A study on the thermal stability of electrodeposited Ni-P-Fe and Ni-P-B at 325℃

Myong Jin Kim [a*], Sang-Hyun Ryu [a], Dong Jin Kim [a], Joung Soo Kim [a], Hong Pyo Kim [a]
[a]*Nuclear Materials Research Division, Korea Atomic Energy Research Institute, 1045 Daedeokdaero, Yuseong, Daejeon, Korea*
[*]*Corresponding author: mjkim@kaeri.re.kr*

1. Introduction

A repair system for damaged steam generator tubes using an electrodeposit sleeving technology was developed for nuclear power plants [1-2]. The electrodeposit sleeving technology is a simple and economical method to repair the damaged steam generator tubes of nuclear power plants. New Ni-alloys deposits such as Ni-P-Fe and Ni-P-B were tried to be electroplated in the steam generator tubes for repairing the tubes inside. And the mechanical properties of these electrodeposited alloys have been studied [3]. But there have been few studies on the thermal stability of the electrodeposited Ni-P-B and Ni-P-Fe [4].

In this paper, the results of study on the thermal stability of Ni-P-Fe and Ni-P-B at 325 ℃ for 30 days will be presented.

2. Experimental

The electrodeposition was performed in a sulfamate bath with 1.39 mol/ℓ Nickel sulfamate, 0.65 mol/ℓ H_3BO_3. Borane-dimethylamine complex as a boron source and ferrous sulfamate as an Fe source were used with their concentrations of 0.001 mol/L and 0.0025 mol/L, respectively, and pH of the solution was adjusted with an amidosulfuric acid. The concentration of phosphorous acid as a P source was 0.0035 mol/L for Ni-P-Fe and 0.007 mol/L for Ni-P-B, respectively. The cathode was the 3/4˝ alloy 600 tube and the anode was a cylindrical Pt. The tube substrate was degreased and activated in 5 wt% NaOH and 5wt% H_2SO_4, respectively, before each deposition. The electroplating was done at a constant temperature of 60 ℃ and an average pulsed current density of 100 mA/cm^2 having 50% duty cycle. After plating, Ni-P-Fe and Ni-P-B deposits were stripped from the cathode, followed by an annealing treatment at 325 ℃ for different time period. Microhardness tests were carried out 10 times for each specimen using an Akashi HM-124 hardness tester with a 50 g load for 10 seconds. The tensile tests were performed three times for each specimen using the Instron 4505 at a strain rate of 1 mm/min. The fracture surface of the test specimens was observed by Scanning Electron Microscope.

3. Results and discussion

2.1 Microhardness tests

Fig. 1 depicts the measured Vickers hardness values of Ni-P-Fe and Ni-P-B alloys as a function of the heat treatment time. The measured hardness shows not much variation regardless of the heat treatment time

2.2 Tensile strength and elongation tests

Fig. 2 and Fig. 3 present ultimate tensile strength of the electrodeposited Ni-P-Fe and Ni-P-B after heat treatment. In case of Ni-P-B, the ultimate tensile strength was slightly increased with the heat treatment time, while that of Ni-P-Fe was decreased sharply after heat treatment in 10 days. Fig. 4 and Fig. 5 indicate the elongation with the increment of the heat treatment time. The elongation of the two deposits decreased at the early period of heat treatment. Fig. 6 shows the fracture surfaces of the tensile test specimens. The fracture surface of the Ni-P-B was relatively smooth and flat, but that of the Ni-P-Fe had two distinctive layers formed during electrodeposition.

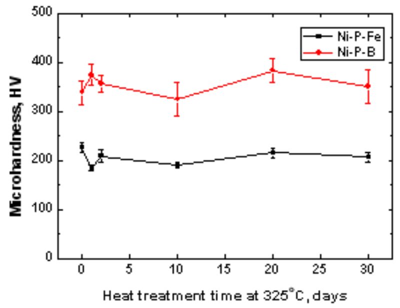


Fig. 1. The room temperature microhardness of the Ni-P-Fe and the Ni-P-B after annealing at 325℃ for different time.

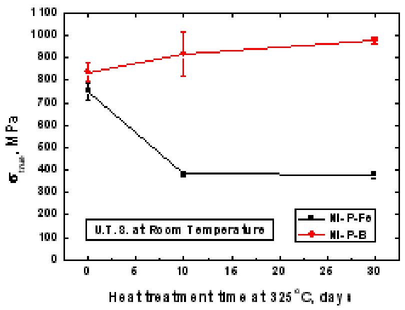


Fig. 2. The room temperature tensile strength of the Ni-P-Fe and Ni-P-B deposits after annealing at 325℃ for different time.

