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A Comprehensive Review on the Corrosion Resistance of Mg-Li Alloys

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Abstract. Magnesium-lithium (Mg-Li) alloys represent the pinnacle of structural light-weighting, essential for aerospace and defense applications requiring high specific stiffness and damping capacity. However, the extreme electrochemical activity of Li and the formation of porous natural surface films with a Pilling-Bedworth ratio (PBR) below 1 severely limit their environmental reliability. This review provides a comprehensive analysis of Mg-Li corrosion mechanisms, detailing thermodynamic instability, the negative difference effect (NDE), and microstructural influences such as α/β phase boundaries and cathodic second phases. We further examine optimization through micro-alloying with rare-earth elements like Sc and Y, which refine grains and enhance film stability. Advanced manufacturing techniques, including severe plastic deformation (SPD) and wire-arc additive manufacturing (WAAM), are evaluated for their ability to homogenize phases and induce dynamic passivation. Finally, the review assesses state-of-the-art surface protection, specifically micro-arc oxidation (MAO) integrated with layered double hydroxides (LDH) for active Cl- capture, and stimuli-responsive smart coatings that provide autonomous self-healing. A synergistic strategy—coupling intrinsic microstructural resistance with multi-layer smart protection—is proposed as the future standard for ensuring the long-term service of Mg-Li alloys in harsh environments.

Keywords: Mg-Li alloys, anti-corrosion, corrosion behavior

1. Introduction

Magnesium-lithium alloys are among the lightest structural metallic materials available today [1, 2]. With the addition of lithium, their density decreases from approximately 1.74 g/cm³ for pure magnesium to 1.35–1.65 g/cm³ [3], which is over one-third lighter than traditional aluminum alloys and more than 75% lighter than steel. Magnesium is abundant on Earth, accounting for about 2% of the crust's composition, providing sufficient mineral resources for the development, research and application of Mg-Li alloys. China is also one of the world's major countries rich in magnesium and lithium resources. Boasting ultra-light weight, excellent specific strength, good processability, outstanding damping performance and electromagnetic shielding capability [4, 5], Mg-Li alloys are widely applied in aerospace, automotive, biomedical, electronic and portable equipment fields [6-8].

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Nevertheless, their broader application is restricted by inherent drawbacks, including low strength, poor stability and unsatisfactory corrosion resistance caused by high chemical activity. This is mainly due to grain coarsening and insufficient alloying elements resulting from increased lithium content, as well as galvanic corrosion triggered by the potential difference between α-Mg and β-Li phases in dual-phase alloys. This further accelerates corrosion, significantly reducing their corrosion resistance [9] and limiting their engineering applications [10, 11].

Various methods have been proposed to address these shortcomings of Mg-Li alloys, such as alloying [12] and grain refinement [13] in terms of processing technologies, as well as surface treatment and anti-corrosion coatings [14-16]. To further understand their corrosion behavior and corrosion protection measures, this paper first elaborates on their corrosion mechanisms, then reviews and summarizes current research progress on corrosion protection of Mg-Li alloys, and discusses several issues regarding future solutions to improve their corrosion resistance. It aims to provide potential guidance for the development and application of new Mg-Li alloys with high corrosion resistance.

2. Corrosion mechanisms of Mg-Li alloys

Corrosion is the main problem limiting the engineering application of Mg-Li alloys. Magnesium has a standard electrode potential of -2.363 V and high chemical activity, making it prone to chemical and electrochemical reactions with oxides and hydroxides in atmospheric and seawater environments. Lithium has an even lower standard electrode potential of -3.045 V than magnesium, so Mg-Li alloys exhibit stronger chemical activity than pure magnesium [17]. The relative densities of the natural protective films formed by magnesium and lithium are 0.79 and 0.57 respectively, which cannot effectively protect the alloy matrix. In corrosive environments, Mg-Li alloys undergo continuous oxidative corrosion accompanied by the shedding of surface corrosion products. In aqueous solutions, corrosion is further aggravated by the erosion of corrosive ions and galvanic corrosion between multiple phases. In short, Mg-Li alloys are highly susceptible to corrosion and severe erosion in most environments.

