The University of Manchester

THE INFLUENCE OF HOT FORMING-QUENCHING (HFQ) ON THE MICROSTRUCTURE AND CORROSION PERFORMANCE OF AZ31 MAGNESIUM ALLOYS

A thesis submitted to the University of Manchester for the degree of Doctor of Philosophy in the Faculty of Engineering and Physical Sciences

2016

Juliawati Binti Alias

School of Materials
Corrosion and Protection Centre
University of Manchester

Table of Contents

64056 words

List of Tables and Figures

Chapter 1

Chapter 2

Chapter 3

Chapter 4

<u>Chapter 5</u>

Chapter 6

Chapter 7

Abstract

The University of Manchester
Juliawati Binti Alias
Doctor of Philosophy
2015

The Influence of Hot Forming-Quenching (HFQ) on Microstructure and Corrosion Performance of AZ31 Magnesium Alloys

The hot forming-quenching (HFQ) process has introduced grains and subgrain growth, accompanied with modification of the intermetallic particle distribution in AZ31 magnesium alloys. Each region of the HFQ component represents significant grain structure variation and surface conditions that contributed to the corrosion susceptibility. The homogeneous grain structure significantly ruled the corrosion propagation features by filiform-like corrosion. Immersion of AZ31 alloys in 3.5 wt.% NaCl indicated higher corrosion rate of HFQ TRC (corrosion rate: 10.129 mm/year), a factor of 10 times, higher than the rolled alloy (corrosion rate: 0.853 mm/year) and a factor of 2 times, higher than the corrosion rate of MCTRC alloy (corrosion rate: 5.956 mm/year). Much lower corrosion rate was indicated in the as-cast TRC and MCTRC alloys, compared to the alloys after HFQ process that revealed the contribution of network or continuous distribution of β-$Mg_{17}Al_{12}$ phase particles to reduce the corrosion driven in chloride solution. In contrast, discontinuous distribution of cathodic β-$Mg_{17}Al_{12}$ phase particles increases the corrosion rate of HFQ TRC alloy by promoting the cathodic reaction and intense filament propagation resembling the coarse interdendritic and grain boundaries attack. The presence of high population densities of cathodic Al_8Mn_5 particles in HFQ rolled AZ31B-H24 alloy significantly reduced the corrosion driven for intense corrosion attack on the rolled alloy. The surface preparation by mechanical grinding process induced MgO and Zn-enrichment layer, accompanied with near surface deformed layer that consisted of nanograins in the range size of 40 to 250 nm. The grinding process refined the surface by removing the cutting damage and marks that formed during the thermomechanical process and led to stable potential of the HFQ AZ31 alloys, in the range of -1.59 to -1.57 V, during open circuit potential (OCP) measurement. The surface regularity with grinding path causing the filament to propagate following the grinding direction. The as-received surface contained many cutting damages and deep scratch marks from the rolling and casting processes that could introduce many corrosion initiation sites. The absence of the grinding direction on the as-received surface could control intense corrosion susceptibility, due to the non-linear filament propagation. The surface irregularity on chromic acid cleaned surface of HFQ rolled AZ31B-H24 alloy also contributed to low corrosion potential of the rolled alloy during OCP and potentiodynamic polarization measurement.

Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright Statement

Acknowledgements

I would like to express my deepest gratitude and appreciation to my supervisor Prof. Xiaorong Zhou, the Professor of Corrosion Science and Engineering who has guided and advised me throughout my research. With his kind support, patient and wise guidance, i have completed my research successfully with a strong encouragement.

I am thankful to Prof. George Thompson as the great co-supervisor for his precious suggestions, knowledge and valuable discussion during all phases of the research work.

A special thanks to Mr. Teruo Hashimoto, Ms. Xiangli Zhong, Mr. Michael Faulkner and Mr. Matt smith for all the help and knowledge with scanning and transmission electron microscopes. A sincere gratitude especially to Mr. Teruo Hashimoto for his spare time and generous knowledge with the SEM analysis, high resolution TEM analysis, specimen preparation using ultramicrotomy and EBSD analysis.

Thanks to all colleagues working in the Corrosion and Protection Centre especially the people in D35, D9 and D10. Also thanks to the friend in Manchester, for all the support, help, useful advice and cheerful friendship during the hard and easy times.

Thanks to my family and to my parents-in-law, who have encouraged me during all times. I would like to dedicate this thesis to my greatest treasure in life; my husband, Mohd Amerul and my two lovely kids, Hanif Zhafran and Nur Ayra Amani, for their continuous encouragement, sacrifices and love. Thank you so much from the bottom of my heart.

Finally, I wish to gratefully acknowledge Malaysian government for the financial support.

Special dedication to my mother, father, brothers and sisters, also to the greatest treasures; my husband and kids.

References

1] Z. Fan, "Towards Affordable, Closed-loop Recycleable Future Low Carbon Vehicle Structures (TARF-LCV)," Brunel, 2012.

[2] R. P. Garrett, J. Lin, and T. A. Dean, "Solution Heat Treatment and Cold Die Quenching in Forming AA 6xxx Sheet Components: Feasibility Study," *Adv. Mater. Res.*, vol. 6–8, pp. 673–680, 2005.

[3] B. L. Mordike, "Physical metallurgy principles," *Journal of Nuclear Materials*, vol. 17. p. 96, 1965.

[4] H. E. Friedrich and B. L. Mordike, *Magnesium technology: Metallurgy, design data, applications*. 2006.

[5] K. U. Kainer, *Magnesium – Alloys and Technology Edited by*. Wiley-Vch, 2003.

[6] S. R. Agnew and Ö. Duygulu, "Plastic anisotropy and the role of non-basal slip in magnesium alloy AZ31B," *Int. J. Plast.*, vol. 21, pp. 1161–1193, 2005.

[7] S. R. Agnew, "Plastic anisotropy of magnesium alloy AZ31B sheet," *Magnes. Technol. 2002*, pp. 169–174, 2002.

[8] A. G. Beer and M. R. Barnett, "Microstructure evolution in hot worked and annealed magnesium alloy AZ31," *Mater. Sci. Eng. A*, vol. 485, no. 1–2, pp. 318–324, Jun. 2008.

[9] D. L. Yin, K. F. Zhang, G. F. Wang, and W. B. Han, "Warm deformation behavior of hot-rolled AZ31 Mg alloy," *Mater. Sci. Eng. A*, vol. 392, pp. 320–325, 2005.

[10] D. Kuc, E. Hadasik, G. Niewielski, and A. Plachta, "Structure and plasticity of the AZ31 magnesium alloy after hot deformation," *J. Acheivements Mater. Manuf. Eng.*, vol. 27, pp. 27–30, 2008.

