Nucleation and growth behavior of protective coating by plasma electrolytic oxidation considering grain size of 6061 aluminum alloy

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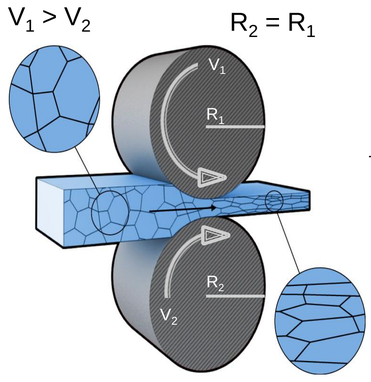
Abstract

The work investigated nucleation and growth mechanism of protective coating during plasma electrolytic oxidation (PEO) by considering grain size of 6061 Al alloy substrate. Prior to PEO treatment, the substrate with grain size of 50 μm (coarse-grain, CG) was deformed via 4-pass differential-speed rolling (DSR) to achieve grain size of 1 μm (fine-grain, FG). Unlike CG, FG caused an early breakdown and more uniform characteristics of plasma sparks, resulting in the thick and compact layer. The nucleation and growth mechanism of the coating layer were scrutinized on the basis of transport behavior of massive electrons across the grain boundaries at the initial stage of PEO. The mechanical and corrosion properties of both samples were evaluated in a quantitative manner.

Experimental

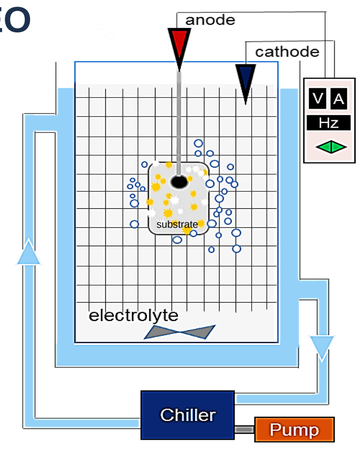
DSR



DSR	
Substrate	6061 Al alloy
Dimension	40 × 10 × 4 mm³
Roll speed ratio	1 : 4
Height reduction	30% per pass
Specimen rotation	180° from RD

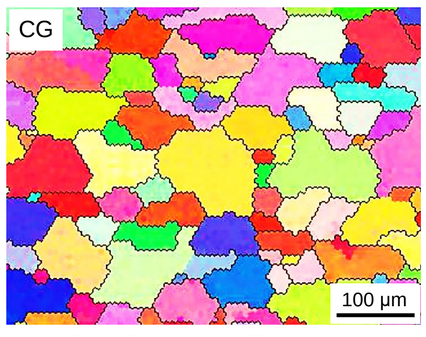
PEO	
Current density	100 mA·cm^{-2}
Frequency	60 Hz
Electrolyte	Na_2SiO_3 0.05 M KOH 0.05 M
Coating time	600 s