Regarding corrosion mechanisms, alloying elements in traditional magnesium alloys have a higher potential than the magnesium matrix, forming cathodic second phases that easily react with oxides and chlorides in the environment to generate corrosion products. Meanwhile, due to the significant potential difference between various phases in Mg-Li alloys, micro-galvanic corrosion becomes the dominant mechanism, with the magnesium matrix acting as an anode to accelerate dissolution—this is a typical form of magnesium alloy corrosion [18, 19].

Corrosion of Mg-Li alloys follows a sequence of preferential lithium dissolution followed by magnesium shedding, leading to a sharp decline in corrosion resistance. Magnesium reacts with corrosive ions in aqueous solutions, with hydrogen evolution occurring at the cathode and dissolution taking place at the anode. The reaction processes are as follows:

Cathodic reaction:

$$H_2O + 2e^- \rightarrow 2H_2 + 2OH^-$$

Anodic reaction:

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$$Mg \rightarrow Mg^{2+} + 2e^{-}$$

$$Li \rightarrow Li^{+} + e^{-}$$

Formation of corrosion products:

$$Mg^{2+} + 2OH^{-} \rightarrow Mg(OH)_2$$

$$Li^{+} + OH^{-} \rightarrow LiOH$$

Under the influence of oxygen and carbon dioxide in the environment, corrosion products undergo further reactions:

$$2Mg^{2+} + O_2 \rightarrow 2\,MgO$$

$$Mg(OH)_2 + CO_2 \rightarrow MgCO_3 + H_2O$$

$$4Li^{+} + O_2 \rightarrow 2\,Li_2O$$

$$2LiOH + CO_2 \rightarrow Li_2CO_3 + H_2O$$

The corrosion behavior of low-lithium Mg-Li alloys is related to the composition of the second phase, grain size and corrosion product film, similar to that of ordinary magnesium alloys. Uniform corrosion dominates in the atmosphere because the oxide layer on the surface of Mg-Li alloys is unstable and easily eroded by water vapor and oxygen to form hydroxides and oxides, resulting in loss of surface luster. In addition, acid rain and salt spray in the atmosphere accelerate the corrosion of Mg-Li alloys. In atmospheric environments, humidity and pollution level are the main factors affecting the corrosion degree of Mg-Li alloys [20]. In aqueous solutions, pitting corrosion, filiform corrosion and galvanic corrosion are the main corrosion forms. Regarding corrosion mechanisms, Song et al. [17] described the characteristics of filiform corrosion in Mg-8Li alloys, pointing out that corrosion preferentially occurs at the interface between α-Mg and β-Li phases, then extends into the highly active β-Li phase. The front end of corrosion filaments is acidic, promoting magnesium dissolution, while the alkaline environment at the tail end facilitates the formation of corrosion products such as $Mg(OH)_2$ and LiOH. The cathodic hydrogen evolution reaction correspondingly accelerates the expansion rate of corrosion filaments. Recent studies show that after initiating at the

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two-phase interface, corrosion preferentially expands in the α-Mg phase in the form of filiform corrosion, while intergranular corrosion occurs in the β-Li phase [21].

Mg-Li alloys with high lithium content exhibit significantly different corrosion characteristics. Studies indicate that when the lithium content exceeds 10.3% to form a single-phase β-Li structure, a dense Li_2CO_3 protective film can form on the alloy surface. This film has a low standard enthalpy of formation and high chemical stability, providing a certain protective effect. However, the formation of this protective film relies on sufficient carbon dioxide supply in the environment; a complete covering takes a long time to form under atmospheric CO_2 concentration. Moreover, corrosive ions such as Cl^- can destroy the integrity of the film, leading to local corrosion. Dong et al. [22] found that the Li_2CO_3 film formed on the surface of Mg-Li alloys is dense and protective, mainly due to the low standard enthalpy of formation and high chemical stability of Li_2CO_3.

Mg-Li alloys with medium lithium content usually have a dual-phase structure, where galvanic corrosion preferentially occurs at the interface. Lithium is the most active metallic element, and adding lithium to magnesium generally reduces the alloy's corrosion resistance. Single-phase β-Li Mg-Li alloys have a BCC crystal structure with a much higher lithium content than single-phase α-Mg alloys. The corrosion resistance of β-Li phase Mg-Li alloys is worse than that of single-phase α-Mg alloys.

