第 52 回高性能 Mg 合金創成加工研究会
日本学術振興会研究拠点形成事業 第 7 回先進 Mg 合金国際セミナー
「マグネシウム合金の腐食挙動と表面処理」

概　要

「リン酸カルシウム被覆生体吸収マグネシウム合金の in vitro および in vivo での腐食挙動」

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＜講演概要＞

生体吸収性マグネシウム合金では、腐食速度を任意に制御し、かつ治癒を促進する表面の開発が求められている。そこで骨形成を促進する水酸アパタイト（HAp）およびその関連化合物による表面被覆が盛んに検討されている。筆者らは、水溶液浸漬処理により HAp 等を被覆する方法を開発した。本講演では、被膜の微細構造およびリン酸カルシウム被覆マグネシウム合金の細胞培養液中やマウス皮下での腐食挙動などを紹介する。

「マグネシウム合金部材の表面処理技術概要」

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＜講演概要＞

マグネシウム合金部材は軽量という最大の特長がありながら、一方腐食しやすいという言葉がつきまとう材料であり、表面処理への要求が大きく期待も大きい。本講演ではその表面処理として適用例が多い化成処理を中心にその技術概要を、最新適用事例を交えながら紹介する。

“Predicting corrosion of magnesium alloys with complex microstructure and reactivity using Scanning Electrochemical Microscopy (SECM)”

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<Abstract>

Various methods are industrially employed in order to fabricate corrosion resistant alloys using different cooling times, mold nature/geometry and post treatments. By using different casting methods, it is possible to vary microstructure distribution and size along to alloying elements distribution across the surface enhancing their corrosion resistance. Since Mg corrosion remains a very active system, the electrochemical processes occurring *in situ* are of great interest when studying the corrosion mechanism. As the corrosion of Mg alloys occurs on the micron and submicron level, Scanning Electrochemical Microscopy (SECM) represents the appropriate alternative to assess the Mg corrosion in situ.

SECM is part of the scanning probe microscopy techniques and involves the measurement of materials fluxes in solution when a microelectrode is placed in close proximity to a substrate. To assess local corrosion fluxes, amperometric or potentiometric modes of SECM can be used.[1] In our work, SECM is employed to measure the ionic concentration distributions and the various electrochemical fluxes during corrosion reaction. Specifically, we will discuss the use of Mg^{2+} sensor similarly to Lamaka and co-workers.[2] and hydrogen evolution sensor during SECM studies, which when combined with numerical simulations yields predictive insight into Mg alloy corrosion.

“Effects of Sn and Zn on Corrosion Behavior of Magnesium Alloys”

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<Abstract>

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The effects of Sn and Zn on corrosion behavior of magnesium alloy extrusions were systematically evaluated in this study. The corrosion behavior of as-extruded Mg-xSn (x=2, 4, 6, 8wt.%) was dependent on the volume fraction of Mg_2Sn particle ([Mg_2Sn]), area fraction of grain boundary ([GB]) and the Sn content dissolved in the matrix phase ([Sn_{sol}]). Both [Mg_2Sn] and [GB] increased the H_2 evolution rate below the E_{corr} level. In contrast, [Sn_{sol}] lowered the H_2 evolution rate. Among the three factors, it was concluded that the [Mg_2Sn] was the determining factor for the polarization behavior of the Mg-xSn alloys. The polarization behavior of as-extruded Mg-xZn (x=1, 2, 3, 4wt.%) was very sensitive to the change of surface film with immersion time. It seemed that Zn increased the H_2 evolution rate and promoted the protectiveness of the surface film.

“Recent research on corrosion, flammability and SCC of Mg alloys”

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<Abstract>

Recent research has shown that MgY and MgGd alloys produced by magnetron sputtering had corrosion rates comparable with those of ultra-high-purity Mg, $P_W = 0.27 \pm 0.07$ mm/y in immersion tests in 3.5% NaCl saturated with $Mg(OH)_2$ for seven days. This is orders of magnitude better than comparable alloys produced by ingot metallurgy in the as-cast or solution-heat-treated conditions. The magnetron sputter deposited Mg alloys have low corrosion rates because they are homogeneous solid solutions with (i) all the alloying elements (Y or Gd) in solid solution, AND (ii) there are no deleterious second phases or Fe-rich phases causing high corrosion rates by galvanic coupling. The low corrosion rates of the magnetron supper Mg alloys indicate what is possible with the production of ultra-high-purity Mg alloys. This expectation is supported by the recent work of Uggowitzer and co-workers in Switzerland who found that the corrosion rate of the ultra-high-purity ZX50 was $P_H = 0.006$ mm/y in a synthetic body fluid. Our recent work indicates that melt purification using Zr can produce ultra-high-purity Mg alloys.

Our research has elucidated the factors that govern the flammability of Mg alloys. A Mg alloy is resistant to burning if there is sufficient alloying to produce a protective film on the surface of the molten Mg. This provides a guiding principle for the development of Mg alloys resistant to burning. In all cases, there is no burning until there is melting of the Mg alloy. The burning alloy will continue to burn or will self extinguish depending on the competing heat fluxes. A Mg rod which is burning at one end will self-extinguish if the heat flux along the Mg rod away from the burning end is greater than the heat flux generated by the burning Mg. Alternatively, an isolated molten blob of Mg will typically burn until consumed.

The key aspects of the stress corrosion of Mg alloys are reviewed and our current research on SCC of Mg alloys is summarised. Most common Mg alloys are susceptible to SCC, even high purity Mg in distilled water. The fact that TGSCC occurs in distilled water means that there is no need for specific damaging ions (like chloride ions) to be present to cause SCC. SCC can occur at low stresses, such as half the yield stress. Our current research is systematically examining the SCC of model binary Mg-X alloys, both in the as-cast and solution-heat-treated conditions.