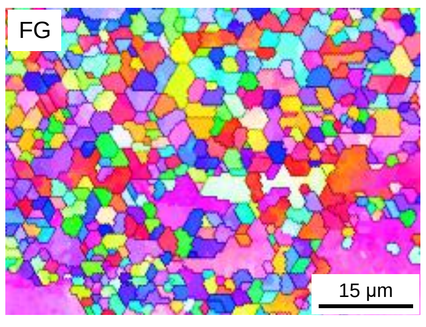
PEO



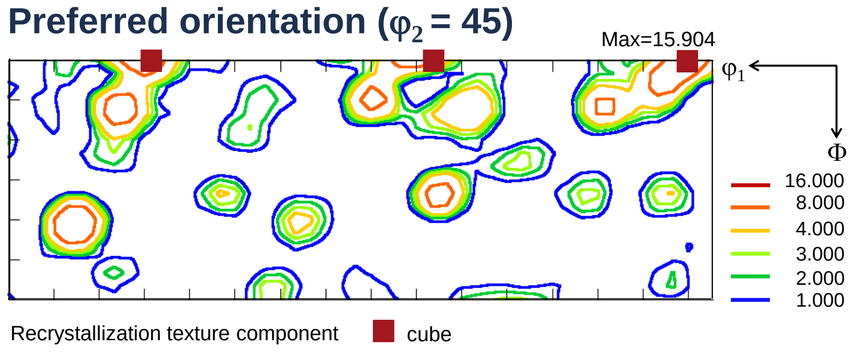
Results and discussion

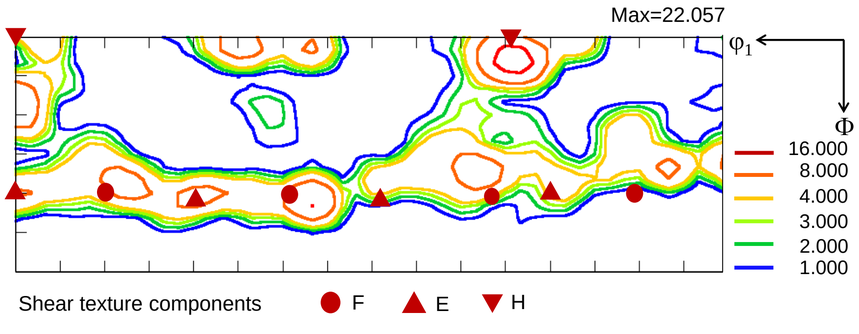
Grain size



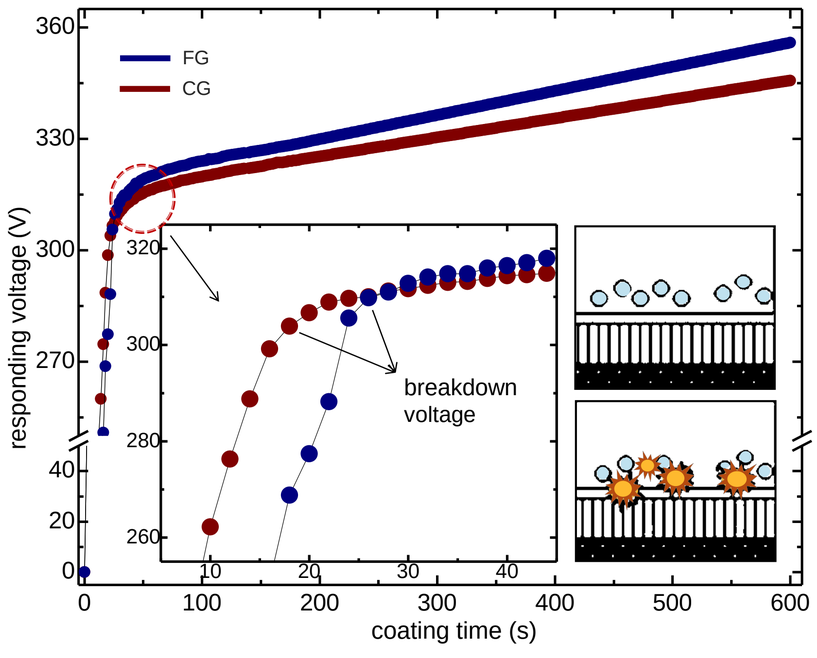


Preferred orientation (φ_2 = 45)