3. Corrosion resistance optimization: alloy design and preparation processes

Optimizing the corrosion resistance of Mg-Li alloys has long been the key to their application. Early research mainly focused on adding alloying elements to adjust composition, as well as optimizing microstructures through plastic deformation and heat treatment processes [23, 24]. This chapter discusses the mechanisms by which alloy design and preparation processes affect the corrosion resistance of Mg-Li alloys.

3.1. Alloy design

Alloying is the most direct method to regulate the corrosion behavior of Mg-Li alloys. Introducing specific alloying elements can change the phase composition, refine grains and improve the compactness of the surface passivation film. For Mg-Li alloys, alloying elements fall into three categories. First, the addition of cathodic elements such as Al and Zn. As shown in Figures 1(b-d), Lin et al. [25] found that adding Al and Zn to Mg-Li alloys promotes the formation of a dense $Mg(OH)_2$ passivation film. Compared with Mg-Li alloys without these elements, the corrosion rate decreases by 30%, effectively slowing down corrosion initiation and progression. Although Sun et al. [26] enhanced the matrix by adding Zn, excessive Zn causes severe segregation, increasing local potential differences and exacerbating galvanic corrosion. In addition, scholars have studied the effects of adding elements such as Ca, Sr and Sn on the properties of Mg-Li alloys [27]. Nene et al. [28] compared L4 (Mg-4Li) and LC41 (Mg-4Li-1Ca) alloys, pointing out that adding Ca not only refines grains but also improves corrosion resistance by forming stable precipitated phases at grain boundaries. Tian et al. [29] added Sn to Mg-Li alloys, weakening anodic corrosion reactions and slowing down corrosion through two key mechanisms: forming Mg_2Sn phases and reducing potential differences. Adding rare earth elements such as Y, Ce, Nd and Gd is another important method to improve the corrosion resistance of Mg-Li alloys, mainly through two mechanisms. First, rare earth elements promote the formation of a denser oxide passivation film on Mg-Li alloys [30]. Second, they inhibit galvanic corrosion between α-Mg and β-Li phases. Peng et al. [7] proved that combined alloying with Sn and Y forms Mg_2Sn and Al_2Y phases in Mg-Li alloys, significantly

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improving mechanical properties through second-phase strengthening and grain refinement. Although the corrosion mode remains unchanged, corrosion resistance is enhanced.

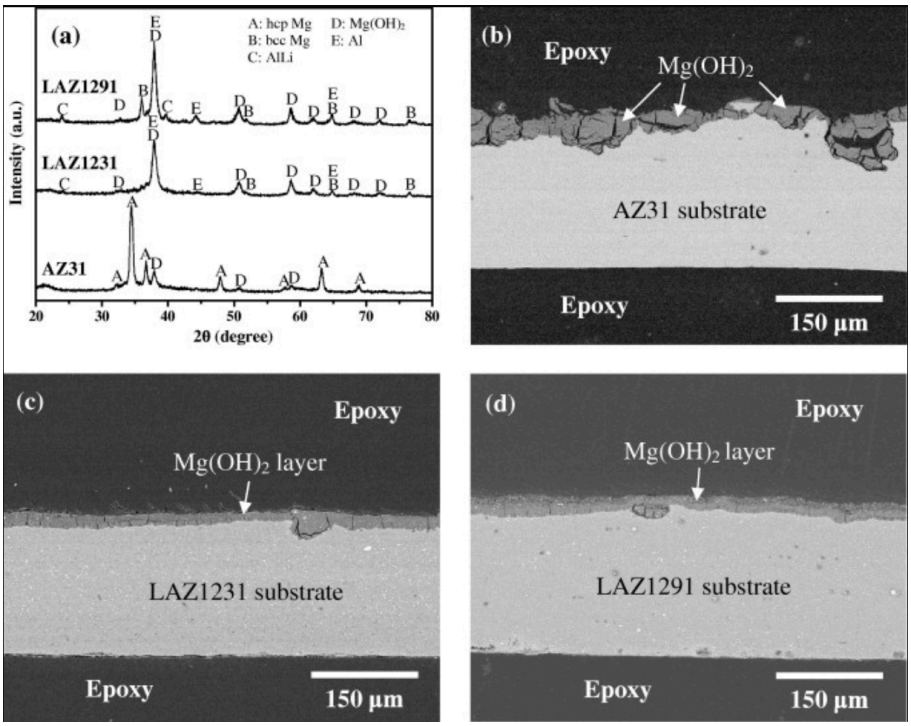

Figure 1. GIXRD pattern from the surface of AZ31, LAZ1231 and LAZ1291 foils. Cross-sectional images of the (b) AZ31; (c) LAZ1231; (d) LAZ1291 [25]

3.2. Effects of advanced preparation processes

In addition to composition design, advanced processing technologies can adjust grain morphology, phase distribution and grain boundary characteristics, thereby altering corrosion pathways.

