FUNDAMENTAL ASPECTS OF LOCALIZED CORROSION OF MAGNESIUM ALLOYS PROMISING FOR IMPLANT SURGERY

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Abstract

Magnesium is very light metal, which possesses many useful properties such as high strength to weight ratio and good electrical and thermal conductivity. Magnesium and its alloys can be used in implant surgery as biodegradable materials. Taking into account the rapid degradation process of Mg alloys in chloride-containing solutions and very complex composition of the human body media, it is worth to study the mechanism and kinetics of the Mg alloys corrosion in solutions, which closely resemble that of human body fluids.

Results

A comparative analysis of the corrosion activity of MA8 magnesium alloy (intended as bioresorbable material) in a medium for cultivation of mammalian cells (minimum essential medium, MEM) and 0.83 % NaCl solution was performed using scanning vibrating electrode technique (SVET), local pH measurements (SIET), hydrogen evolution tests, OCP, PDP and EIS tests. Corrosion products formed on the alloy surface are characterized using XRD and SEM-EDX analysis, Raman spectroscopy. Hydrogen evolution rate is higher for samples in NaCl solution in comparison with MEM. The impedance modulus in the frequency range from 10^5 Hz down to 10^{-1} Hz for the sample immersed in MEM was higher than that for the sample immersed in NaCl. This indicates higher protective ability of the corrosion film formed in MEM compared to that formed during immersion in NaCl solution. Ca and P rich deposits were formed in the corrosion layer.

The model of corrosion mechanism of MA8 magnesium alloy in MEM, which includes three stages of the development of corrosion product film, is proposed. The formation on the surface of magnesium alloy sample in MEM of corrosion product layer, including magnesium-substituted hydroxyapatite, stabilizes the local pH below 9.0 and, along with organic acids, does not allow increasing the pH during corrosion of the Mg alloy. The obtained results indicate the prospect of using bioresorbable magnesium in implant surgery [1, 2].