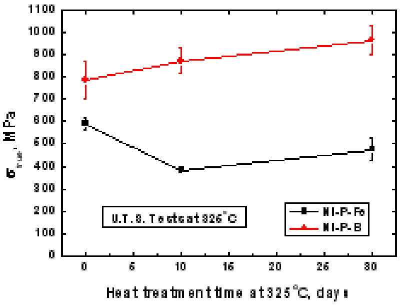


Fig. 3. The tensile strength of the Ni-P-Fe and Ni-P-B deposits measured at 325℃ after annealing at the same temperature for different time.

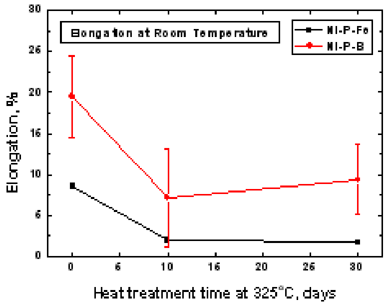


Fig. 4. The elongation of the Ni-P-Fe and Ni-P-B deposits measured at R.T. after annealing at 325°C for different time.

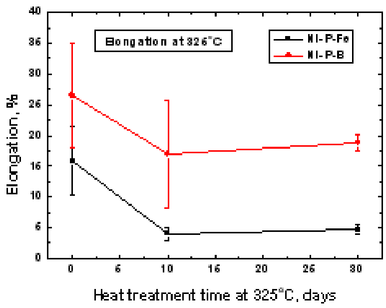
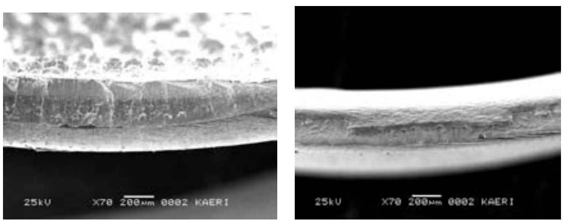
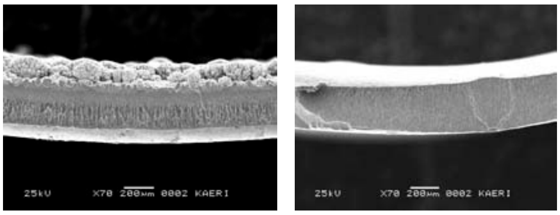


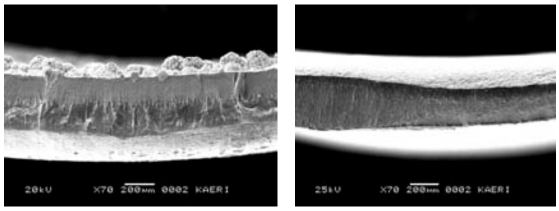
Fig. 5. The elongation of the Ni-P-Fe and Ni-P-B deposits measured at 325℃ after annealing at the same temperature for different time.



(a) (d)



(b) (e)



(c) (f)

Fig. 6. The fracture surfaces obtained at room temperature of (a) the Ni-Fe-P as-plated and (b) heat treated at 325°C for 10 days (c) and for 30 days, (a) the Ni-P-B as-plated and (b) heat treated at 325°C for 10 days (c) and for 30 days

4. Conclusions

The mechanical properties of the electrodeposited Ni-P-B and Ni-P-Fe alloys after annealing at 325 ℃ for different periods of annealing time were studied. According to the test results, their microhardness did not change much with the annealing time. The tensile strength of the electrodeposited Ni-P-B was slightly increased and the elongation was decreased with the heat treatment time. In the case of the Ni-P-Fe, however, the tensile strength and the elongation were decreased with heat treatment time. SEM images show the fracture surface of the Ni-P-B was smooth and flat, while that of the Ni-P-Fe had two distinctive layers formed during electroplating.

REFERENCES

[1] F. Gonzalez, A. M. Brennenstuhl, G. Palumbo, U. Erb and P. C. Lichtenberger, Materials Science Forum, 225-227, p.831, 1996.
[2] A. Robertson, U. Erb, and G. Palumbo, Nanostructured Materials, Vol. 12, p.1035, 1999.
[3] D. J. Kim, M. H. Seo, and J. S. Kim, Corrosion science and technology, Vol. 3, p.112, 2004.
[4] D. J. Kim, M. J. Kim, J. S. Kim and H. P. Kim, Nuclear engineering and technology, Vol. 39, p.231, 2007.