3.2.1. Deformation technologies

Deformation technologies are widely used to improve the corrosion resistance of Mg-Li alloys, including forging, rolling, extrusion and plastic deformation. These technologies mainly enhance corrosion resistance by reducing grain size. Traditional deformation methods such as rolling, forging and extrusion can refine grains and increase grain boundary density, facilitating rapid nucleation and coverage of passivation films. However, for dual-phase (α+β) Mg-Li alloys, the selection of deformation parameters is extremely strict. Studies show that an excessively large rolling ratio (e.g., from 3 to 10) severely elongates and fractures the ductile α-Mg phase, significantly increasing the exposed area of the highly electrochemically active β-Li phase and causing a sharp deterioration in overall corrosion resistance.

To overcome the limitations of traditional deformation, friction stir processing (FSP) has been successfully applied to modify Mg-Li alloys in recent years. Recent research by Liu et al. shows that FSP combined with liquid carbon dioxide (CO_2) rapid quenching can refine grains of dual-phase Mg-Li-Al-Zn alloys to approximately 2 μm, while promoting the uniform distribution of high-density nano-precipitated phases. This extreme microstructure reconstruction not only completely inhibits the formation of harmful phases (such as coarse AlLi phases) but also promotes the

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formation of an aluminum-rich protective layer on the surface, resulting in an extremely low electrochemical degradation rate of 0.72 $mg \cdot cm^{-2} \cdot day^{-1}$. Equal channel angular pressing (ECAP) is also a severe plastic deformation technique. Liu et al. [31] found that appropriate deformation processing can refine grains of Mg-Li alloys to micron or even nanometer scale, and the increased grain boundary density facilitates rapid nucleation of surface protective films. However, in dual-phase (α-Mg+β-Li) alloys, severe deformation fractures the ductile α-Mg phase, widely exposing the highly active β-Li phase. If proper annealing is not performed after processing to eliminate internal stress, residual strain energy will induce more severe intergranular corrosion.

3.2.2. Rapid solidification technologies

During the manufacturing of Mg-Li alloys, twin-roll quenching, melt spinning and spray casting are used. Meschter et al. [32] studied the microstructures of Mg-9Li, Mg-9Li-1Si and Mg-9Li-1Ce alloys prepared by twin-roll quenching and conventional processes. The results show that twin-roll quenching refines the alloy microstructure by 10–30 times compared with conventional processes. As shown in Figure 2, Matsuda et al. [33] prepared Mg-13Li-4Si-1Ag specimens with a thickness of 50–100 μm using melt spinning. Optical microscopy (Figures 2(a, b)) reveals uniform composition of the specimens, and SEM surface morphology (Figures 2(c, d)) shows fine and uniform distribution of intermetallic phases (Mg_2Si, 2–3 nm) and a highly refined matrix.