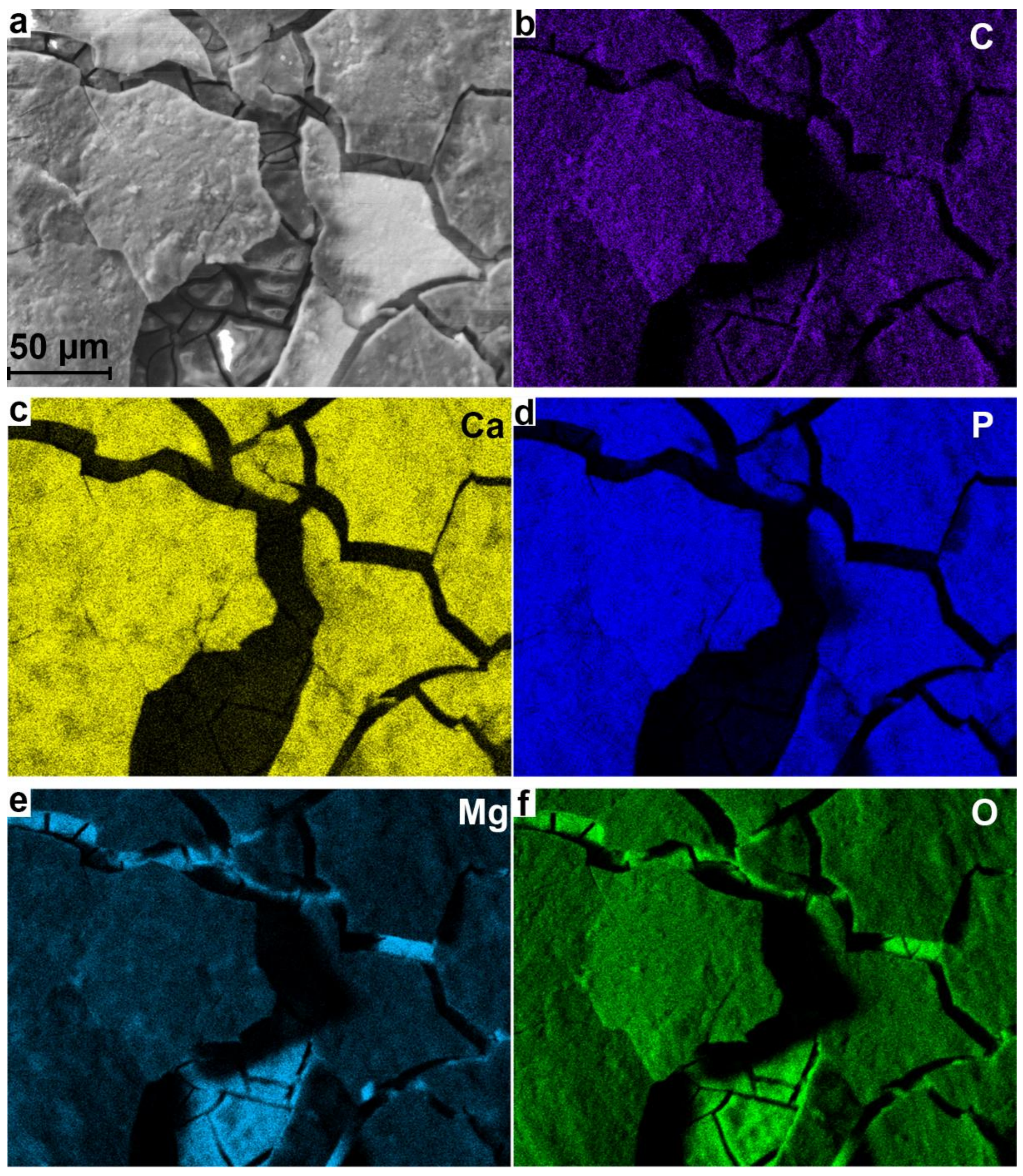

Fig. 3 SEM image (a) of the film formed on the MA8 Mg alloy after immersion in MEM solution for 30 days and corresponding EDX maps (b-f) of the elements (C, Ca, P, Mg, O) distribution in this area.