[11] W. J. Kim, S. W. Chung, C. S. Chung, and D. Kum, "Superplasticity in thin magnesium alloy sheets and deformation mechanism maps for magnesium alloys at elevated temperatures," *Acta Mater.*, vol. 49, pp. 3337–3345, 2001.

[12] A. Yamashita, Z. Horita, and T. G. Langdon, "Improving the mechanical properties of magnesium and a magnesium alloy through severe plastic deformation," *Mater. Sci. Eng. A*, vol. 300, pp. 142–147, 2001.

[13] T.-C. Chang, J.-Y. Wang, C.-M. O, and S. Lee, "Grain refining of magnesium alloy AZ31 by rolling," *J. Mater. Process. Technol.*, vol. 140, no. 1–3, pp. 588–591, Sep. 2003.

[14] T. Al-Samman and G. Gottstein, "Room temperature formability of a magnesium AZ31 alloy: Examining the role of texture on the deformation mechanisms," *Mater. Sci. Eng. A*, vol. 488, pp. 406–414, 2008.

[15] N. Stanford, D. Atwell, A. Beer, C. Davies, and M. R. Barnett, "Effect of microalloying with rare-earth elements on the texture of extruded magnesium-

based alloys," *Scr. Mater.*, vol. 59, pp. 772–775, 2008.

[16] N. Stanford, "The effect of rare earth elements on the behaviour of magnesium-based alloys: Part 2 - recrystallisation and texture development," *Mater. Sci. Eng. A*, vol. 565, pp. 469–475, 2013.

[17] J. Bohlen, M. R. Nürnberg, J. W. Senn, D. Letzig, and S. R. Agnew, "The texture and anisotropy of magnesium-zinc-rare earth alloy sheets," *Acta Mater.*, vol. 55, pp. 2101–2112, 2007.

[18] K. Hantzsche, J. Bohlen, J. Wendt, K. U. Kainer, S. B. Yi, and D. Letzig, "Effect of rare earth additions on microstructure and texture development of magnesium alloy sheets," *Scripta Materialia*, vol. 63. pp. 725–730, 2010.

[19] G. V Raynor, *The Physical Metallurgy of Magnesium and Its Alloys*. London: Pergamon Press, 1959.

[20] C. S. Robert, *Magnesium and Its Alloys*. New York, NY: John Wiley & Sons, 1960.

[21] K. Maruyama, M. Suzuki, and H. Sato, "Creep Strength of Magnesium-Based Alloys," vol. 33, no. March, 2002.

[22] M. O. Pekguleryuz, "Creep resistant Magnesium Die casting alloys based on alkaline earth elements," *Mater. Trans.*, vol. 42, pp. 1258–1267, 2001.

[23] D. Duly and Y. Brechet, "Nucleation mechanism of discontinuous precipitation in Mg-Al alloys and relation with the morphology," *Acta Metall. Mater.*, vol. 42, no. 9, pp. 3035–3043, Sep. 1994.

[24] G. Britain and S. Martin, "Macroscopic kinetics of discontinuous precipitation in a Mg-8.5 wt% Al alloy," vol. 40, no. 9, 1992.

[25] D. Duly, J. P. Simon, and Y. Brechet, "On the competition between continuous and discontinuous precipitations in binary Mg-Al alloys," vol. 43, no. 1, pp. 101–106, 1995.

[26] A. Luo and M. O. Pekguleryuz, "Review Cast magnesium alloys for elevated temperature applications," vol. 29, pp. 5259–5271, 1994.

[27] M. O. Pekguleryuz, K. U. Kainer, A. Arslan Kaya, and R. Neelameggham, "Alloying behavior of Magnesium and alloy design," in *Fundamentals of Magnesium Alloy Metallurgy*, Woodhead Publishing Limited, 2013, pp. 152–196.

[28] A. K. Dahle, Y. C. Lee, M. D. Nave, P. L. Scha, and D. H. Stjohn, "Development of the as-cast microstructure in Magnesium-Aluminium alloys," *J. Light Met.*, no. 1, pp. 61–72, 2001.

[29] H. Watari, K. Davey, M. T. A. Rasgado, T. Haga, and N. Koga, "Semisolid Twinroll Casting Process of Magnesium Alloy Sheets," vol. 1314, no. 2004, 2010.

[30] H. Watari, T. Haga, N. Koga, and K. Davey, "Feasibility study of twin roll casting process for magnesium alloys," *J. Mater. Process. Technol.*, vol. 192–193, pp. 300–305, 2007.

[31] T. Mino, M. Asakawa, D. Lee, T. Fujiwara, K. Matsuzaki, and M. Kobayashi, "Twin-roll strip casting of AZ61 magnesium alloy and improvement of formability by structure-control rolling," vol. 177, pp. 534–538, 2006.

[32] S. S. Park, Y. S. Oh, D. H. Kang, and N. J. Kim, "Microstructural evolution in twin-roll strip cast Mg – Zn – Mn – Al alloy," vol. 451, no. August 2005, pp. 352–355, 2007.

[33] D. H. Kang, D. Kim, S. Kim, G. T. Bae, K. H. Kim, and N. J. Kim, "Relationship between stretch formability and work-hardening capacity of twin-roll cast Mg alloys at room temperature," *Scr. Mater.*, vol. 61, no. 7, pp. 768–771, 2009.

[34] R. Cook, P. G. Grocock, P. M. Thomas, D. V Edmonds, and J. D. Hunt, "Development of the twin-roll casting process," vol. 55, pp. 76–84, 1995.

[35] M. Yun, S. Lokyer, and J. D. Hunt, "Twin roll casting of aluminium alloys," vol. 280, pp. 116–123, 2000.

[36] W. Guang-shan, D. I. Hong-shuang, and H. Feng, "Preparation of AZ31 magnesium alloy strips using vertical twin-roll caster," vol. 6326, no. August 2009, 2010.

[37] T. Haga, K. Tkahashi, M. Ikawaand, and H. Watari, "Twin roll casting of aluminum alloy strips," *J. Mater. Process. Technol.*, vol. 153–154, pp. 42–47, 2004.

[38] I. Bayandorian, Y. Huang, Z. Fan, S. Pawar, X. Zhou, and G. E. Thompson, "The impact of melt-conditioned twin-roll casting on the downstream processing of an AZ31 magnesium alloy," *Metall. Mater. Trans. A Phys. Metall. Mater. Sci.*, vol. 43, pp. 1035–1047, 2012.

[39] M. Masoumi, F. Zarandi, and M. Pekguleryuz, "Microstructure and texture studies on twin-roll cast AZ31 (Mg-3wt.%Al-1wt.%Zn) alloy and the effect of thermomechanical processing," *Mater. Sci. Eng. A*, vol. 528, pp. 1268–1279, 2011.