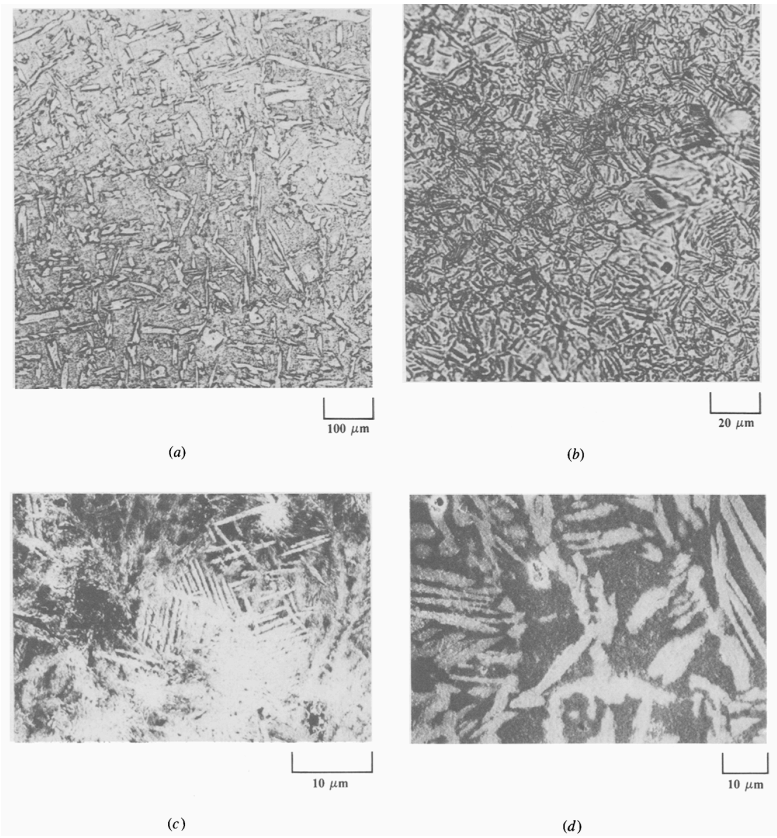

Figure 2. Microstructures of Mg-9Li alloys: (a) Mg-9.05Li, chill-cast (optical), (b-d) roller quenched flakes: (b) Mg-8.66Li (optical), (c) Mg-8.35Li-1.08Si (SEM), and (d) Mg-8.50Li-0.55Ce (SEM). hcp plates in bcc matrix [33]

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3.2.3. Additive manufacturing

In recent years, additive manufacturing technology has brought breakthroughs in the integrated design of structure and function for lightweight alloys. Xie et al. [34] prepared thin-walled LA103Z Mg-Li alloys using wire-arc additive manufacturing (WAAM) based on gas tungsten arc welding (GTAW). The results show that the grain size in the bottom region of the LA103Z thin wall differs significantly from that in the middle and upper regions, as shown in Figure 3(a). The main phases of the LA103Z thin wall include α-Mg phase, β-Li phase and some granular second phases (LiAl, Li_2MgAl). In addition, Figures 3(b, c) show that the thermal effect of subsequent deposited layers promotes the phase transformations of β-Li→α-Mg+β-Li and Li_2MgAl→LiAl. The mechanical properties of the LA103Z thin wall are comprehensively affected by multiple factors such as grain size, proportion and morphology of the α-Mg phase.

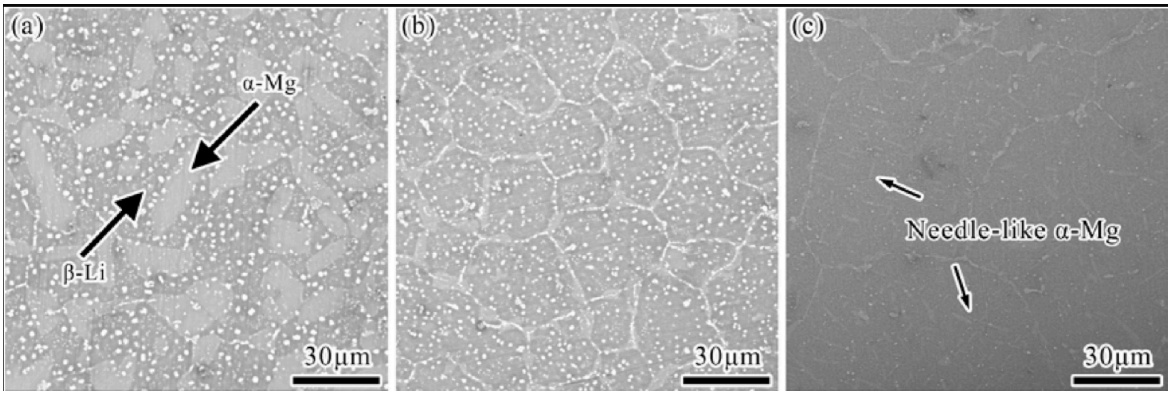

Figure 3. SEM micrographs of the LA103Z thin wall: (a) the microstructure of the bottom regions, (b) the microstructure of the middle regions, (c) the microstructure of the top regions [34]

In summary, although alloying and processing technologies can improve the mechanical properties and corrosion resistance of Mg-Li alloys, the improvement is limited and still insufficient to meet the requirements of practical engineering applications. Therefore, surface protection is a more promising approach to significantly enhance the corrosion resistance of Mg-Li alloys and improve their practicality in engineering applications.

