: the movement of the charged powder particles in suspension under an applied electric field between the working electrode and counter electrode, and electrophoresis by deposition of particles on the working electrode [4]. Irregular rough surfaces are produced by the formation and decay of a protective layer during pitting corrosion [4]. Since the roughness and irregularities of the pit significantly influence the current distribution over the surface of the electrode specimen, it is necessary to quantitatively characterize the pit morphology and investigate the effect of the surface irregularity of the pit on the movement of charged powder particles to the pitted electrode specimen during electrophoretic deposition.

2. Experimental Technique

Ni nanoparticles were synthesized by a pulsed wire evaporation (PWE) method [5]. It was observed that the average particle size of the Ni nanoparticles about 70 nm. Hypermer KD-2 (HKD-2, Uniqema UK) was used as a dispersant. To prepare the Ni-dispersed solution, HKD-2 (1, 3, 5, 7, 9, 11, and 13 wt.%) was first dissolved into 100 ml of ethanol, and Ni nanoparticles (0.005, and 0.01 wt.%) were then added into a dispersant containing the ethanol solution. Finally, the suspension was ultrasonicated for 1.5 h. The zeta potential of Ni nanoparticles in the surfactant dispersed ethanol was measured from -32 to -17 mV in values by using a Nano-ZS zeta sizer (Malvern, UK). A two-electrode electrochemical cell was employed for the electrophoretic deposition. The scratched specimens of the Ni plate and Pt coated mesh were used as a working electrode and counter electrode, respectively. The Ni-dispersed solution was used as the electrolyte. The area

of the specimen exposed to the electrolyte amounted to 1 cm². Constant electric fields of 180 Vcm⁻¹ were applied to the specimens using a DAP-2002R dc power supply (DawooNanotec), and the electrophoretic current value during electrophoretic deposition was measured using a multimeter (SAEHAN, Korea).

3. Results and discussion

The relation between zeta potential and concentration of surfactant (HKD-2), and the pH for the 0.01 wt.% Ni nanoparticles are shown in Fig. 1. The highest absolute value of the zeta potential was observed at 1 wt.% of HKD-2 in a Ni dispersed medium. The zeta potential value of the Ni nanoparticle dispersed in ethanol without a surfactant showed a positive value. The Ni surface was changed to electronegative when the HKD-2 was immersed in ethanol at and above 1 wt.%. The absolute values of the zeta potential were slightly decreased, as the concentration of HKD-2 was raised. It is shown that the isoelectric point IEP of Ni was around pH= 6. The Ni surface is electronegative when the pH is above 7. Thus, the cationic surfactant is easily absorbed onto the Ni nanoparticles surface. The zeta potential decreases with an increasing pH value up to 10.5. The plot seems to maintain balance when the solution is neutral; the zeta potential then has the maximal absolute value at 27.5 mV when the pH value reaches 10.5. In other words, the surface modification of Ni should be easier owing to the increase in the hydroxyl groups. The conductivity of the Ni-dispersed medium was increased, as the amount of HKD-2 was increased. The relation between the conductivity and pH in 0.01 wt.-%Ni dispersed suspension was also measured. The conductivity showed the lowest value, when the pH value was increased to 10.5. The reduced conductivity results in increasing repulsive interaction between Ni nanoparticles, as the absolute zeta potential was raised.

The absolute values of the zeta potential were slightly reduced, as the concentration of HKD-2 was raised. It was measured to be -20 mV at and below 9 wt.% of HKD-2. The addition of HKD-2 led to an increase in zeta potential values and electrical conductivity of the Ni particles suspension. This may be attributed to the high molecular weight and steric stabilization by the molecular structure of HKD-2. On the other hand, as the concentration of Ni particles was increased, the zeta potential was slightly decreased owing to coagulation between Ni particles. When the amount of HKD-2 and Ni particles was increased in the mixed solution, the values of electrical conductivity of the suspension were

grown owing to an increase in the amount of metallic powder in the medium.

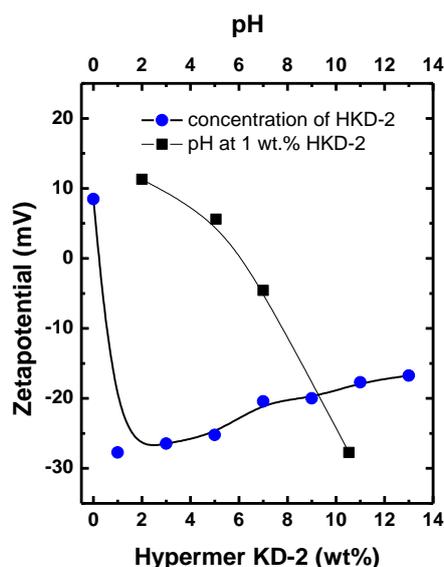


Fig. 1 The zeta potential values with concentration of Hypermer KD-2 and pH for the Ni dispersed suspension at 0.01 wt% Ni nanoparticles.