[40] Y. Huang, I. Bayandorian, and Z. Fan, "Microstructure control during twin roll casting of an AZ31 magnesium alloy," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 27, p. 012065, Jan. 2012.

[41] S. A. Lockyer, M. Yun, J. D. Hunt, and D. V Edmonds, "Micro- and Macrodefects in Thin Sheet Twin-Roll Cast Aluminum Alloys," *Mater. Charact.*, no. 37, pp. 301–310, 1996.

[42] Z. Fan, G. Liu, and M. Hitchcock, "Solidification behaviour under intensive forced convection," *Mater. Sci. Eng. A*, vol. 413–414, pp. 229–235, Dec. 2005.

[43] Z. Fan, Y. Wang, M. Xia, and S. Arumuganathar, "Enhanced heterogeneous nucleation in AZ91D alloy by intensive melt shearing," *Acta Mater.*, vol. 57, pp. 4891–4901, 2009.

[44] G. Scamans, H. Li, and Z. Fan, "Melt Conditioned Casting of Aluminum Alloys," pp. 1395–1400, 2012.

[45] S. R. Agnew, J. A. Horton, T. M. Lillo, and D. W. Brown, "Enhanced ductility in strongly textured magnesium produced by equal channel angular processing," *Scr. Mater.*, vol. 50, no. 3, pp. 377–381, Feb. 2004.

[46] S. S. Park, G. T. Bae, D. H. Kang, I. H. Jung, K. S. Shin, and N. J. Kim, "Microstructure and tensile properties of twin-roll cast Mg-Zn-Mn-Al alloys," *Scr. Mater.*, vol. 57, pp. 793–796, 2007.

[47] F. Kang, Z. Li, J. T. Wang, P. Cheng, and H. Y. Wu, "The activation of ⟨c + a⟩ non-basal slip in Magnesium alloys," *J Mater. Sci*, vol. 47, pp. 7854–7859, 2012.

[48] M. R. Barnett, "Twinning and the ductility of magnesium alloys. Part II. 'Contraction' twins," *Mater. Sci. Eng. A*, vol. 464, no. 1–2, pp. 8–16, 2007.

[49] S. R. Agnew, C. N. Tomé, D. W. Brown, T. M. Holden, and S. C. Vogel, "Study of slip mechanisms in a magnesium alloy by neutron diffraction and modeling," *Scr. Mater.*, vol. 48, pp. 1003–1008, 2003.

[50] J. D. Robson, N. Stanford, and M. R. Barnett, "Effect of precipitate shape on slip and twinning in magnesium alloys," *Acta Mater.*, vol. 59, no. 5, pp. 1945–1956, 2011.

[51] G. E. Dieter, D. Bacon, S. M. Copley, C. a Wert, and G. L. Wilkes, *Adapted by*. 1988.

[52] J. W. Christian and S. Mahajan, "Deformation twinning," *Progress in Materials Science*, vol. 39. pp. 1–157, 1995.

[53] Y. T. Zhu, X. Z. Liao, and X. L. Wu, "Deformation twinning in nanocrystalline materials," *Progress in Materials Science*, vol. 57, no. 1. pp. 1–62, 2012.

[54] Z. Zhang, M. Wang, Z. Li, N. Jiang, S. Hao, J. Gong, and H. Hu, "Twinning, dynamic recovery and recrystallization in the hot rolling process of twin-roll cast AZ31B alloy," *J. Alloys Compd.*, vol. 509, no. 18, pp. 5571–5580, May 2011.

[55] M. R. Barnett, "Twinning and the ductility of magnesium alloys. Part I: 'Tension' twins," *Mater. Sci. Eng. A*, vol. 464, no. 1–2, pp. 1–7, 2007.

[56] M. Knezevic, A. Levinson, R. Harris, R. K. Mishra, R. D. Doherty, and S. R. Kalidindi, "Deformation twinning in AZ31: Influence on strain hardening and texture evolution," *Acta Mater.*, vol. 58, no. 19, pp. 6230–6242, 2010.

[57] Z. S. Basinski and J. W. Christian, "Crystallography of deformation by twin boundary movements in indium-thallium alloys," *Acta Metall.*, vol. 2, no. 1, pp. 101–116, 1954.

[58] H. J. Mcqueen, "Encyclopedia of Materials : Science and Technology," in *Dynamic recovery and recrystallization*, 2001, pp. pp. 2375–2381.

[59] A. Galiyev, R. Kaibyshev, and G. Gottstein, "Correlation of plastic deformation and dynamic recrystallization in magnesium alloy ZK60," *Acta Mater.*, vol. 49, no. 7, pp. 1199–1207, Apr. 2001.

[60] C. E. Dreyer, W. V. Chiu, R. H. Wagoner, and S. R. Agnew, "Formability of a more

randomly textured magnesium alloy sheet: Application of an improved warm sheet formability test," *J. Mater. Process. Technol.*, vol. 210, pp. 37–47, 2010.

[61] F. K. Chen and T. B. Huang, "Formability of stamping magnesium-alloy AZ31 sheets," *J. Mater. Process. Technol.*, vol. 142, pp. 643–647, 2003.

[62] E. Doege and K. Dro, "Sheet metal forming of magnesium wrought alloys — formability and process technology," vol. 115, pp. 14–19, 2001.

[63] S. Kim, M. Okido, Y. Mizutani, R. Ichino, S. Tanikawa, and S. Hasegawa, "Formation of Anodic Films on Mg – Al Alloys in NaOH solutions at Constant Potentials," vol. 44, no. 5, pp. 1036–1041, 2003.

[64] L. Wang, M. Strangwood, D. Balint, J. Lin, and T. A. Dean, "Formability and failure mechanisms of AA2024 under hot forming conditions," *Mater. Sci. Eng. A*, vol. 528, no. 6, pp. 2648–2656, Mar. 2011.

[65] M. S. Mohamed, A. D. Foster, J. Lin, D. S. Balint, and T. A. Dean, "Investigation of deformation and failure features in hot stamping of AA6082: Experimentation and modelling," *Int. J. Mach. Tools Manuf.*, vol. 53, no. 1, pp. 27–38, Feb. 2012.

[66] G. Ben Hamu, D. Eliezer, and L. Wagner, "The relation between severe plastic deformation microstructure and corrosion behavior of AZ31 magnesium alloy," *J. Alloys Compd.*, vol. 468, pp. 222–229, 2009.

[67] R. M. Wang, A. Eliezer, and E. Gutman, "Microstructures and dislocations in the stressed AZ91D magnesium alloys," *Mater. Sci. Eng. A*, vol. 344, pp. 279–287, 2003.