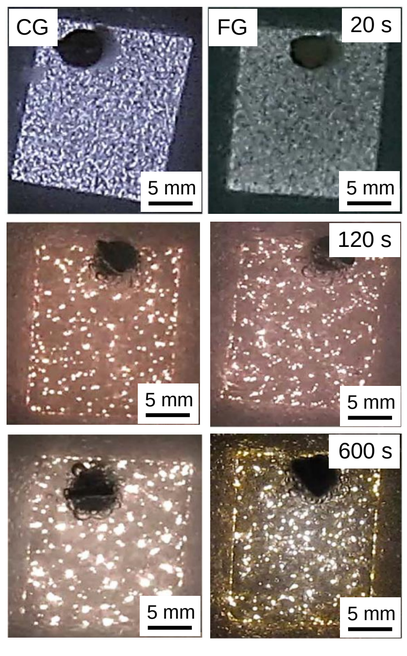




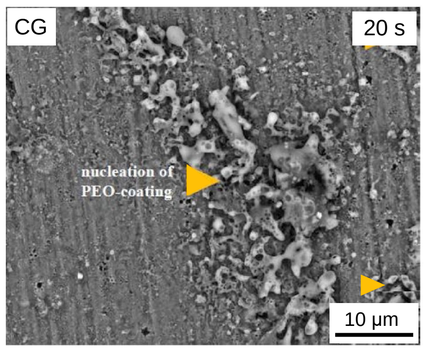
Voltage-time response

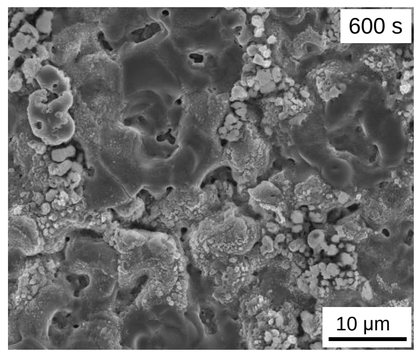


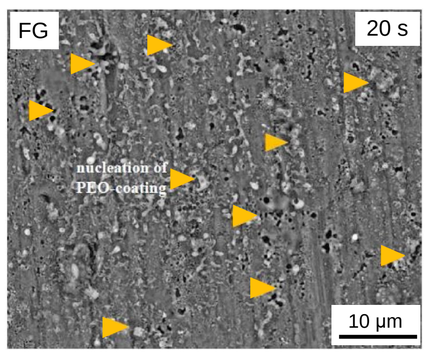
Spark appearance

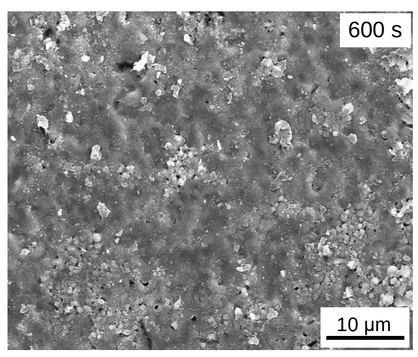


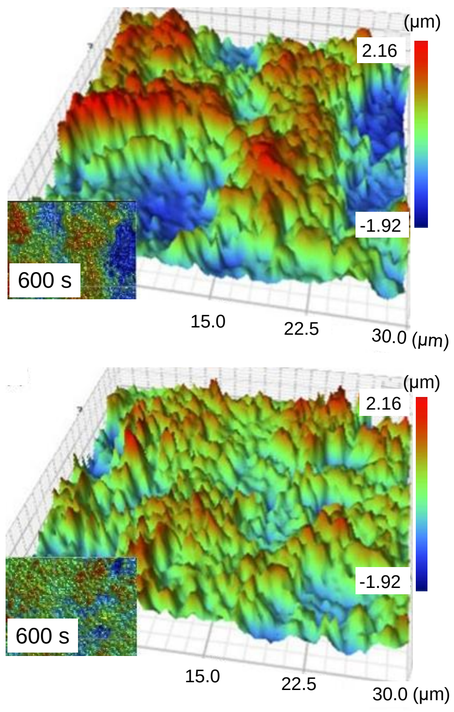
Surface characteristics



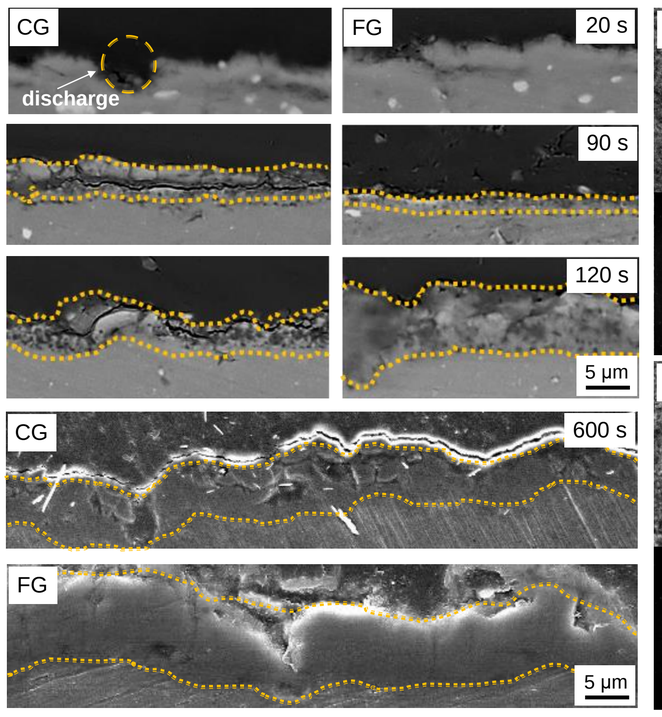


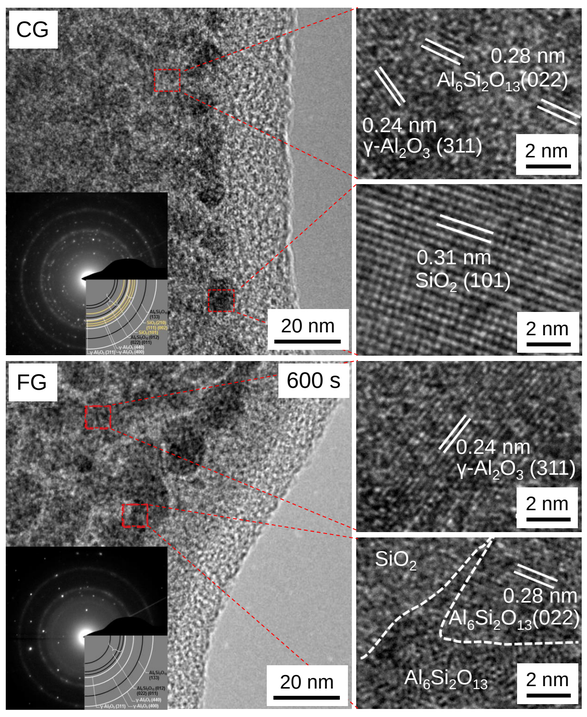




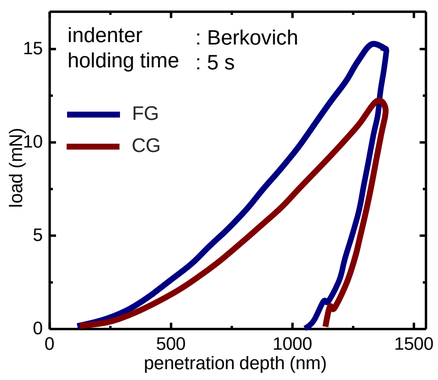


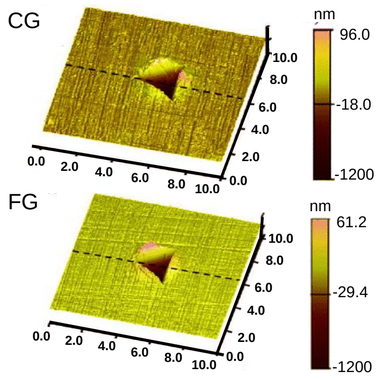
Cross-section characteristics