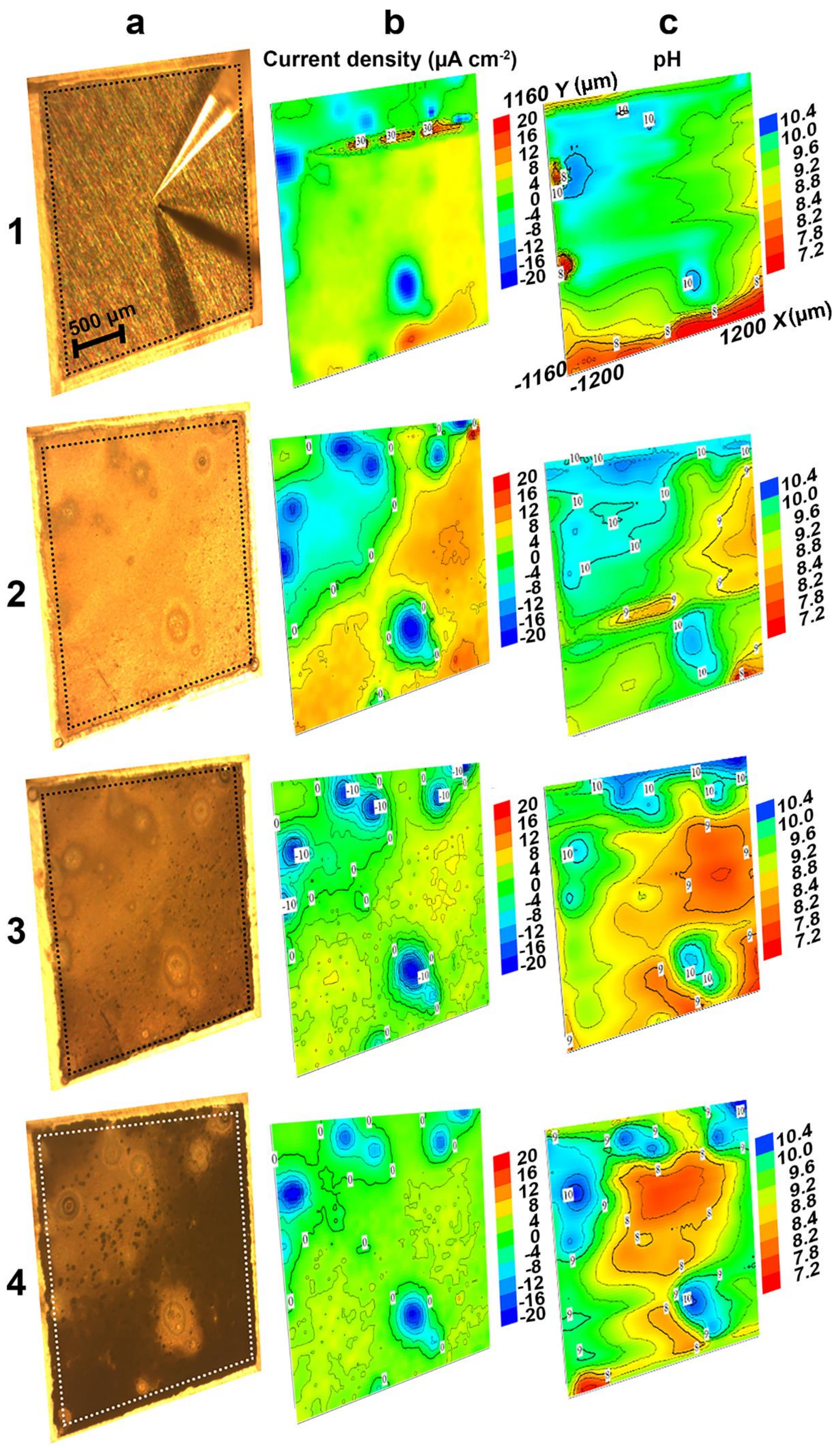

Fig. 1 Optical images of the investigated area (limited by frame) (a) before exposure (1), after 24 (2), 48 (3) and 70 (4) h of the sample exposure to 0.83 % NaCl solution as well as SVET (b) and SIET (c) maps after 2 (1), 24 (2), 48 (3) and 70 (4) h of the sample exposure.