[68] Y. Snir, G. Ben-Hamu, D. Eliezer, and E. Abramov, "Effect of compression deformation on the microstructure and corrosion behavior of Magnesium alloys," *J. Alloys Compd.*, vol. 528, pp. 84–90, 2012.

[69] M. Ben-haroush, G. Ben-hamu, D. Eliezer, and L. Wagner, "The relation between microstructure and corrosion behavior of AZ80 Mg alloy following different extrusion temperatures," vol. 50, pp. 1766–1778, 2008.

[70] W. Song, H. J. Martin, A. Hicks, D. Seely, C. A. Walton, W. B. Lawrimore, P. T. Wang, and M. F. Horstemeyer, "Corrosion behaviour of extruded AM30 magnesium alloy under salt-spray and immersion environments," *Corros. Sci.*, vol. 78, pp. 353–368, 2014.

[71] G. Song and A. Atrens, "Understanding Magnesium Corrosion—A Framework for Improved Alloy Performance," *Adv. Eng. Mater.*, vol. 5, pp. 837–858, 2003.

[72] E. Ghali, *Corrosion resistance of Aluminium and Magnesium and alloys-Understanding, performance and testing*. John Wiley & Sons, 2010.

[73] M. Liu, S. Zanna, H. Ardelean, I. Frateur, P. Schmutz, G. Song, A. Atrens, and P. Marcus, "A first quantitative XPS study of the surface films formed , by exposure to water , on Mg and on the Mg – Al intermetallics : Al_3Mg_2 and $Mg_{17}Al_{12}$," *Corros. Sci.*, vol. 51, no. 5, pp. 1115–1127, 2009.

[74] G. G. Perrault, "The potential-pH diagram of the Magnesium-water system," *Electroanal. Chem. Interfacial Electrochem.*, vol. 51, pp. 107–119, 1974.

[75] L. Wang, B.-P. Zhang, and T. Shinohara, "Corrosion behavior of AZ91 magnesium alloy in dilute NaCl solutions," *Materials & Design*, vol. 31. pp. 857–863, 2010.

[76] G. Song, D. S. T. John, and J. Nairn, "The anodic dissolution of Magnesium and Sulphate solutions in chloride," vol. 39, no. l, pp. 1981–2004, 2004.

[77] M. Abulsain, A. Berkani, F. A. Bonilla, Y. Liu, M. A. Arenas, P. Skeldon, G. E. Thompson, P. Bailey, T. C. Q. Noakes, K. Shimizu, and H. Habazaki, "Anodic oxidation of Mg – Cu and Mg – Zn alloys," vol. 49, pp. 899–904, 2004.

[78] J. M. Hernández-López, a. Němcová, X. L. Zhong, H. Liu, M. a. Arenas, S. J. Haigh, M. G. Burke, P. Skeldon, and G. E. Thompson, "Formation of barrier-type anodic films on ZE41 magnesium alloy in a fluoride/glycerol electrolyte," *Electrochim. Acta*, vol. 138, pp. 124–131, Aug. 2014.

[79] G. L. Song and A. Atrens, "Corrosion mechanisms of Magnesium alloys," *Adv. Eng. Mater.*, no. 1, pp. 11–33, 1999.

[80] G. L. Makar and J. Kruger, "Corrosion of magnesium," *International Materials Reviews*, vol. 38, no. 3. pp. 138–153, 1993.

[81] E. Gulbrandsen, "Anodic behaviour of Mg in HCO3/CO2-3 buffer solutions Quasi-steady measurements," *Electrochim. Acta*, vol. 37, no. 8, pp. 1403–1412, 1992.

[82] S. Bender, J. Goellner, A. Heyn, and S. Schmigalla, "A new theory for the negative difference effect in magnesium corrosion," *Mater. Corros.*, no. 8, pp. 707–712, Aug. 2012.

[83] T. R. Thomaz, C. R. Weber, T. P. Jr, L. F. P. Dick, and G. Knörnschild, "The negative difference effect of magnesium and of the AZ91 alloy in chloride and stannate-containing solutions," *Corros. Sci.*, vol. 52, no. 7, pp. 2235–2243, 2010.

[84] G. L. Song and Z. Xu, "Effect of microstructure evolution on corrosion of different crystal surfaces of AZ31 Mg alloy in a chloride containing solution," *Corros. Sci.*, vol. 54, pp. 97–105, 2012.

[85] G.-L. Song, "The Effect of Texture on the Corrosion Behavior of AZ31 Mg Alloy," *Jom*, vol. 64, no. 6, pp. 671–679, Jun. 2012.

[86] E. Ghali, W. Dietzel, and K. U. Kainer, "General and Localized Corrosion of Magnesium Alloys: A Critical Review," *J. Mater. Eng. Perform.*, vol. 22, no. 10, pp. 2875–2891, Oct. 2013.

[87] J. D Hanawalt, "Corrosion Studies of Magnesium and Its Alloys," *Philadelphia Meet.*, 1941.

[88] F. Pan, J. Mao, X. Chen, J. Peng, and J. Wang, "Influence of impurities on microstructure and mechanical properties of ZK60 magnesium alloy," *Trans. Nonferrous Met. Soc. China*, vol. 20, no. 7, pp. 1299–1304, Jul. 2010.

[89] H. Matsubara, Y. Ichige, K. Fujita, H. Nishiyama, and K. Hodouchi, "Effect of impurity Fe on corrosion behavior of AM50 and AM60 magnesium alloys," *Corros. Sci.*, vol. 66, pp. 203–210, Jan. 2013.

[90] P. R. Roberge, *Corrosion Engineering Principles and Practice*, vol. 32, no. 3. McGraw Hill, 2006.

[91] W. H. Slabaugh and M. Grotheer, "Mechanism of Filiform Corrosion," *Ind. Eng. Chem.*, vol. 46, no. 5, pp. 1014–1016, May 1954.

[92] A. Afseth, J. H. Nordlien, G. M. Scamans, and K. Nisancioglu, "Filiform corrosion of binary aluminium model alloys," *Corros. Sci.*, vol. 44, pp. 2529–2542, 2002.

[93] X. Zhou, G. E. Thompson, and G. M. Scamans, "The influence of surface treatment on filiform corrosion resistance of painted aluminium alloy sheet," *Corros. Sci.*, vol. 45, pp. 1767–1777, 2003.

[94] Y. Liu, X. Zhou, G. Thompson, T. Hashimoto, G. Scamans, and a Afseth, "Precipitation in an AA6111 aluminium alloy and cosmetic corrosion," *Acta Mater.*, vol. 55, no. 1, pp. 353–360, Jan. 2007.

