Enrichment Effect During Ion Beam Sputter Deposition of Mg Alloys ◇

J.W. Gerlach [a], Y. Bohne [a], S. Mändl [a], B. Rauschenbach [a], M. Schubert, and W. Assmann
[a] Leibniz-Institut für Oberflächenmodifizierung, Leipzig

Magnesium and its alloys could meet the requirements for transportation applications due to their excellent weight-to-strength ratio. However, improvements in the presently poor corrosion behaviour have to be made as an unprotected use of these alloys under atmospheric conditions is almost excluded. One path to meet these requirements, beside the development of modern alloys, is the formation of nanocrystalline or amorphous phases.

Ion beam sputtering is known to allow the congruent transfer of material from the target to the substrate at low deposition temperatures while achieving very high cooling rates on the substrate. Furthermore, an increased energy per particle compared to evaporation methods should lead to pore-free high-density coatings with excellent adhesion properties and slightly compressive stress within the films.

In the present experiment, four different alloys were used as sputter targets, commercially pure (cp) Mg and the MgAl-alloys AZ91, AM50, and AE42 (the first number in the alloy code indicates the weight% of Al). Si(100) was employed as substrate material. Argon ions with an energy between 800 and 1200 eV at a total current of 30 - 40 mA were used for sputtering. Subsequent ERDA measurements were performed with a position sensitive ionization chamber using 200 MeV Au ions.

The deposition rate varied between 2 and 10 μm/h at a target-substrate distance of 15 cm. Thicker films were found for higher ion energies and cp-Mg whereas lower ion energies or additional alloying elements reduced the deposition rate [1].

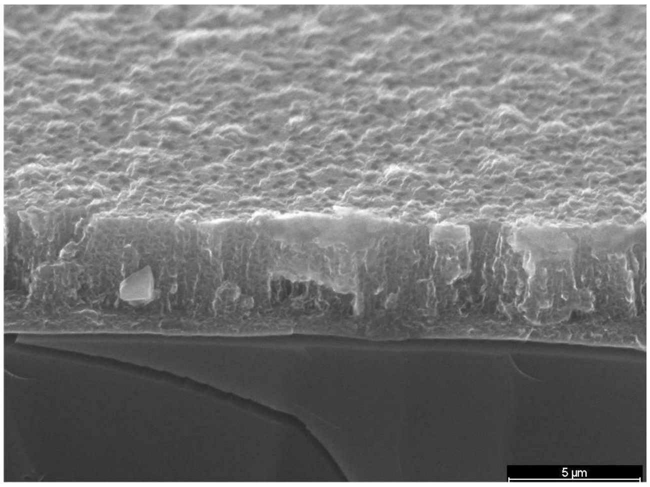

Fig. 1: SEM viewgraph of a thin film deposited from cp-Mg within 30 min at 1200 eV ion energy

At the same time, densely packed columnar grains with a diameter of approximately 1 μm were found for all films (see Fig. 1), covering the whole substrate. A rather good adhesion can be inferred from the fractured sample.

ERDA was used to measure the chemical composition of the samples. Concentration of all sample components (as indicated in Fig. 2) could be determined with reasonable accuracy. Contaminations of O, N and C were found on all films with respective concentrations of 0.3, 0.2 and 0.1 at.%. At 800 eV ion energy the Al content varied from 2.4 and 2.5 at.% for AE42 and AM50 up to 3.5 at.% in AZ91. Compared to base material of the sputter targets the alloys show a reduction of the Al content by about 50%. Increasing the ion energy to 1200 eV results in a further reduction of the Al content to about 15%. Complementary RBS and SIMS measurements revealed similar tendencies for the heavier components of the alloys [2]. An upper limit for the Ar sputter beam contamination was found to be at 1.0 at% with EDX. Apparently, sputter yield and angular distribution are strongly dependent on the ion energy for these multi-component sputter targets. Further investigations are going on to understand the different sputter deposition rates.

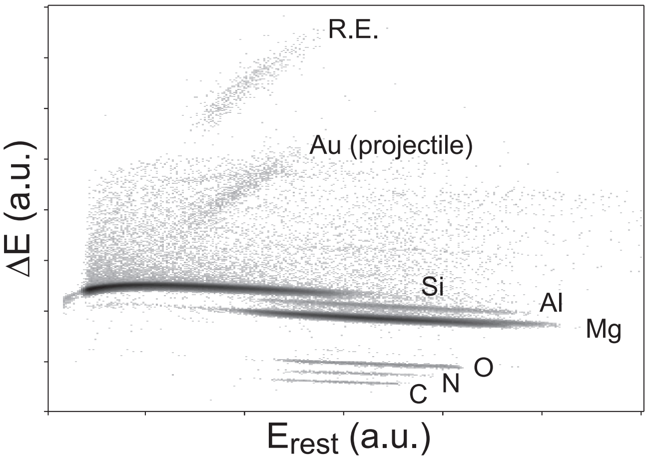

Fig. 2: $\Delta E - E_{rest}$ spectrum of ERDA with 200 MeV Au ions of a 850 nm thick sputter deposited film using a AE42 sputter target and 800 eV Ar ions. R.E. indicates rare earth elements alloy component, mainly Ce and La.

X-ray diffraction measurements have shown that only the hexagonal Mg phase is present in the surface layer while no additional precipitates are formed. However, a slight variation of the lattice constant was found which is due to to the changing Al content and stress. The microcrystalline films exhibited improved corrosion properties with a higher polarisation resistance and an extended passive array compared to the as-cast alloys [1]. Within the sputter deposited films only minor variations of these properties with the ion energy were observed.

References

[1] C. Blawert *et al.*, The Minerals, Metals & Materials Society Meeting 2005, San Francisco, CA (Feb 2005)

[2] Y. Bohne *et al.*, DPG Spring Meeting, Berlin, 2005 (Mar 2005)

◇ This project was supported by the DFG within SPP 1168 "Erweiterung der Einsatzgrenzen von Magnesiumlegierungen"