EFFECTIVENESS OF FATTY ACIDS ON WEAR RESISTANCE OF ANODIC COATINGS

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INTRODUCTION

The utilization of anodized aluminum (Al) for high-tech applications is increasing rapidly. Despite its hardness, wear of anodic coating remains one of the major problems. Polytetrafluoroethylene (PTFE) coatings are often used to improve the wear resistance of anodized Al. Nevertheless, the non-wetting nature and high molecular size of PTFE polymers are not favorable for penetrating into nanopores of anodic coating. As an alternative, fatty acids (FA) were used for friction tests on anodized Al alloys 6082 and 7075.

MATERIALS

Technical grade oleic a. (70% pure), lauric a. (>90% pure) and fluoropolymer-based DryFilm RA/IPA dispersion of 25% solids (DuPont) were used for impregnating the anodic coatings. The properties of Al alloys are present in Table 1.

Table 1. *Elemental composition (wt.%) and surface properties of investigated alloys*

Al alloy	Al, wt.%	Fe, wt.%	Si, wt.%	Mg, wt.%	Mn, wt.%	Cu, wt.%	Zn, wt.%	Surface roughness *Ra*, µm	Vickers microhardness $HV_{0.02}$, kg/mm²
6082	96.72	0.54	1.10	1.02	0.61	-	-	1.28 ± 0.08	139 ± 10
7075	87.39	-	-	2.80	-	2.08	7.74	0.86 ± 0.08	99 ± 10

EXPERIMENTAL

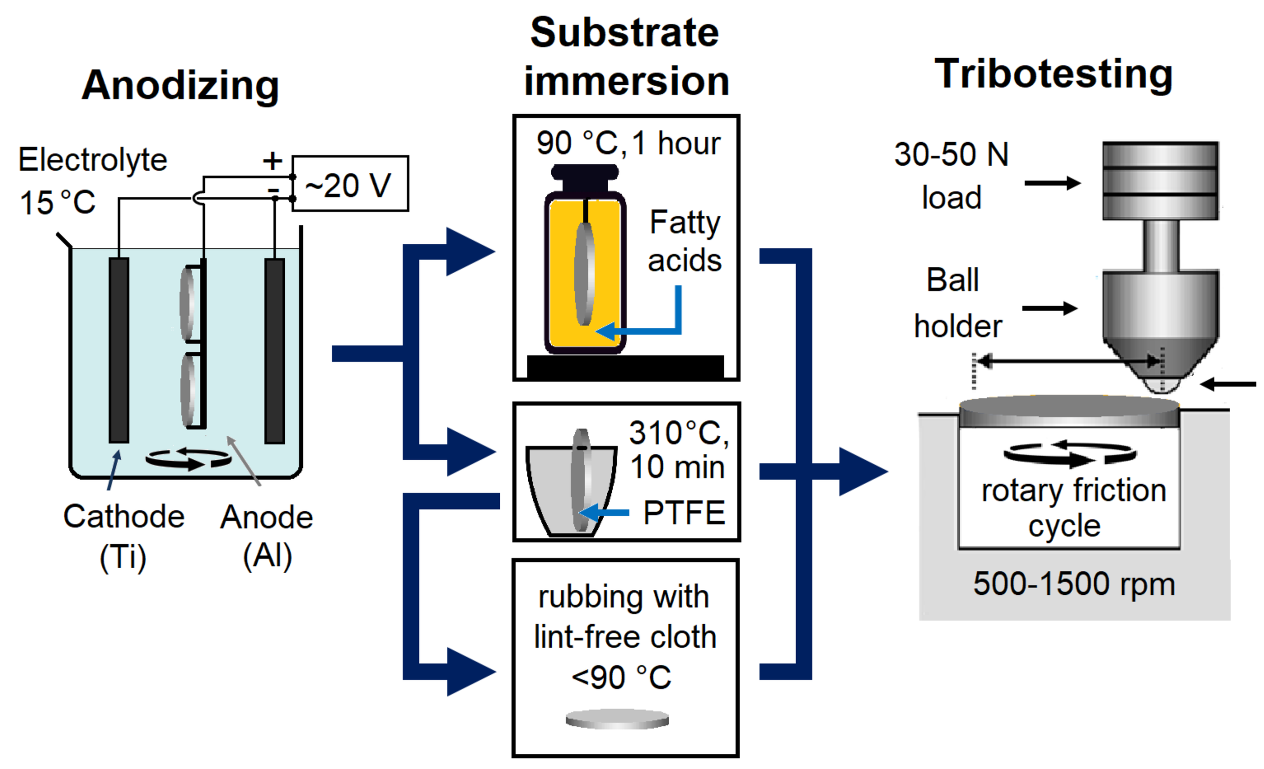

Fig. 1. *The principal scheme of specimen preparation and investigation: 1) anodizing; 2) substrate immersion; 3) tribotesting*

Anodizing. Anodization was performed in H_2SO_4/oxalic a. (Type III) electrolyte (15 °C, 20 V, 200 A/m²) for 70 min at 2 A/dm² anodic current density and 15 °C temperature to produce hard Al_2O_3 coatings of 60 µm thickness, see Fig. 1.