[95] Y. Liu, a. Laurino, T. Hashimoto, X. Zhou, P. Skeldon, G. E. Thompson, G. M. Scamans, C. Blanc, W. M. Rainforth, and M. F. Frolish, "Corrosion behaviour of mechanically polished AA7075-T6 aluminium alloy," *Surf. Interface Anal.*, vol. 42, no. 4, pp. 185–188, Apr. 2010.

[96] Y. Liu, a. Laurino, T. Hashimoto, X. Zhou, P. Skeldon, G. E. Thompson, G. M. Scamans, C. Blanc, W. M. Rainforth, and M. F. Frolish, "Corrosion behaviour of mechanically polished AA7075-T6 aluminium alloy," *Surf. Interface Anal.*, vol. 42, no. 4, pp. 185–188, Apr. 2010.

[97] A. E. Hughes, J. M. C. Mol, B. R. W. Hinton, and S. Van Der Zwaag, "A morphological study of filiform corrosive attack on cerated AA2024-T351 aluminium alloys," *Corros. Sci.*, vol. 47, pp. 107–124, 2005.

[98] A. Afseth, J. H. Nordlien, G. M. Scamans, and K. Nisancioglu, "Filiform corrosion of AA3005 aluminium analogue model alloys," *Corros. Sci.*, vol. 44, pp. 2543–2559, 2002.

[99] L. F. Hou, Y. H. Wei, X. F. Shu, and B. S. Xu, "Nanocrystalline structure of magnesium alloys subjected to high energy shot peening," *J. Alloys Compd.*, vol. 492, pp. 347–350, 2010.

[100] H. Kitahara, T. Yada, F. Hashiguchi, M. Tsushida, and S. Ando, "Mg alloy sheets with a nanocrystalline surface layer fabricated by wire-brushing," *Surf. Coatings Technol.*, vol. 243, pp. 28–33, Mar. 2014.

[101] K. Xu, A. Wang, Y. Wang, X. Dong, X. Zhang, and Z. Huang, "Surface nanocrystallization mechanism of a rare earth magnesium alloy induced by HVOF supersonic microparticles bombarding," *Appl. Surf. Sci.*, vol. 256, no. 3, pp. 619–626, Nov. 2009.

[102] D. L. Hawke, J. E. Hillis, M. Pekguleryuz, and I. Nakatsugawa, "Corrosion Behavior." pp. 194–210.

[103] Y. P. Ren, G. W. Qin, W. L. Pei, S. Li, Y. Guo, and H. Da Zhao, "Phase equilibria of Mg-rich corner in Mg-Zn-Al ternary system at 300°C," *Trans. Nonferrous Met. Soc. China (English Ed.*, vol. 22, pp. 241–245, 2012.

[104] S. Das, N. S. Barekar, O. El Fakir, L. Wang, a. K. Prasada Rao, J. B. Patel, H. R. Kotadia, a. Bhagurkar, J. P. Dear, and Z. Fan, "Effect of melt conditioning on heat treatment and mechanical properties of AZ31 alloy strips produced by twin roll casting," *Mater. Sci. Eng. A*, vol. 620, pp. 223–232, 2015.

[105] J. E. Lein, T. K. Aune, and K. Ni, "The Role of $Mg_{17}Al_{12}$ Phase in the Corrosion of Mg AIIoy AZ91 *," vol. 45, no. 9, pp. 741–748, 1989.

[106] O. Lunder, J. E. Lein, S. M. Hesjevik, T. K. Aune, and K. Nisancioglu, "Corrosion morphologies on magnesium alloy AZ91," *Mater. Corros.*, vol. 45, pp. 331–340, 1994.

[107] G. Song, A. L. Bowles, and D. H. StJohn, "Corrosion resistance of aged die cast magnesium alloy AZ91D," *Mater. Sci. Eng. A*, vol. 366, no. 1, pp. 74–86, Feb. 2004.

[108] R. Ambat, N. N. Aung, and W. Zhou, "Evaluation of microstructural effects on corrosion behaviour of AZ91D magnesium alloy," vol. 42, pp. 1433–1455, 2000.

[109] R. K. S. Raman, "The Role of Microstructure in Localized Corrosion of Magnesium Alloys," vol. 35, no. August, 2004.

[110] E. Ghali, "Corrosion and protection of magnesium alloys," *Mater. Sci. Forum*, vol. 350, pp. 261–272, 2000.

[111] F. Witte, V. Kaese, H. Haferkamp, E. Switzer, a Meyer-Lindenberg, C. J. Wirth, and H. Windhagen, "In vivo corrosion of four magnesium alloys and the associated bone response.," *Biomaterials*, vol. 26, no. 17, pp. 3557–63, Jun. 2005.

[112] Z. Li, X. Gu, S. Lou, and Y. Zheng, "The development of binary Mg-Ca alloys for use as biodegradable materials within bone.," *Biomaterials*, vol. 29, no. 10, pp. 1329–44, Apr. 2008.

[113] A. C. Hänzi, I. Gerber, M. Schinhammer, J. F. Löffler, and P. J. Uggowitzer, "On the in vitro and in vivo degradation performance and biological response of new biodegradable Mg-Y-Zn alloys.," *Acta Biomater.*, vol. 6, no. 5, pp. 1824–33, May 2010.

[114] S. Zhang, X. Zhang, C. Zhao, J. Li, Y. Song, C. Xie, H. Tao, Y. Zhang, Y. He, Y. Jiang, and Y. Bian, "Research on Mg-Zn alloy as a degradable biomaterial.," *Acta Biomater.*, vol. 6, no. 2, pp. 626–40, Feb. 2010.

[115] Y. Chen, Z. Xu, C. Smith, and J. Sankar, "Recent advances on the development of magnesium alloys for biodegradable implants," *Acta Biomater.*, vol. 10, no. 11, pp. 4561–4573, 2014.

[116] N. Hara, Y. Kobayashi, D. Kagaya, and N. Akao, "Formation and breakdown of surface films on magnesium and its alloys in aqueous solutions," *Corros. Sci.*, vol. 49, no. 1, pp. 166–175, Jan. 2007.

[117] A. Pardo, M. C. Merino, A. E. Coy, F. Viejo, R. Arrabal, and S. Feliú, "Influence of microstructure and composition on the corrosion behaviour of Mg/Al alloys in chloride media," *Electrochim. Acta*, vol. 53, no. 27, pp. 7890–7902, Nov. 2008.

[118] K. D. Ralston, G. Williams, and N. Birbilis, "Effect of pH on the grain size dependence of magnesium corrosion," *Corrosion*, vol. 68, pp. 507–517, 2012.