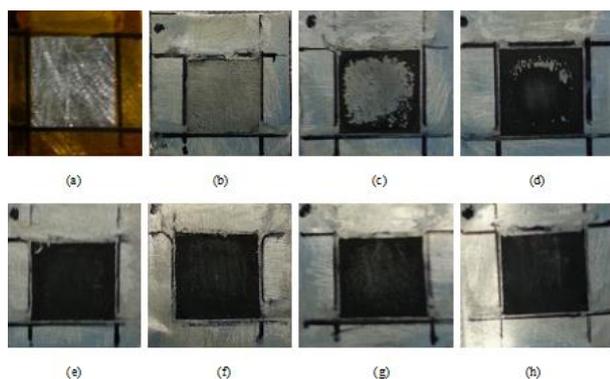


Fig. 2 photographs of the Ni particle deposited surface of a scratched plate subjected to a constant electric field E of 180 Vcm^{-1} for 300 s. (a) base, (b) 1 wt.%, (c) 3 wt.%, (d) 5 wt.%, (e) 7 wt.% (f) 9 wt.%, (g) 11 wt.%, (h) 13 wt.% HKD-2

The 0.005 wt.-%-Ni immersed suspensions were prepared at various dispersant conditions (HKD-2: 1, 3, 5, 7, 9, 11, and 13 wt.%). However, Ni nanoparticles were not deposited at the suspension condition with the highest value of zeta potential. The condition of the deposition was determined to be 7 wt.% for the- HKD-2 dispersed suspension. The coated powders at 7 wt.% HKD-2 showed good adhesion with the substrate, though the deposited Ni-plate was carried out by ultrasonic treatment. The 0.01 wt.-% Ni reinforced suspensions with various content of HKD-2 were prepared. The condition of the EPD was determined at 7 wt.-%- HKD-2 and in the 0.01 wt.-% and 0.005 wt.-%-Ni dispersed suspensions. The absolute values of these suspensions are 20 mV and 21 mV, respectively. These values are sufficient to carry out EPD. The conductivities of these mediums were 0.026 and 0.024

mS/cm. These values are higher than the suspension including the low concentration of HKD-2 below 7 wt.%. Though the conductivities of the suspension including at and above 9 wt.-%-HDK were enhanced at and above 0.035 mS/cm, the adhesion between the nanoparticles and a plate were worse. This results in low absolute values of zeta potential below 20 mV of the suspensions. It should be emphasized here that the absolute values of zeta potential of the suspension are required at and above 20 mV. In addition, we found that the conductivity of the suspension is one of the critical conditions for the EPD.

4. Conclusions

To deposit Ni nanoparticles, the electrophoretic deposition (EPD) was executed using two electrode cells in the suspension, which was produced in organic solvents using Hypermer KD-2 (HKD-2) as a dispersant. The zeta potential values of the stable suspension were determined to be approximately 30 mV at 1 wt.% of HKD-2 and 0.005 wt.% of Ni powder in the suspension. However, the coating of Ni particles on the substrate of the Ni plate was fabricated in the suspension at 7 wt% HKD-2 or more. It was found that the EPD process was important not only for the zeta potential of the suspension but also the conductivity. In addition, it was confirmed that the smooth surface of the deposited Ni coating was relatively obtained when the concentration of Ni particles was low.

Acknowledgement

Industrial Source Technology Development Program (10043868) of the Ministry of Knowledge Economy (MKE), Korea.

REFERENCES

- [1] C. Kaya, F. Kaya, B. Su, B. Thomas, A.R. Boccaccini, Structural and Functional Thick Ceramic Coatings by Electrophoretic Deposition, *Surface & Coatings Technology*, Vol. 191, pp. 303-310, 2005.
- [2] Gyoung-ja Lee, Min-Ku Lee, Chang-Kyu Rhee, Self-repairing Technology by Electrophoresis of Ni Nano-particles for Heat Exchanger Tubes, *Journal of Korean Powder Metallurgy Institute*, Vol. 14, No. 4, pp.238-244, 2007.
- [3] I. Zhitomirsky, Cathodic electrodeposition of ceramic and organoceramic materials. Fundamental aspects, *Advances in Colloid and Interface science*, Vol.97, pp.281, 2002
- [4] Gyoung-ja Lee, Young-Rang Uhm, Chang-Kyu Rhee, Determination of Fractal Dimension and Surface Characterization of Metal Nano-powder Using Nitrogen Gas Adsorption Methode, *Journal of Korean Powder Metallurgy Institute*, Vol. 14, No. 6, pp. 391-398, 2007
- [5] Y. R. Uhm, J.H. Park, W.W. Kim, C.-H. Cho, C.K. Rhee, Magnetic properties of nano-size Ni synthesized by the pulsed wire evaporation (PWE) method, *Materials Science and Engineering B*, Vol. 106, pp. 224-227, 2004.