Improved ceramic oxide layers on magnesium alloys through a combination of pulsed plasma-electrolytic oxidation and chemical nanotechnology

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Background and Aims

The use of magnesium as a construction material can be very beneficial especially in application fields where weight reduction plays an important role, as in automobile or aviation industries. Due to its very low weight, a broader use of magnesium could help to significantly reduce fuel consumption and the associated costs and pollution. However, the widespread application of magnesium alloys is still considerably hindered by their high susceptibility to corrosion. A second issue is their low resistance to abrasion. One possible approach to enhance both corrosion and wear resistance of magnesium alloys is their pretreatment by anodic oxidation. Specifically, plasma-electrolytic oxidation (PEO) is a promising technique since it allows the generation of ceramic type oxidic coatings with very good adhesion to the substrate and excellent protective properties.

Results

- Immobilizing corrosion inhibitors on microporous nanoparticles
  - Mesoporous SiO2 nanoparticles as carriers for corrosion inhibiting lanthanide cations
    - High surface area and loading capacity
    - Tailoring of loading and release behaviour via functionalization of particle surface
  - Loading of carrier particles with lanthanide cations
    - Grafting of particle surface with amino functionality (fig. 1)
    - Increased affinity and loading capacity for lanthanide cations (fig. 2).
  - pH-dependent release of lanthanide cations
    - Inhibitor release at acidic pH by protonation of amine function (fig. 3 and 4)

- PEO and simultaneous nanoparticle incorporation
  - Optimization of anodizing batch composition
    - Pulsed galvanostatic anodizing of Mg AZ31 (20 mA/cm²)
    - Anodizing bath with 10 g/L Na2SiO3 and varying KOH content:
      - 5 g/L KOH
      - 7.5 g/L KOH
      - 10 g/L KOH
  - Incorporation of nanoparticles into PEO coating
    - Pulsed anodizing of Mg AZ31 (20 mA/cm²)
    - Incorporation of compact nanoparticles via addition to anodizing bath (fig. 7)
    - Incorporation of lanthanide cation filled zeolite particles via addition to anodizing bath (fig. 8)

Outlook

- Incorporation of amino-functionalized, Ce³⁺ carrying nanoparticles in PEO coatings
  - Enhancement of loading capacity for Ce³⁺ corrosion inhibitor via activation of particle surface for more efficient amino-functionalization
- Incorporation of zeolite nanoparticles
  - Screening for zeolite framework type with optimal loading and release properties with respect to lanthanide cations
- Improvement of solid SiO₂ nanoparticles
  - Application of modified particles with lowered sintering temperature
  - Sintering of particles through high temperatures involved in PEO
  - Densification of composite coatings