3.3. Surface protection technologies: coatings and surface treatment

As mentioned earlier, although alloying and bulk plastic deformation can improve the inherent corrosion resistance of Mg-Li alloys to a certain extent, the highly negative standard electrode potentials of magnesium and lithium mean matrix modification cannot fundamentally block the spontaneous electrochemical reaction between the material and corrosive media. Thus, implementing surface engineering interventions to establish physical or chemical barriers between the alloy and service environments is an indispensable final defense to promote the practical engineering application of Mg-Li alloys. Current surface protection strategies are mainly divided into two systems: surface micro-modification technologies that maintain unchanged chemical composition [35, 36], and anti-corrosion coating technologies that introduce foreign substances.

Broadly defined, surface treatment refers to modifying the microstructure of the substrate material to enhance surface properties while maintaining its original macroscopic chemical composition, such as surface heat treatment and local severe plastic deformation. Quench-strengthened Mg-Li-Al alloys exhibit excellent specific properties, superior to other magnesium

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alloys including high-strength Mg-RE alloys [37]. However, water quenching has the adverse effect of brittleness in the β phase of aluminum alloys. Previous studies have shown that complete BCC–Mg–Li–Al alloys have almost no ductility after water quenching [38], making them nearly unusable. To achieve reasonable ductility, the concentrations of lithium and aluminum must be reduced to form an α+β dual phase [39]. Typically, when lithium and aluminum concentrations decrease from 13% and 5% to 3% respectively, ductility increases from nearly zero to about 18%. However, the main problem with α+β dual-phase Mg–Li–Al alloys is their rapid corrosion [8, 40]. The standard potential of the β phase (BCC Mg–Li) is even lower than that of the α phase (HCP Mg–Li), forming a local corrosion morphology originating from micro-galvanic coupling within the structure, where the β phase acts as a local anode [41]. As a result, the mass loss rate of α+β dual-phase Mg–Li alloys in marine atmospheres is approximately 4–6 times that of the commonly used commercial magnesium alloy AZ31. Due to the low hardness and easy oxidation of Mg-Li alloys, conventional surface heat treatment is difficult to control. In recent years, researchers have focused on high-energy beam or solid-state microstructure reconstruction technologies such as laser surface melting and surface friction stir processing. Laser surface melting uses a high-energy laser beam to instantly melt the alloy surface layer, followed by ultra-rapid solidification under an extremely high temperature gradient. This process not only eliminates casting defects such as shrinkage porosity on the surface but also completely dissolves coarse second phases prone to local galvanic corrosion into the matrix, forming a dense, highly homogeneous supersaturated solid solution layer on the surface, thereby significantly reducing the surface self-corrosion current. Surface friction stir processing introduces severe plastic deformation and frictional heat on the alloy surface via a high-speed rotating stirring pin, achieving surface grain nanocrystallization and optimizing grain boundary characteristics. This has been discussed in the manufacturing process section earlier.

When simple surface micro-modification fails to meet the requirements of harsh marine or industrial atmospheric environments, surface anti-corrosion protective coatings must be introduced to further enhance the corrosion resistance of Mg-Li alloys.

3.3.1. Chemical conversion coatings

Stannate conversion coatings are one of the most widely studied chromium-free chemical conversion technologies, usually prepared in alkaline solutions with pH > 12.4 [42]. Studies show that stannate conversion coatings prepared on Mg-8Li alloy surfaces are mainly composed of hemispherical $MgSnO_3 \cdot 3H_2O$ particles. The most uniform and dense coating with optimal corrosion resistance is obtained after 60 minutes of immersion. Recent studies have further improved the comprehensive performance of stannate coatings through functional additive modification. Introducing polyacrylic acid (PAA) to prepare Sn/PAA composite coatings on AZ31 magnesium alloy surfaces reduces the corrosion current density by nearly two orders of magnitude (from 1.06×10^{-4} to 2.35×10^{-6} $A\cdot cm^{-2}$) compared with the uncoated substrate, while achieving a hardness of 2.00 ± 0.26 GPa and an elastic modulus of 60.74 ± 6.39 GPa, significantly improving mechanical durability [43]. Figure 4 illustrates the mechanism by which PAA affects coating uniformity: PAA chains promote dense spherical grain accumulation through strong surface adsorption and extended conformation, enhancing coating uniformity and thickness and providing new ideas for green conversion coating design.

