Formation of Electroless Nickel-Boron on Magnesium and AZ91D Alloy

E. Correa[1], A. A. Zuleta[1], L. Guerra[1], J. G. Castaño[1], F. Echeverría[1], A. Baron-Wiecheć[2], P. Skeldon[2] and G. E. Thompson[2]
[2]LATEST2, School of Materials, The University of Manchester

Due to a low density and high strength-to-weight ratio, magnesium alloys have become a commonly preferred choice for weight reduction in applications such as automobile and computer parts, aerospace components, mobile phones, sporting goods, handheld tools and household equipment. However, poor corrosion and wear resistance are challenges to the successful use of magnesium alloys. Various coatings, which provide a means to avoid direct contact of the alloy with the environment, are being investigated to provide corrosion protection. Recently, electroless nickel–boron has attracted research interest due to its ability to provide a hard, wear and corrosion resistant surface. The most difficult aspect of the electroless process is often the selection of an appropriate pre-treatment, which should promote a rapid initiation of the electroless coating and minimize corrosion of the substrate. Some plating technologies use hydrofluoric acid (HF) or chromic compounds in order to protect the magnesium surface or to generate a suitably rough surface to enhance coating adhesion. However, such chemicals are hazardous to health. Notably, little work has been reported on the formation of electroless Ni–B on magnesium alloys without the use of these compounds.

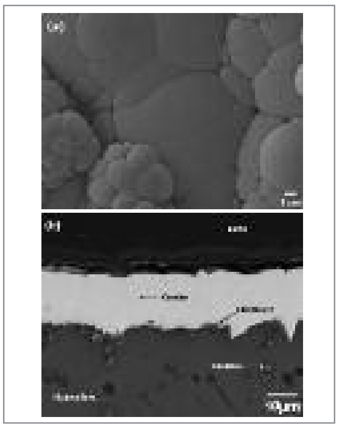

Fig. 1 Scanning electron micrographs (backscattered electrons) of magnesium in (a) plan and (b) cross-section after 120 min immersion in an alkaline Ni–B electroless bath containing 5 g/l NH_4HF_2.

Within the LATEST2 programme, in collaboration with the University of Antioquia, procedures have been developed to coat commercial purity magnesium and the general purpose casting alloy AZ91 by means of an electroless Ni–B process that provides a uniform, adherent and continuous layer without employing HF or chromic compounds. The substrates were mechanically polished with wet 100 grit SiC paper, then grit-blasted with alumina (150 µm), rinsed with deionized water, immersed sequentially in ultrasonic baths containing acetone and ethanol, and dried in a hot air stream. A final cleaning was carried out in 37 g/l NaOH and 10 g/l Na_3PO_4 for 10 min at 65 °C, followed by activation in 200 g/l NH_4HF_2 at room temperature for 10 min, and finally immersion in an electroless bath containing various additives, listed in Table 1, including NH_4HF_2, which is easier to handle, less volatile and cheaper than HF.

Table 1. Chemical composition of the electroless nickel plating bath and coating conditions.

Chemical composition	
$NiCl_2{\cdot}6H_2O$	20 g/l
$NaBH_4$	8 g/l
CH_4N_2S	1 mg/l
$C_2H_8N_2$	35 ml/l
NaOH	110 g/l
NH_4HF_2	Variable
Operating conditions	
pH	> 12
Temperature	80 °C
Plating time	120 min

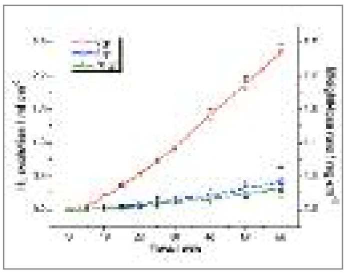

Fig. 2 Dependence of the amount of hydrogen evolved and average weight loss rate on time of immersion in 3.5 wt.% sodium chloride solution for magnesium with electroless Ni–B coatings formed in baths containing different concentrations of NH_4HF_2.

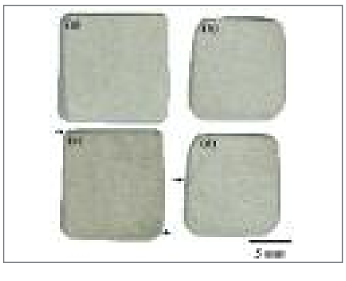

Fig. 3 The appearances of specimens treated in an electroless bath containing 5 g/l before (a, b) and after (c, d) immersion in 3.5 wt.% sodium chloride solution for 60 minutes. Arrows point to locations of corrosion.

Figure 1 shows the typical nodular morphology of the coatings, which can be grown to various thicknesses by selection of the time of immersion in the electroless bath. The rate of coating growth is approximately constant, of the order 10 µm/h, and only weakly dependent on the composition of the substrate. Control of the fluoride concentration in the electroless bath is important to minimize the corrosion rate of the coated alloy, as demonstrated in Figure 2, which displays the amount of hydrogen gas generated due to corrosion of the coated magnesium in sodium chloride solution. The coatings were formed in baths with a range of fluoride contents, with the results showing that corrosion is accelerated by an excess of fluoride, which is related to generation of porosity in the coating. With an optimized bath composition, corrosion of coated coupons following immersion in sodium chloride solution is limited to the edges and corners, as shown in figure 3. Further testing has revealed an excellent wear resistance of the coatings, with a greatly reduced wear rate compared with that of the uncoated alloy. Parallel investigations have also developed baths for generation of Ni-P coatings, which generally show a better corrosion protection than Ni-B coatings. Work is continuing on the development of the coatings.

Acknowledgements: [1]Centro de Investigación, Innovación y Desarrollo de Materiales—CIDEMAT, Universidad de Antioquia UdeA, Calle 70 No. 52-21, Medellín, Colombia

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Publications: A. A. Zuleta, E. Correa, M. Sepúlveda, L. Guerra, J.G. Castaño, F. Echeverría, P. Skeldon and G. E. Thompson, Effect of NH_4HF_2 on deposition of alkaline electroless Ni-P coatings as chromium-free pre-treatments for magnesium. Corros. Sci. 55 (2012) 194-200.

E. Correa, A. A. Zuleta, M. Sepúlveda, L. Guerra, J.G. Castaño, F. Echeverría, P. Skeldon and G. E. Thompson, Nickel-boron plating on magnesium and AZ91D alloy by a chromium-free electroless process. Surf. Coat. Technol. 206 (2012) 3088-3093.

Esteban Correa, Alejandro Alberto Zuleta, Laura Guerra, Maryory Goméz Botero, Juan G. Castaño, Félix Echeverría, Hong Liu, Peter Skeldon and George E. Thompson, Tribological behaviour of electroless Ni-B coatings on magnesium and AZ91D alloy. Wear 305 (2013) 115-123

E. Correa, A. A. Zuleta, L. Guerra, J. G. Castaño, F. Echeverría, A. Baron-Wiecheć, P. Skeldon and G. E. Thompson, Formation of electroless Ni-B on bifluoride-activated magnesium and AZ91D alloy. J. Electrochem. Soc. 160 (2013) D327-D336.

E. Correa, A. A. Zuleta, L. Guerra, M. A. Gómez, J. G. Castaño, F. Echeverría, H. Lui, A. Baron-Wiecheć, T. Hashimoto, P. Skeldon and G. E. Thompson. Coating development during electroless Ni-B plating on magnesium and AZ91D alloy. Surf. Coat. Technol. 232 (2013) 784-794.