Substrate immersion. The anodized discs were immersed in heated FA for 1 hour at 90 °C, then pulled out and suspended vertically to drip off for 1 hr at 90 °C. For PTFE, the anodized discs were immersed for 15 min into the dispersion then removed and suspended vertically in air for 30 min, all at room temp. Afterwards the PTFE specimens were placed into the tube furnace RS 80/500/11 (Germany) at 310 °C for 10 min curing, then taken out and optionally rubbed with a lint-free cloth for 10-15 s before cooling below 90 °C.

Tribological tests. Ball-on-Disc Tribometer (Anton Paar) or Micro-PoD TR-20 M63 (Ducom) were used for friction tests. A bearing steel 100Cr6 ball of 6 mm OD and 96.5% purity was fixed into the holder and pressed under the 30 N or 50 N load against the coated specimen, mounted on a rotary part. The rotational motion of 500 rpm or 1500 rpm resulted in a track length of 31.4 mm for one revolution.

Characterization of anodic coatings

Anodization produces hard coatings of ~60 µm thickness with nanopores less than 20 nm, see Table 2.

Table 2. *Characteristics of surface pores, obtained after anodization*

Al alloy	Coating thickness, µm	Pore diameter, nm	Pore density, pores/µm²	Porosity, %
6082	56 ± 2	15 ± 2	1040 ± 121	23
7075	61 ± 2	12 ± 4	1806 ± 77	26

SEM images reveal differences between anodic coatings. Anodization of 7075 alloy produces large voids, Fig. 2, possibly as a result of unevenly dissolved alloying elements, which are more abundant than in 6082. The voids might cause problems in hardness, which increases only slightly after anodization in 7075. However, such voids might accommodate large molecules of PTFE easier than 6082.

