# Electrochemical Behavior Of Some Alloys Of Technological Importance In Aqueous Solutions.

**By**

**Ghada Mohamed Ahmed Abd El-Hafez**
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**1-Prof.Dr. Waheed.A. Badawy**
Prof. of Physical Chemistry, Faculty of Science, Cairo University

**2- Assistant Prof. Dr. N.H. Helal**
Assistant Prof. of Physical Chemistry, Faculty of Science, Fayoum University

**3-Dr. M.M. El Rabiee**
Lecturer of Physical Chemistry, Faculty of Science, Fayoum University

# *Summary*

Magnesium and magnesium alloys as a structural materials have numerous advantages compared to aluminum or plastics. They are light materials, e.g. lighter than Al by almost 40%. They have better castability and excellent damping capability. Compared to plastics, although they have almost the same specific density, magnesium and magnesium alloys have excellent shielding electromagnetic interference "EMI" capabilities, environmental stability, better heat dissipation and recycling abilities. These factors made the use of magnesium and magnesium alloys an attractive materials for the automotive, aerospace, electronics and consumer products industries.

An application of magnesium alloys in portable electronic equipments provides ruggedness, high impact strength, EMI protection and an aesthetic surface finish. These factors made magnesium very attractive in the design of new lined of video/photographic equipments, portable personal computers and notebooks, cellular and satellite mobile phones, personal LCD projectors, portable communication equipments and carry-on audio/video headsets.

The present work represents a systematic and detailed investigation concerning the corrosion and passivation behavior of some Mg-xAl (x=5, 10, and 15 mass %), Mg-Al-Zn and Mg-Al-Zn-Mn alloys in aqueous solutions of different pH covering the acidic, neutral and basic media. Also, the inhibition of the corrosion process in these media was considered. The use of different amino acids as environmentally safe corrosion inhibitors for magnesium and magnesium alloys was also investigated.

The work presented in this thesis is divided into three chapters. Chapter I is subdivided into two sections. The first one is an introduction reviewing the relevant literature, and the second summarizes the aim of the whole investigation.

Chapter II is devoted to the experimental part. It includes specification of the electrodes and chemicals beside the details of the electrochemical cell and measuring systems. It describes also details of the electrode pretreatment, polarization and impedance techniques.

The experimental data are presented and discussed in chapter III where, they are divided into three main parts. In the first part the electrochemical behavior of Mg and Mg-xAl alloys in naturally aerated stagnant aqueous solutions covering the acidic, neutral and basic media were described. After long time of the electrode immersion in aqueous solutions, the corrosion resistance of the alloy increased as the Al content was increased and Mg-10Al was found to be the most corrosion resistant of the investigated materials. The obtained results show also that in acidic solutions of pH=2, a continuous corrosion is taking place until the steady state is reached. In neutral solutions, a passive film develops on the metal surface. In basic solutions at pH=12 a corrosion/passivation process occurs. The calculated activation energy of dissolution process reveals that the rate determining step for the corrosion of Mg and its alloys is a one electron transfer process. The electrochemical impedance data were analyzed using an equivalent circuit model. The results of the DC measurements are consistent with those of the EIS, investigations.

The second part presents the electrochemical behavior of Mg-10Al, Mg-Al-Zn and Mg-Al-Zn-Mn alloys in naturally aerated stagnant aqueous solutions of different pH. It is aimed at the study of the effect of alloying elements Zn and Zn plus Mn where the percent of Al in these alloys was kept almost the same. The results show that the presence of Zn

and Mn together has improved the electrochemical properties of Mg-Al alloys. The results show also that in acidic solutions of pH=2, a continuous corrosion is taking place until the steady state is reached. In neutral solutions a passive film develops on the metal surface. In basic solutions of pH=12 a corrosion/passivation process occurs. The calculated activation energy reveals that the rate determining step for the dissolution process is also a one electron transfer process. The impedance data were fitted to theoretical data according to the proposed equivalent circuit model which describes the electrode/electrolyte interface.

The third part directed towards the investigation of the corrosion inhibition process in neutral solutions. In this respect different amino acids (such as glycine, alanine, valine, leucine, threonine, phenylalanine, glutamic acid, cysteine and tyrosine) were used as environmentally safe inhibitors. This part is subdivided into three sections.

In the first section, the effect of different amino acids on the inhibition of corrosion of Mg-10Al alloy was investigated. Tyrosine was found to be the best of the investigated amino acids as corrosion inhibitor for Mg-10Al alloy in neutral solutions. The corrosion inhibition process is based on the adsorption of the amino acid molecule on the alloy surface. The resistance and the relative thickness of the adsorbed layer were also investigated.

In the second section, the corrosion inhibition of Mg-Al-Zn alloy in neutral solutions was investigated. A critical concentration of phenylalanine of 2 mM was found to suitable for the corrosion inhibition process. An efficiency of more than 87% was obtained. The resistance and the relative thickness of the adsorbed layer increase with the increase in the time of immersion of the alloy in the solution containing amino acids. This indicates a strong adsorption of the amino acids on the alloy surface. The amino acid molecule is present in neutral solutions as

*Zwitterion*. So, the protonated amino group could be electrostatically attracted to the cathodic sites and the oxygen atom of the carbonyl group to the anodic sites of the alloy surface.

In the third section, the effect of the amino acids on the inhibition of the corrosion of Mg-Al-Zn-Mn alloy in neutral solutions was investigated. The aminoacids shift the corrosion potential, $E_{corr}$, to more positive values. The positive shift of $E_{corr}$ is an indication that the amino acid behaves as an anodic inhibitor. Cystein was found the best amino acid as corrosion inhibitor for the Mg-Al-Zn-Mn alloy. A concentration of 0.1mM gives a corrosion inhibition efficiency of ≈ 73%. The whole corrosion inhibition process is based on the adsorption of the amino acid molecules on the active sites of the different alloys. In all cases the activation free energy of the adsorption process was found to obey the Langmuir adsorption process.