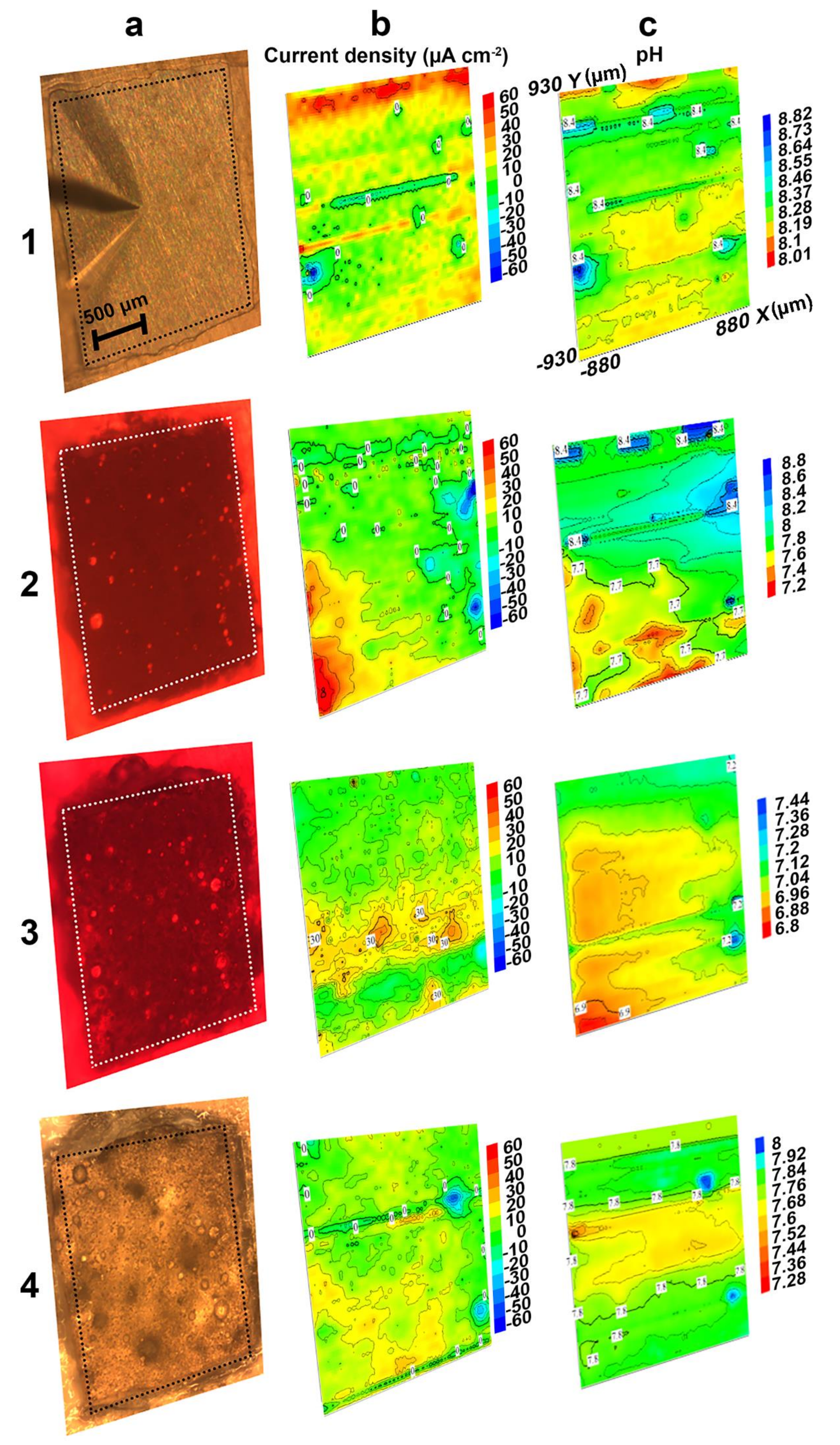

Fig. 2 Optical images of the investigated area (limited by frame) (a) before exposure (1), after 24 (2), 48 (3) and 70 (4) h of the sample exposure to MEM solution as well as SVET (b) and SIET (c) maps after 2 (1), 24 (2), 48 (3) and 70 (4) h of the sample exposure.