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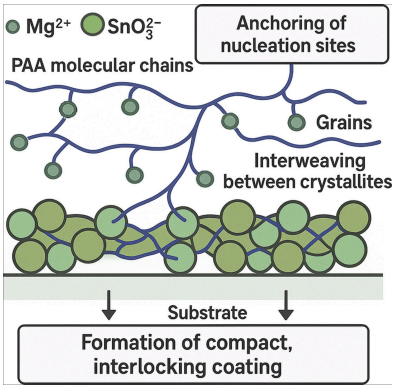

Figure 4. Schematic diagram of the formation mechanism for Sn/PAA coating [43]

Rare earth conversion coatings have received widespread attention due to their environmentally friendly nature. Acidic cerium nitrate conversion treatment is an important alternative to chromate, featuring a simple electrolyte composition and easy maintenance and recycling [44]. Studies show that the film formation mechanism of AZ91D magnesium alloy in Ce/H_2O_2 conversion solution involves selective dissolution of the dual-phase structure. Due to the potential difference between the α phase (-1.71 V vs SHE) and the β phase (-1.0 V vs SHE), the α phase passivates while the β phase preferentially dissolves in alkaline stannate solutions, with $MgSnO_3 \cdot 3H_2O$ particles mainly precipitating in the eutectic α+β region. In acidic cerium salt solutions, increased interface pH drives CeO_2 deposition, but severe corrosion in the central region of the primary α phase easily causes coating blistering. This finding reveals the key influence of matrix microstructure on conversion coating formation.

In addition to stannate and rare earth conversion coatings, environmentally friendly surface treatment technologies such as phosphate, vanadate, molybdate and phytic acid conversion coatings have also been applied to Mg-Li alloys. Phosphate conversion coatings provide short-term protection by forming insoluble phosphates such as $CaHPO_4 \cdot 2H_2O$ and $Ca_3(PO_4)_2$; vanadate conversion coatings have self-healing properties; as shown in Figure 5, phytic acid conversion coatings form dense protective layers through the multi-tooth chelating ability of their six-phosphate cyclic structure [45]. However, single chemical conversion coatings are usually thin (sub-micron thickness) and wear-resistant, so they are mostly used as base coatings for organic coatings in practical engineering.

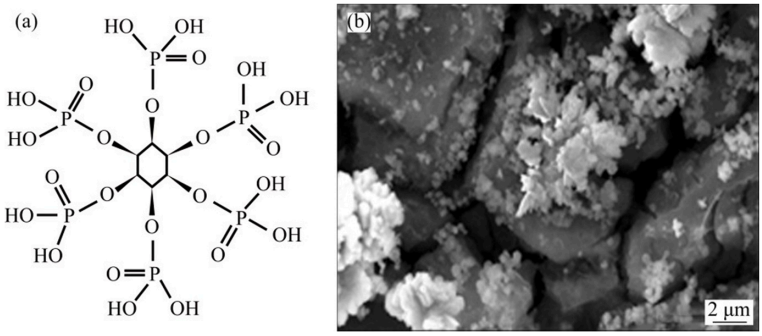

Figure 5. (a) Molecular chemical structure of phytic acid and (b) surface morphology of phytic acid coatings on Mg-Li alloy [46]

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3.3.2. Electroless plating and electroplating

Electrochemical deposition technologies enhance the corrosion resistance of Mg-Li alloys by depositing metal or alloy coatings on the surface to form physical barriers isolating corrosive media.

