The Subsurface Structure of Abraded Al Alloys and its Influences on Corrosion

Shan-Shan Wang
Fontana Corrosion Center, Department of Materials Science and Engineering, The Ohio State University, Columbus, OH 43210, USA
E-mail: wang.3608@osu.edu.

Al alloys subjected to surface abrasion exhibit an altered surface layer (ASL) with unique microstructure as the result of heavy shear deformation [1-10]. This ASL microstructure is extremely unstable even at room temperature (RT), and its evolution is strongly affected by sample geometry (bulk or TEM sample) and temperature [3,4]. In the ASL on freshly-abraded Al-Zn-Mg-Cu samples, pre-existing η′/η precipitates and grain boundaries are deformed and bent toward the abrasion direction. After 7-day natural aging of the abraded bulk sample, ultrafine subgrains form locally in the ASL, while unusual Al_2Cu (θ) and Mg_xZn_y phases precipitate at these subgrain boundaries; however, some deformed η′/η precipitates decompose. Repeated observation of this TEM specimen with storage at RT shows that more ultrafine subgrains and θ particles form in the ASL, and Zn diffuses out of Mg_xZn_y particles to form a Zn particle. These unusual Zn and θ phases continued to grow and coarsen during 42-month natural aging of the TEM specimens [3]. Artificial aging of abraded bulk samples at 50 °C for 1 h significantly accelerate the formation of subgrains and θ particles in the ASL [4]. Because of the unique ASL microstructure, abraded alloy surfaces exhibit a different corrosion resistance than the underlying substrate [1,2,6-10]. The ASLs on Al-Zn-Mg-Cu alloys are preferentially attacked at lower potentials than the underlying substrates during potentiodynamic polarization in an NaCl solution, resulting in surface layer attack that would undermine any protective coating system. Long-term natural aging or short-period artificial aging increases the breakdown potential and improves the corrosion resistance of the ASL [6]. The ASLs on AA2024 and sensitized AA5083 are more resistant to corrosion owing to the solute redistribution in the ASL [9,10]. Clearly the details of the ASL microstructure and its evolution play a critical role in the corrosion properties of abraded Al alloys.

Acknowledgements: Dr. Gerald S. Frankel, Dr. Daniel Huber, Henk Colijn and Anup Panindre at The Ohio State University (OSU), Dr. Jonathan Poplawsky at Oak Ridge National Laboratory (ORNL), and Drs. Guo-Hua Fan, Jian-Tang Jiang and Liang Zhen at Harbin Institute of Technology (HIT) contributed to this work. Focused ion beam and transmission electron microscopy were conducted at Center for Electron Microscopy and Analysis at OSU and at HIT. Atom probe tomography was conducted at Center for Nanophase Materials Sciences at ORNL, which is a U.S. DOE Office of Science User Facility.

References:

1. Z. Zhao, G.S. Frankel, On the first breakdown in AA7075-T6, Corros. Sci. 49 (2007) 3064–3088.
2. Z. Zhao, G.S. Frankel, The effect of temper on the first breakdown in AA7075, Corros. Sci. 49 (2007) 3089–3111.
3. S.S. Wang, J.T. Jiang, G.H. Fan, A.M. Panindre, G.S. Frankel, and L. Zhen, “Accelerated precipitation and growth of phases in an Al-Zn-Mg-Cu alloy processed by surface abrasion”, *Acta Mater.*, 131 (2017) 233–245.

4. S.S. Wang, D. Huber, J. Poplawsky, H. Colijn, and G.S. Frankel, “The Subsurface Structure of Abraded Al-Zn-Mg-Cu Alloy”, Submitted to Acta Mater, 2020.
5. S.S. Wang, J.T. Jiang, G.H Fan, L. Yang, S.L. Dai, G.S. Frankel, and L. Zhen, “Microstructure evolution in abrasion-induced surface layer on an Al-Zn-Mg-Cu alloy”, *Mater. Charact.*, 98 (2014) 18-25.
6. S.S. Wang, J.T. Jiang, G.H. Fan, G.S. Frankel and L. Zhen, “Effects of long-term natural aging on the altered surface layer on an Al-Zn-Mg-Cu alloy and on corrosion properties”, *Electrochim. Acta*, 266 (2018) 34-42.
7. S.S. Wang, J.T. Jiang, S.L Dai, D.N. Seidman, G.S. Frankel, and L. Zhen, “Effect of surface roughness on breakdown behavior of Al-Zn-Mg-Cu alloy”, *J. Electrochem. Soc.*, 161, (2014) C433-C440.
8. S.S. Wang, G.S. Frankel, J.T. Jiang, J.F. Chen, S.L. Dai, and L. Zhen, “Mechanism of localized breakdown of 7000 series aluminum alloys”, *J. Electrochem. Soc.*, 160, (2013) C493-C502.
9. S.S. Wang, F. Yang, and G.S. Frankel, “Effect of altered surface layer on localized corrosion of AA2024”, *J. Electrochem. Soc.*, 164, (2017) C317-C323.
10. J. Seong, F. Yang, F. Scheltens, G.S. Frankel, and N. Sridhar, “Influence of the altered surface layer on the corrosion of AA5083”, *J. Electrochem. Soc*., 162, (2015) C209-C218.