[119] F. Zucchi, V. Grassi, A. Frignani, C. Monticelli, and G. Trabanelli, "Electrochemical behaviour of a magnesium alloy containing rare earth elements," *J. Appl. Electrochem.*, vol. 36, pp. 195–204, 2006.

[120] N. Birbilis, M. A. Easton, A. D. Sudholz, S. M. Zhu, and M. A. Gibson, "On the corrosion of binary magnesium-rare earth alloys," *Corros. Sci.*, vol. 51, pp. 683–689, 2009.

[121] R. Rettig and S. Virtanen, "Composition of corrosion layers on a magnesium rare-earth alloy in simulated body fluids," *J. Biomed. Mater. Res. - Part A*, vol. 88, pp. 359–369, 2009.

[122] A. E. Coy, F. Viejo, P. Skeldon, and G. E. Thompson, "Susceptibility of rare-earth-magnesium alloys to micro-galvanic corrosion," *Corros. Sci.*, vol. 52, pp. 3896–3906, 2010.

[123] X. J. Liu, I. Ohnuma, R. Kainuma, and K. Ishida, "Thermodynamic assessment of the Aluminum-Manganese (Al-Mn) binary phase diagram," *J. Phase Equilibria*, vol. 20, no. 1, pp. 45–56, Jan. 1999.

[124] X. Zhou, G. E. Thompson, and G. M. Scamans, "The influence of surface treatment on filiform corrosion resistance of painted aluminium alloy sheet," *Corrosion Science*, vol. 45. pp. 1767–1777, 2003.

[125] Z. Chen, Y. Yang, and H. Jiao, "Some Applications of Electron Back Scattering Diffraction (EBSD) in Materials Research," *Scan. Electron Microsc.*, p. 830 pages, 2012.

[126] N. T. Kirkland, N. Birbilis, and M. P. Staiger, "Assessing the corrosion of biodegradable magnesium implants: a critical review of current methodologies and their limitations.," *Acta Biomater.*, vol. 8, no. 3, pp. 925–36, Mar. 2012.

[127] G. Williams, K. Gusieva, and N. Birbilis, "Localized Corrosion of Binary Mg-Nd Alloys in Chloride-Containing Electrolyte Using a Scanning Vibrating Electrode Technique," *Corrosion*, vol. 68, no. 6, pp. 489–498, Jun. 2012.

[128] G. Williams, H. A. L. Dafydd, and R. Grace, "The localised corrosion of Mg alloy AZ31 in chloride containingelectrolyte studied by a scanning vibrating electrode technique," *Electrochim. Acta*, vol. 109, pp. 489–501, 2013.

[129] S. Das, S. X. Ji, O. El Fakir, L. L. Wang, J. P. Dear, J. G. Lin, I. Stone, G. Scamans, and

Z. Y. Fan, "Melt Conditioned Twin Roll Casting (MC-TRC) of Thin Mg-Alloy Strips for Direct Stamping of Mg Components," *Mater. Sci. Forum*, vol. 765, pp. 170–174, Jul. 2013.

[130] N. N. Aung and W. Zhou, "Effect of grain size and twins on corrosion behaviour of AZ31B magnesium alloy," *Corrosion Science*, vol. 52, no. 2. pp. 589–594, 2010.

[131] B. J. Wang, D. K. Xu, J. H. Dong, and W. Ke, "Effect of the crystallographic orientation and twinning on the corrosion resistance of an as-extruded Mg-3Al-1Zn (wt.%) bar," *Scr. Mater.*, vol. 88, pp. 5–8, 2014.

[132] Z. Zhang, M. Wang, Z. Li, N. Jiang, S. Hao, J. Gong, and H. Hu, "Twinning, dynamic recovery and recrystallization in the hot rolling process of twin-roll cast AZ31B alloy," *J. Alloys Compd.*, vol. 509, no. 18, pp. 5571–5580, May 2011.

[133] S. A. Farzadfar, É. Martin, M. Sanjari, E. Essadiqi, M. A. Wells, and S. Yue, "On the deformation, recrystallization and texture of hot-rolled Mg–2.9Y and Mg–2.9Zn solid solution alloys—A comparative study," *Mater. Sci. Eng. A*, vol. 534, pp. 209–219, Feb. 2012.

[134] S. E. Ion, F. J. Humphreys, and S. H. White, "Dynamic recrystallisation and the development of microstructure during the high temperature deformation of magnesium," *Acta Metall.*, vol. 30, no. 10, pp. 1909–1919, Oct. 1982.

[135] M. Y. Wang, Y. J. Xu, T. Jing, G. Y. Peng, Y. N. Fu, and N. Chawla, "Growth orientations and morphologies of α-Mg dendrites in Mg–Zn alloys," *Scr. Mater.*, vol. 67, no. 7–8, pp. 629–632, Oct. 2012.

[136] G.-L. Song, *Corrosion electrochemistry of magnesium and its alloys*. Elsevier, 2011.

[137] S. Das, N. S. Barekar, O. El Fakir, L. Wang, A. K. Prasada Rao, J. B. Patel, H. R. Kotadia, A. Bhagurkar, J. P. Dear, and Z. Fan, "Effect of melt conditioning on heat treatment and mechanical properties of AZ31 alloy strips produced by twin roll casting," *Mater. Sci. Eng. A*, vol. 620, pp. 223–232, Jan. 2015.

[138] G. Scamans and Z. Fan, "Twin Roll Rheocasting of Aluminium Alloys."

[139] Y. Wang, M. Xia, Z. Fan, X. Zhou, and G. E. Thompson, "The effect of Al_8Mn_5 intermetallic particles on grain size of as-cast Mg–Al–Zn AZ91D alloy," *Intermetallics*, vol. 18, no. 8, pp. 1683–1689, Aug. 2010.

[140] H. Zhang, Y. Liu, J. Fan, H. J. Roven, W. Cheng, B. Xu, and H. Dong, "Microstructure evolution and mechanical properties of twinned AZ31 alloy plates at lower elevated temperature," *J. Alloys Compd.*, vol. 615, pp. 687–692, Dec. 2014.

[141] M. Knezevic, A. Levinson, R. Harris, R. K. Mishra, R. D. Doherty, and S. R. Kalidindi, "Deformation twinning in AZ31: Influence on strain hardening and texture evolution," *Acta Mater.*, vol. 58, no. 19, pp. 6230–6242, 2010.

[142] B. Mansoor, "Microstructural Evolution and Mechanical Properties of High Strength Magneisum Alloys," 2010.

[143] O. Muránsky, M. R. Barnett, D. G. Carr, S. C. Vogel, and E. C. Oliver, "Investigation of deformation twinning in a fine-grained and coarse-grained ZM20 Mg alloy: Combined in situ neutron diffraction and acoustic emission," *Acta Mater.*, vol. 58, no. 5, pp. 1503–1517, Mar. 2010.