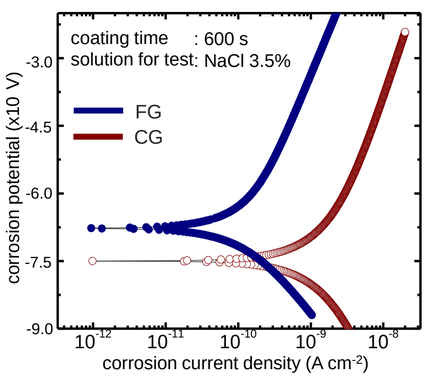


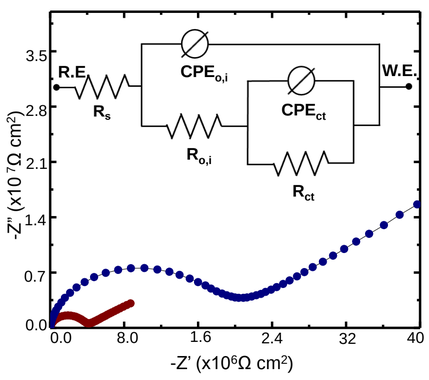
Tribological response



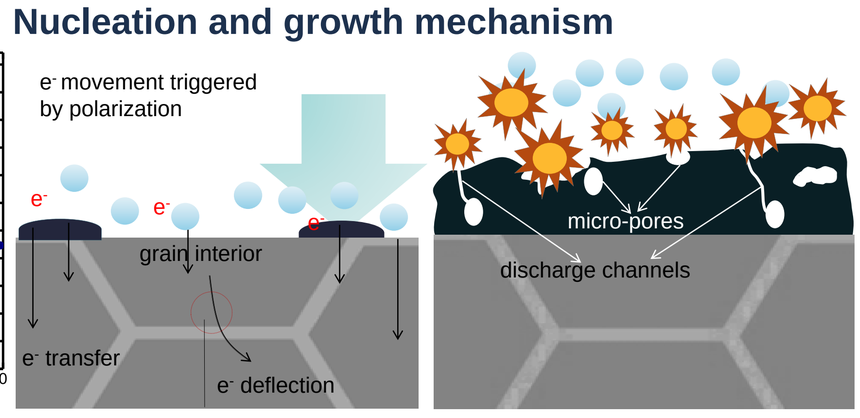


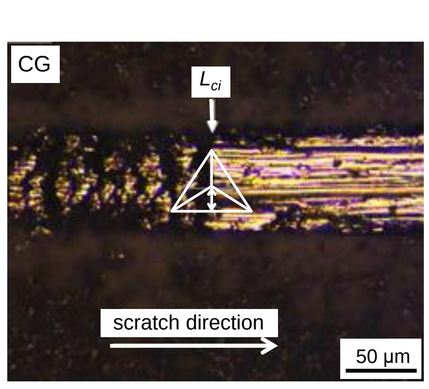
Corrosion assessment

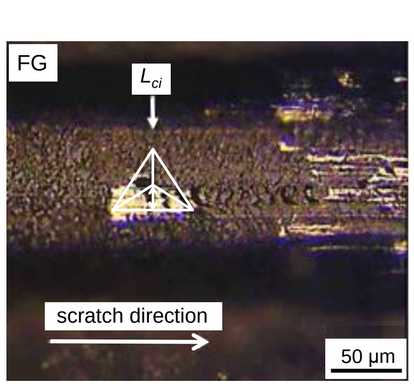


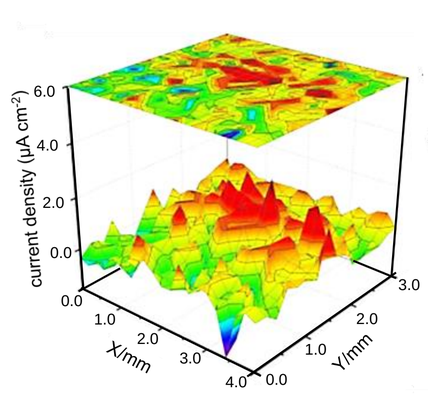


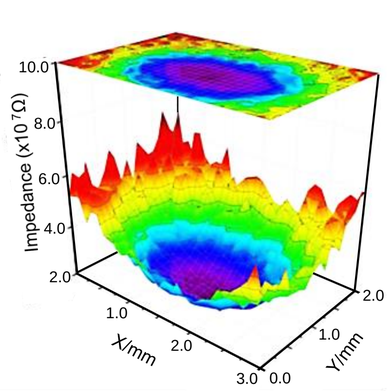
Nucleation and growth mechanism

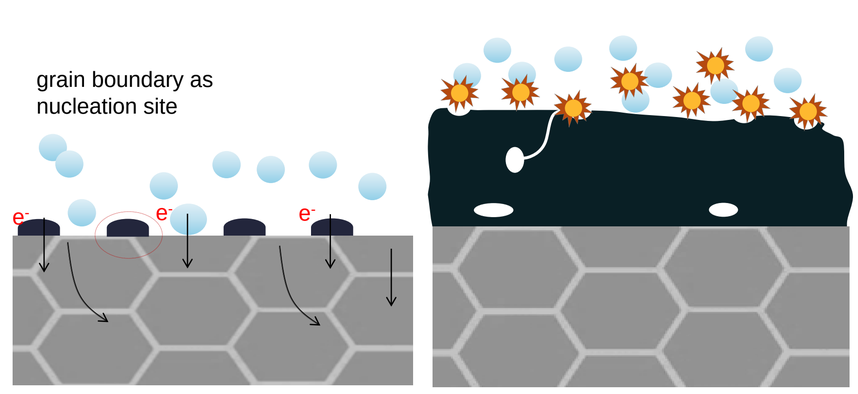












Summary

Fundamental formation mechanism of protective coating formed during PEO was investigated by taking the initial grain size of 6061 Al alloy into account. Apparently, breakdown phenomenon in CG appeared earlier than that in FG as scattering and even deflection of electrons across grain boundaries might be intensified with a decrease in grain size, triggering nucleation kinetics that would allow the initial film to develop uniformly. As a result, the present condition with the use of fine-grain (1 μm in diameter) caused the uniform occurrence of plasma sparks affecting the formation of sound coating in 6061 Al alloy.