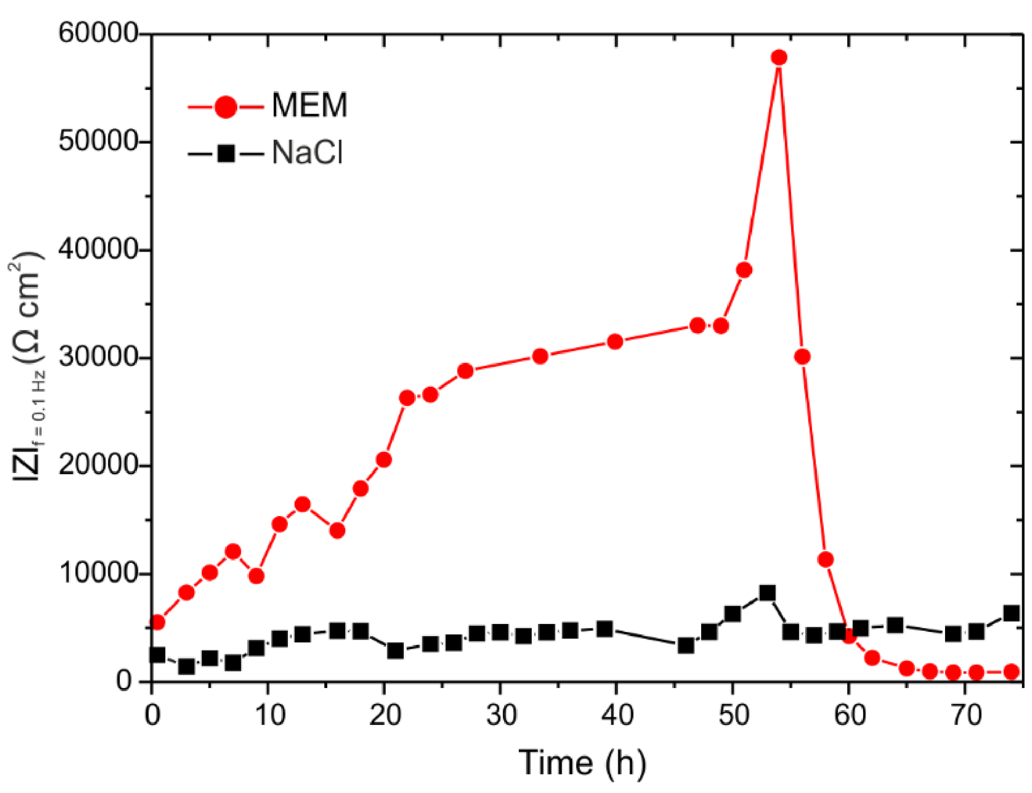

Fig. 4 Impedance modulus (measured at the lowest frequency $|Z|_{f=0.1Hz}$) evolution during sample immersion in NaCl solution and in MEM.

Ion	K^+	Cl^-	Ca^{2+}	CO_3^{2-}	SO_4^{2-}	Mg^{2+}	PO_4^{3-}	Na^+
Concentration (mM)	5.4	125.0	1.8	26.0	0.8	0.8	0.9	142.9

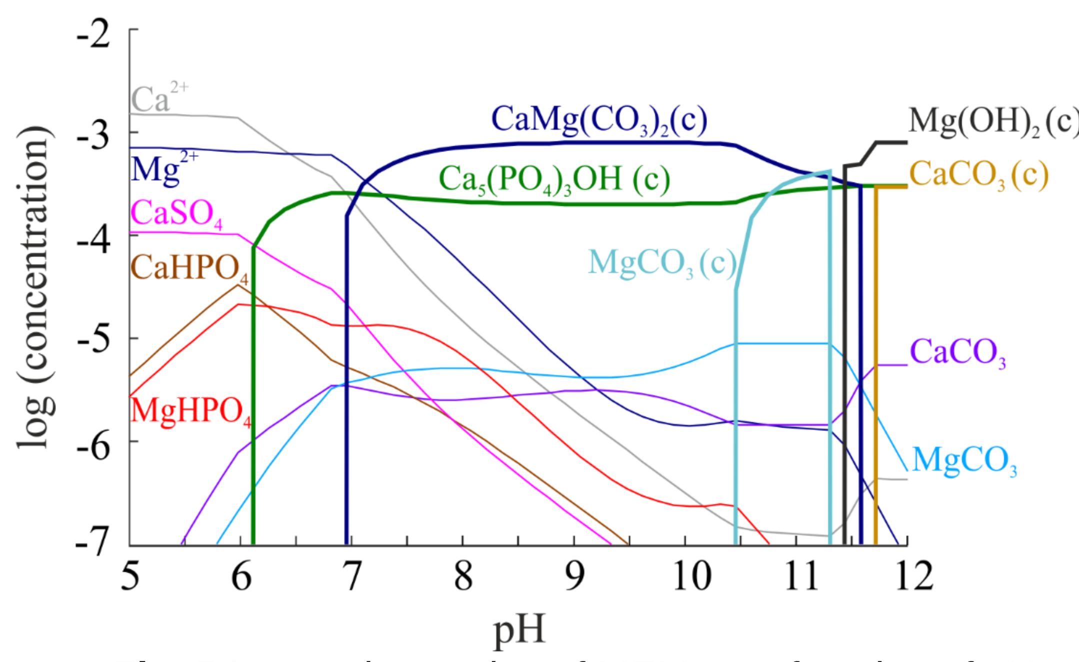

Fig. 5 Inorganic species of MEM as a function of pH. Ions and concentrations correspond to their content in MEM. The diagram was made using Hydra/Medusa® software.