[144] T. Laser, C. Hartig, M. R. Nürnberg, D. Letzig, and R. Bormann, "The influence of calcium and cerium mischmetal on the microstructural evolution of Mg–3Al–1Zn during extrusion and resulting mechanical properties," *Acta Mater.*, vol. 56, no. 12, pp. 2791–2798, Jul. 2008.

[145] S. Lun Sin, D. Dubé, and R. Tremblay, "Characterization of Al–Mn particles in AZ91D investment castings," *Mater. Charact.*, vol. 58, no. 10, pp. 989–996, Oct. 2007.

[146] T. Laser, M. R. Nürnberg, A. Janz, C. Hartig, D. Letzig, R. Schmid-Fetzer, and R. Bormann, "The influence of manganese on the microstructure and mechanical properties of AZ31 gravity die cast alloys," *Acta Mater.*, vol. 54, no. 11, pp. 3033–3041, Jun. 2006.

[147] P. Cao, L. Lu, and M. O. Lai, "Grain growth and kinetics for nanocrystalline magnesium alloy produced by mechanical alloying," *Mater. Res. Bull.*, vol. 36, no. 5–6, pp. 981–988, Mar. 2001.

[148] G. Song, B. Johannesson, S. Hapugoda, and D. StJohn, "Galvanic corrosion of magnesium alloy AZ91D in contact with an aluminium alloy, steel and zinc," *Corros. Sci.*, vol. 46, no. 4, pp. 955–977, Apr. 2004.

[149] K. N. Braszczynska-Malik and L. Froyen, "Microstructure of AZ91 alloy deformed by equal channel angular pressing," *Zeitschrift fur Met.*, vol. 96, no. 8, pp. 913–917, 2005.

[150] A. D. King, N. Birbilis, and J. R. Scully, "Accurate Electrochemical Measurement of Magnesium Corrosion Rates; a Combined Impedance, Mass-Loss and Hydrogen Collection Study," *Electrochim. Acta*, vol. 121, pp. 394–406, Mar. 2014.

[151] N. Perez, *Eectrochemistry and Corrosion Science*. Kluwer Academic Publishers, 2004.

[152] J. Liao, M. Hotta, and N. Yamamoto, "Corrosion behavior of fine-grained AZ31B magnesium alloy," *Corros. Sci.*, vol. 61, pp. 208–214, Aug. 2012.

[153] G. Song, A. Atrens, and M. Dargusch, "Influence of microstructure on the corrosion of diecast AZ91D," *Corros. Sci.*, vol. 41, no. 2, pp. 249–273, Feb. 1998.

[154] G. Song, A. Atrens, and X. Wu, "Corrosion behaviour of AZ21, AZ501 and AZ91 in sodium chloride," *Corros. Sci.*, vol. 40, pp. 1769–1791, 1998.

[155] G.-L. Song and Z. Xu, "The surface, microstructure and corrosion of magnesium alloy AZ31 sheet," *Electrochim. Acta*, vol. 55, no. 13, pp. 4148–4161, 2010.

[156] R. T. Ruggeri and T. R. Beck, "An analysis of Mass-transfer in filiform corrosion," *Corrosion*, vol. 39, pp. 452–465, 1983.

[157] J. Weissenrieder and C. Leygraf, "In Situ Studies of Filiform Corrosion of Iron," *J. Electrochem. Soc.*, vol. 151, no. 3, p. B165, 2004.

[158] A. Afseth, J. H. Nordlien, and G. M. Scamans, "Infuence of heat treatment and surface conditioning on filiform corrosion of aluminium alloys AA3005 and AA5754," vol. 43, 2001.

[159] A. J. Coleman, H. N. McMurray, G. Williams, A. Afseth, and G. M. Scamans, "Filiform Corrosion on 6000 Series Aluminium: Kinetics and Inhibition Strategies," *Materials Science Forum*, vol. 519–521. pp. 629–634, 2006.

[160] A. Afseth, J. H. Nordlien, G. M. Scamans, and K. Nisancioglu, "Effect of thermo-mechanical processing on filiform corrosion of aluminium alloy AA3005," *Corros. Sci.*, vol. 44, pp. 2491–2506, 2002.

[161] A. Afseth, J. H. Nordlien, G. M. Scamans, and K. Nisancioglu, "Influence of heat treatment and surface conditioning on filiform corrosion of aluminium alloys AA3005 and AA5754," *Corros. Sci.*, vol. 43, no. 12, pp. 2359–2377, Dec. 2001.

[162] Mars G. Fontana, *Corrosion*, Third., vol. 47. McGraw Hill, 1955.

[163] R. Lindström, L.-G. Johansson, G. E. Thompson, P. Skeldon, and J.-E. Svensson, "Corrosion of magnesium in humid air," *Corros. Sci.*, vol. 46, no. 5, pp. 1141–1158, May 2004.

[164] R. Lindström and J.-E. Svensson, "The influence of carbon dioxide on the atmospheric corrosion of some Magnesium alloys in the presence of NaCl."

[165] H. N. McMurray, A. Holder, G. Williams, G. M. Scamans, and A. J. Coleman, "The kinetics and mechanisms of filiform corrosion on aluminium alloy AA6111," in *Electrochimica Acta*, 2010, vol. 55, pp. 7843–7852.

[166] G. Williams and R. Grace, "Chloride-induced filiform corrosion of organic-coated magnesium," in *Electrochimica Acta*, 2011, vol. 56, pp. 1894–1903.

[167] C. F. Sharman, "Filiform Underfilm Corrosion of Lacquered Steel Surfaces," *Nature*, vol. 153, no. 3890, pp. 621–622, 1944.

[168] G. Williams and H. N. McMurray, "The mechanism of group (I) chloride initiated filiform corrosion on iron," *Electrochem. commun.*, vol. 5, pp. 871–877, 2003.

[169] N. T. Kirkland, J. Lespagnol, N. Birbilis, and M. P. Staiger, "A survey of bio-corrosion rates of magnesium alloys," *Corrosion Science*, vol. 52. pp. 287–291, 2010.

[170] N. Birbilis, a. D. King, S. Thomas, G. S. Frankel, and J. R. Scully, "Evidence for enhanced catalytic activity of magnesium arising from anodic dissolution," *Electrochim. Acta*, vol. 132, pp. 277–283, Jun. 2014.

[171] S. W. Xu, K. Oh-ishi, S. Kamado, H. Takahashi, and T. Homma, "Effects of different cooling rates during two casting processes on the microstructures and mechanical properties of extruded Mg–Al–Ca–Mn alloy," *Mater. Sci. Eng. A*, vol.

