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Microstructure and Mechanical Properties of Nanocrystalline Ni-Al_2O_3 Composites by Electrodeposition

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Abstract – Nanocomposite materials consisting of a nanocrystalline Ni matrix (grain size 50-60 nm) and nano-size Al_2O_3 particulates (average particle size: 30 nm) up to 1.5 wt.% have been synthesized by electrodeposition. Hardness of Ni–Al_2O_3 nanocomposite was about 1.7 times that of nanocrystalline pure Ni. However, tensile test of Ni–Al_2O_3 nanocomposite decreased to about 1/2 times that of nanocrystalline Ni. Fracture surface exhibited a typical dimpled surface with dispersed Al_2O_3 particles on it. Concentration of Al_2O_3 on the fracture surface was more than 3 times that of the bulk concentration. Therefore it is considered that the aggregated Al_2O_3 particles caused initiation of cracks and the reduction of tensile stress..

It has been reported that nanocrystalline Ni with grain size less than 100 nm can be synthesized by electrodepositon, and they exhibited extremely high strength by grain refinement. If nanocrystalline materials contain precipitations of nano-size, they may exhibit higher strength by both grain size reduction (Hall-Petch law) and precipitation hardening. The purpose of the study was to fabricate a nanocrystalline Ni-Alumina composite by electrodeposition method and to characterize their microstructure using SEM, TEM, analysis and to determine mechanical properties.

Nanocrystalline Ni- Al_2O_3 composites were electrodeposited in the bath of consisting of 500g/ℓ nickel sulfamate, 15 g/ℓ nickel chloride, 30 g/ℓ boric acid and 2g/ℓ saccharin. γ-Al_2O_3 powders (30nm in average diameter) were suspended in the bath. The pH was adjusted to a constant value of 4 by sulphuric acid at 50±1C. Direct current was used, and the current density was 30mA/cm^2. A nickel plate of 99.9% purity was used as the anode, and stainless steel plate was used as the cathode. Plating time was 3 h, and always stirring it by a magnetic stirrer placed at the cell bottom. Grain size was determined by direct measurement on transmission electron microscope (TEM, JEM2100F) bright-field micrographs.

Observation by TEM on Ni- Al_2O_3 composite revealed the average grain size was 55nm. EDS map of the sample is shown in Fig.1. The Al_2O_3 particles are uniformly distributed throughout the Ni matrix. However, many agglomerates of Al_2O_3 particles with cluster sizes about 5μm are also observed. Relationship between Al_2O_3 concentration in the bath and amount of deposit is shown in Fig.2. The amount of Al_2O_3 deposit increased with amount of Al_2O_3 concentration to the bath to 40g/ℓ, but it decreased in 50g/ℓ. It seems that there is an optimum contents of alumina powders in the bath. Relationship between Al_2O_3 content in the deposite and Vickers microhardness is shown in Fig.3. The Vickers microhardness increase with amount of Al_2O_3 content.

Fractured surfaces were observed after tensile test. The surface exhibited a typical dimple surface containing Al_2O_3 particles in the bottom. Some Al_2O_3 particles were cohered in the fracture face. The Al_2O_3 content of fracture surface by EDS analysis was 5-8 wt.%, and it is higher than that of the bulk content. Therefore, it can be considered that the cause of the decrease tensile stress is cohesion of Al_2O_3 content.

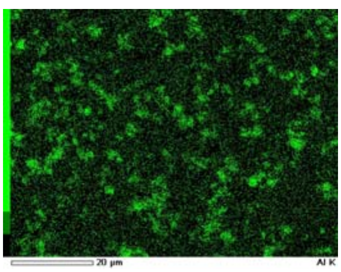

Figure 1: EDS image of dispersed Alumina particles in Ni deposite.

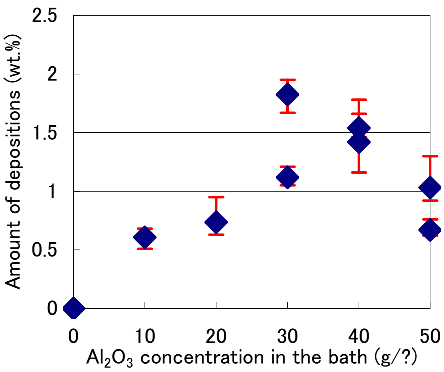

Figure 2: Relation between amount of alumina deposited in Ni and that in the bath. deposite.

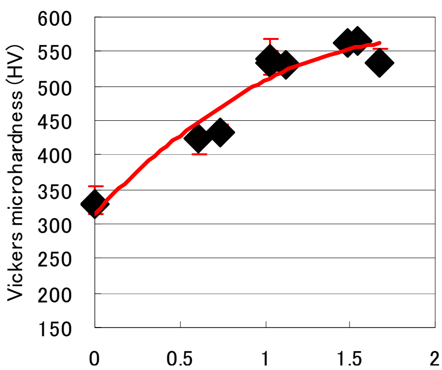

Figure 3: Relation between amount of alumina deposited in Ni and Vickershardenss.