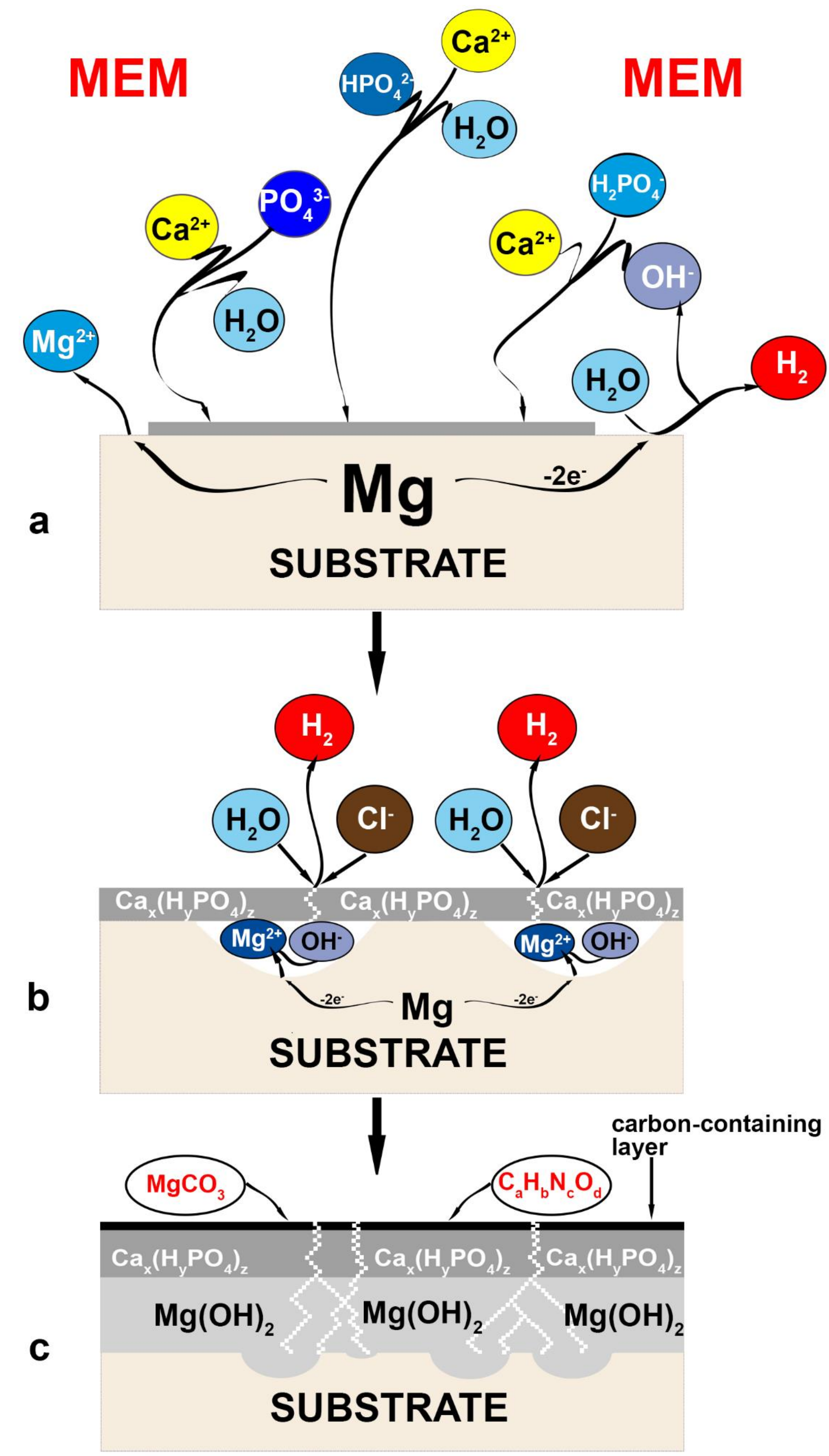

Fig. 6 The schematic illustrations of the possible corrosion mechanism for MA8 Mg alloy in the MEM. Three stages (a, b, c) of the corrosion film evolution were revealed.

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[2] A.S. Gnedenkov, S.V. Lamaka, S.L. Sinebryukhov, D.V. Mashtalyar, V.S. Egorkin, I.M. Imshinetskiy, A.G. Zavidnaya, M.L. Zheludkevich, S.V. Gnedenkov Electrochemical behaviour of the MA8 Mg alloy in minimum essential medium, Corros. Sci. 168 (2020) 108552.

This work was supported by the Grant of Russian Science Foundation, Russia (project no. 19-73-00078).