542, pp. 71–78, Apr. 2012.

[172] M. Y. Wang, J. J. Williams, L. Jiang, F. De Carlo, T. Jing, and N. Chawla, "Dendritic morphology of α-Mg during the solidification of Mg-based alloys: 3D experimental characterization by X-ray synchrotron tomography and phase-field simulations," *Scr. Mater.*, vol. 65, no. 10, pp. 855–858, Nov. 2011.

[173] M. Van Loo, D. D. Laiderman, and R. R. Bruhn, "Filiform corrosion," in *Ninth Annual Conference, NACE*, 1953.

[174] A. Samaniego, I. Llorente, and S. Feliu, "Combined effect of composition and surface condition on corrosion behaviour of magnesium alloys AZ31 and AZ61," *Corros. Sci.*, vol. 68, pp. 66–71, 2013.

[175] R. G. Song, C. Blawert, W. Dietzel, and a. Atrens, "A study on stress corrosion cracking and hydrogen embrittlement of AZ31 magnesium alloy," *Mater. Sci. Eng. A*, vol. 399, no. 1–2, pp. 308–317, Jun. 2005.

[176] G. L. Song, "Potential and current distributions of one-dimensional galvanic corrosion systems," *Corros. Sci.*, vol. 52, no. 2, pp. 455–480, 2010.

[177] D. Orlov, K. D. Ralston, N. Birbilis, and Y. Estrin, "Enhanced corrosion resistance of Mg alloy ZK60 after processing by integrated extrusion and equal channel angular pressing," *Acta Mater.*, vol. 59, no. 15, pp. 6176–6186, 2011.

[178] M. Taheri, J. R. Kish, N. Birbilis, M. Danaie, E. a. McNally, and J. R. McDermid, "Towards a Physical Description for the Origin of Enhanced Catalytic Activity of Corroding Magnesium Surfaces," *Electrochim. Acta*, vol. 116, pp. 396–403, Jan. 2014.

[179] Z. Pu, G.-L. Song, S. Yang, J. C. Outeiro, O. W. Dillon, D. A. Puleo, and I. S. Jawahir, "Grain refined and basal textured surface produced by burnishing for improved corrosion performance of AZ31B Mg alloy," *Corros. Sci.*, vol. 57, pp. 192–201, Apr. 2012.

[180] N. Wojtowicz, I. Danis, F. Monies, P. Lamesle, and R. Chieragati, "The Influence of Cutting Conditions on Surface Integrity of a Wrought Magnesium Alloy," *Procedia Eng.*, vol. 63, pp. 20–28, 2013.

[181] P. Marcus, "Corrosion Mechanisms in Theory and Practice," in *Corrosion Mechanisms in Theory and Practice*, CRC Press, 2002, pp. 349–393.

[182] A. J. Bard and L. R. Faulkner, *Electrochemical Methods - Fundamentals and Applications second edition*. 2000.

[183] A. Atrens, M. Liu, N. I. Z. Abidin, and G.-L. Song, *Corrosion of Magnesium Alloys*. Elsevier, 2011.

[184] Z. Zhao, "Role of surface active layers on localized breakdown of aluminum alloy 7075," 2006.

[185] E. Poorqasemi, O. Abootalebi, M. Peikari, and F. Haqdar, "Investigating accuracy

of the Tafel extrapolation method in HCl solutions," *Corros. Sci.*, vol. 51, no. 5, pp. 1043–1054, 2009.

[186] F. Mansfeld, "Tafel slopes and corrosion rates obtained in the pre-Tafel region of polarization curves," *Corros. Sci.*, vol. 47, no. 12, pp. 3178–3186, 2005.

[187] G. Kear and F. C. Walsh, "The characteristics of a true Tafel slope," *Corros. Mater.*, vol. 30, no. 6, pp. S1–S4, 2005.

[188] Z. Shi, M. Liu, and A. Atrens, "Measurement of the corrosion rate of magnesium alloys using Tafel extrapolation," *Corros. Sci.*, vol. 52, no. 2, pp. 579–588, 2010.

[189] M. F. Montemor and M. G. S. Ferreira, "Electrochemical study of modified bis-[triethoxysilylpropyl] tetrasulfide silane films applied on the AZ31 Mg alloy," *Electrochim. Acta*, vol. 52, pp. 7486–7495, 2007.

[190] H. E. Jamil, M. F. Montemor, R. Boulif, a. Shriri, and M. G. S. Ferreira, "An electrochemical and analytical approach to the inhibition mechanism of an amino-alcohol-based corrosion inhibitor for reinforced concrete," *Electrochim. Acta*, vol. 48, no. 23, pp. 3509–3518, 2003.

[191] Z. Pu, O. W. Dillon, D. A. Puelo, and I. S. Jawahir, *Surface Modification of Magnesium and its Alloys for Biomedical Applications*. Elsevier, 2015.

[192] F. Hashimoto, Y. B. Guo, and a. W. Warren, "Surface integrity difference between hard turned and ground surfaces and its impact on fatigue life," *CIRP Ann. - Manuf. Technol.*, vol. 55, no. 2, pp. 81–84, 2006.

[193] ASM Vol 3, *Alloy Phase Diagrams*. 2004.

[194] H. Leth-Olsen, A. Afseth, and K. Nisancioglu, "Filiform corrosion of aluminium sheet. II. Electrochemical and corrosion behaviour of bare substrates," *Corros. Sci.*, vol. 40, pp. 1195–1214, 1998.

[195] C. I. M. P. Brady and K. A. Unocic, "Understanding Protective Film Formation by Magnesium Alloys in Automotive Applications Overview : New Project," 2013.

[196] R. Mola, "Fabrication and Microstructure of Layers Containing Intermetallic Phases on Magnesium," vol. 13, no. 1, pp. 99–102, 2013.

[197] Y. Liu, X. Zhou, G. Thompson, T. Hashimoto, G. Scamans, and a Afseth, "Precipitation in an AA6111 aluminium alloy and cosmetic corrosion," *Acta Mater.*, vol. 55, no. 1, pp. 353–360, Jan. 2007.

[198] H. Leth-Olsen and K. Nisancioglu, "Filiform Corrosion Morphologies on Painted Aluminum Alloy 3105 Coil Material," *Corrosion*, vol. 53, pp. 705–717, 1997.

[199] X. Fan, Z. He, S. Yuan, and P. Lin, "Investigation on strengthening of 6A02 aluminum alloy sheet in hot forming-quenching integrated process with warm forming-dies," *Mater. Sci. Eng. A*, vol. 587, pp. 221–227, Dec. 2013.