Electroless plating (autocatalytic plating) is a technology that uses reducing agents to reduce metal ions in the plating solution and deposit them on the substrate surface without external current. Electroless Ni-P coatings are an important choice for Mg-Li alloy protection due to their excellent corrosion resistance, wear resistance and uniform deposition characteristics. To address severe corrosion of the plating solution caused by the high chemical activity of Mg-Li alloys, a two-step process can effectively control deposition: first, forming a thin nickel layer in an alkaline pre-plating solution of $NiCO_3 \cdot 2Ni(OH)_2 \cdot 4H_2O$, then thickening in an acidic plating solution of $NiSO_4 \cdot 6H_2O$. This results in a dense Ni-P coating with a phosphorus content of 13.56 wt% and a hardness of HV 549. The corrosion potential shifts positively to -0.249 V (vs SCE), and the polarization curve shows a long passivation zone, demonstrating excellent anti-corrosion performance [47].

Environmentally friendly pretreatment is an important development direction for electroless plating. Traditional hexavalent chromium and HF pretreatment are limited due to toxicity and strong corrosiveness, while molybdate pretreatment shows good prospects as an alternative. Studies show that molybdate conversion coating pretreatment on Mg-8Li alloy surfaces can effectively reduce the potential difference between the coating and the substrate, forming a compact and uniform Ni-P coating. Electrochemical tests reveal a significant reduction in corrosion current density and a positive shift in corrosion potential, and hydrogen permeation tests confirm that the coating provides good protection for the substrate [48]. This process avoids the use of carcinogens and strong acids, complying with green manufacturing requirements.

Electroplating deposits metal ions on the cathode surface by applying current in an electrolyte solution. For Mg-Li alloys, alkaline copper plating solutions avoid excessive corrosion of the substrate in acidic environments, followed by acidic copper plating and chromium plating to obtain dense and uniform composite coatings [49]. Studies show that electroplating Cu on Mg-9Li-1Zn alloy surfaces significantly improves hardness, wear resistance and corrosion resistance; further electroplating Cr/Cu composite coatings forms an effective corrosion barrier [50].

Due to the high chemical activity and easy oxidation of Mg-Li alloys, strict pretreatment is required before electrochemical deposition to ensure good coating adhesion. A typical process includes degreasing → pickling → activation → zinc immersion or electroless nickel pre-plating → main coating deposition. In recent years, environmentally friendly pretreatment technologies have received widespread attention. Molybdate conversion coating pretreatment can replace traditional chromate and fluoride, ensuring coating quality while reducing environmental pollution. Optimization of pretreatment processes is a key prerequisite for obtaining high-quality protective coatings.

4. Conclusion and outlook

Mg-Li alloys have broad application prospects, but currently, insufficient corrosion resistance severely limits their large-scale engineering applications. Although some progress has been made in corrosion resistance design for Mg-Li alloys, many challenges remain. Improving corrosion resistance solely by adjusting alloy composition and processing technology has limited effects and still fails to meet the requirements of large-scale engineering applications. Surface treatment can significantly enhance the corrosion resistance of Mg-Li alloys, with the microstructure and chemical composition of coatings being artificially designable. However, among current coating technologies,

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widely used chemical conversion coatings usually have insufficient thickness, wear resistance and corrosion resistance, requiring further optimization and protection measures. Micro-arc oxidation coatings often have microcracks and micropores, making it difficult to achieve uniform protection over large areas and requiring additional sealing treatment. In addition, substrate treatment methods greatly affect the effectiveness and durability of coatings. Admittedly, significant progress has been made in protective coatings for Mg-Li alloys, but ensuring their long-term service reliability remains an urgent problem to be solved. To overcome these challenges, future research should prioritize preparation methods and coating design.

(1) Substrate pretreatment and post-treatment: Adopt reasonable treatment methods to prepare a more uniform surface, improving coating adhesion and durability. Post-treatment can effectively eliminate tiny defects in coatings, significantly enhance coating performance and improve long-term stability and durability.

(2) Adopt new processing technologies and combine multiple coating preparation technologies to prepare Mg-Li alloys with higher corrosion resistance. Meanwhile, reduce preparation costs through technological improvements to form industrially applicable new technical solutions.

(3) Expand the types of multi-functional coatings and design and prepare more coating systems using composite coating technologies to develop new functional coatings with desired properties. Priority research should focus on self-healing coatings and coatings with excellent biocompatibility, controllable degradation rate and antibacterial functions urgently needed in biomedical fields, greatly expanding the application scope of Mg-Li alloys.

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