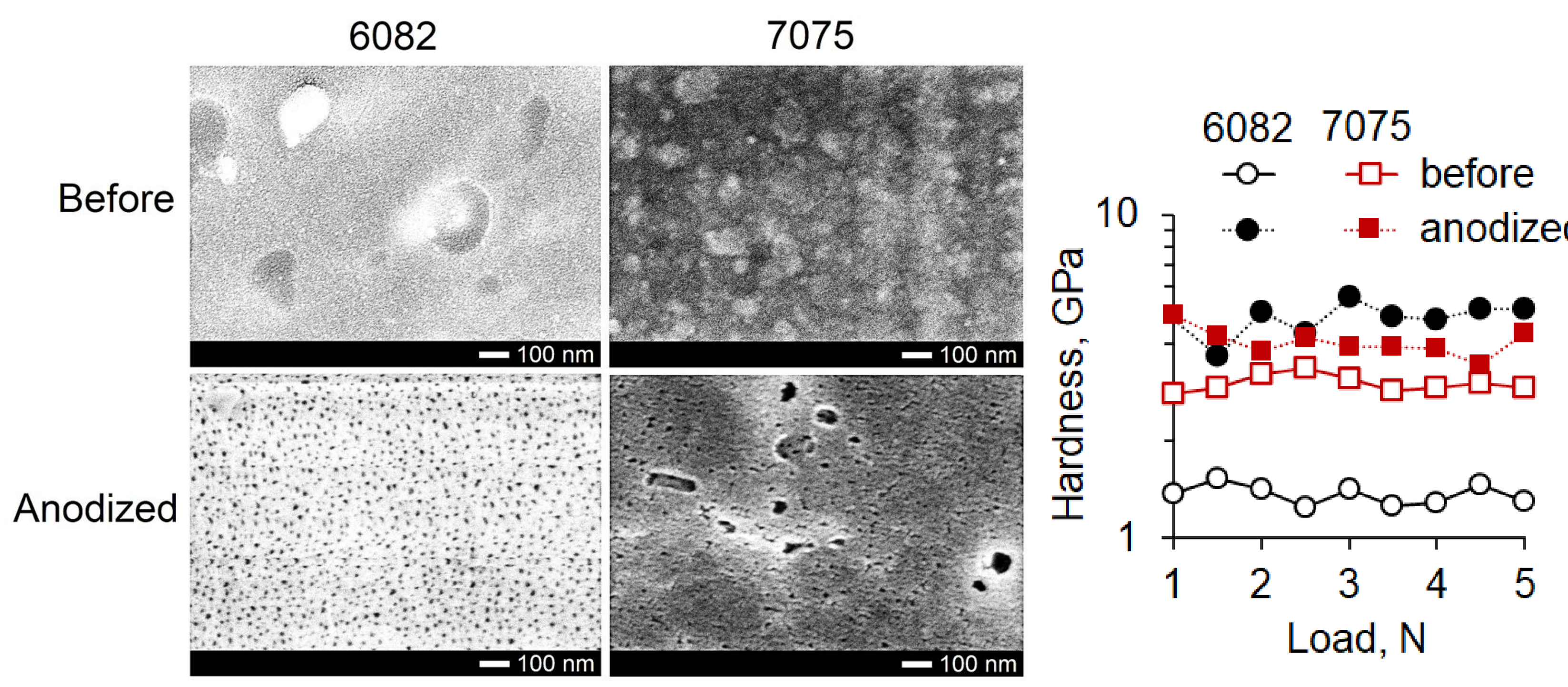

Fig. 2. *SEM images of Al surfaces before and after anodization (left) and its hardness (right)*

Friction tests

Friction results showed that impregnation of FA and PTFE coatings significantly reduces initial Coefficient of Friction (COF) below 0.1, Fig. 3.

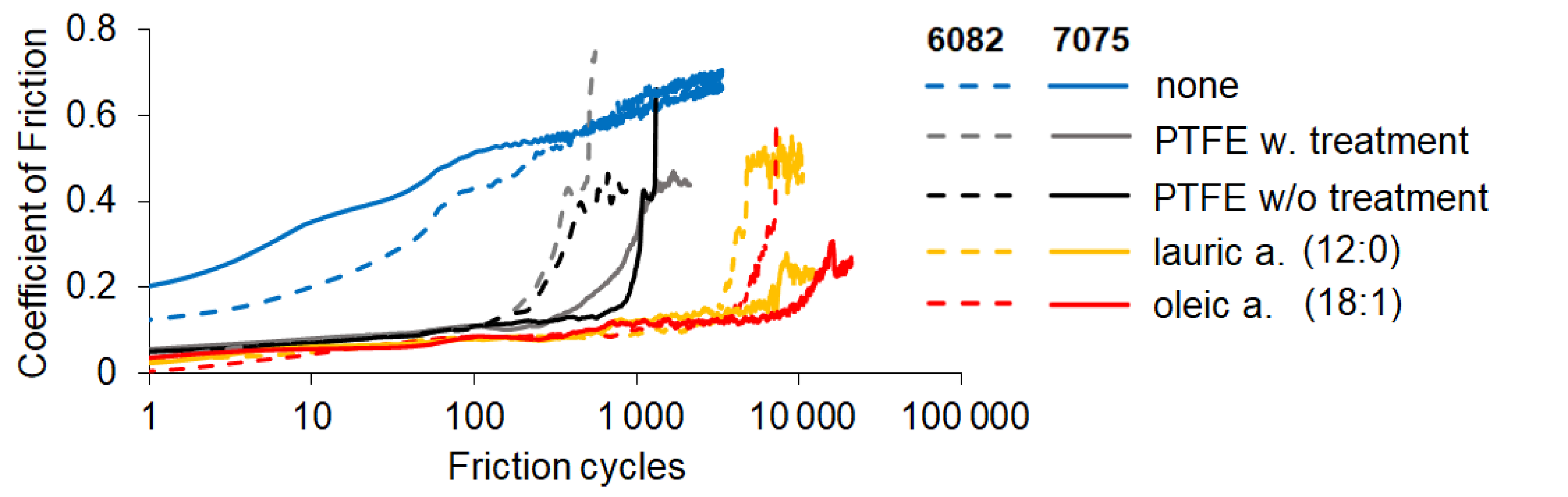

Fig. 3. *Influence of PTFE and FA on friction tendencies of anodized 6082 and 7075 alloys under 50 N load and 500 rpm velocity*

The nanopores below 20 nm ID appear not large enough for PTFE penetration, which could maintain low COF up to only 1000 friction cycles acting as barrier lubricant. The thermo-mechanical treatment did not improve the effectiveness of PTFE either. PTFE on 7075 showed better wear resistance than on 6082, possibly due to better polymer penetration into the voids. However, FA performs clearly better by being able to migrate into nanopores and withstand nearly 10 000 friction cycles under 50 N load. FA likely reacts with Al hydroxides in the friction zone by forming soaps and improves the ability to sustain low friction. This ability seems to improve by increasing the carbon number of aliphatic chain of FA, see Fig. 4.

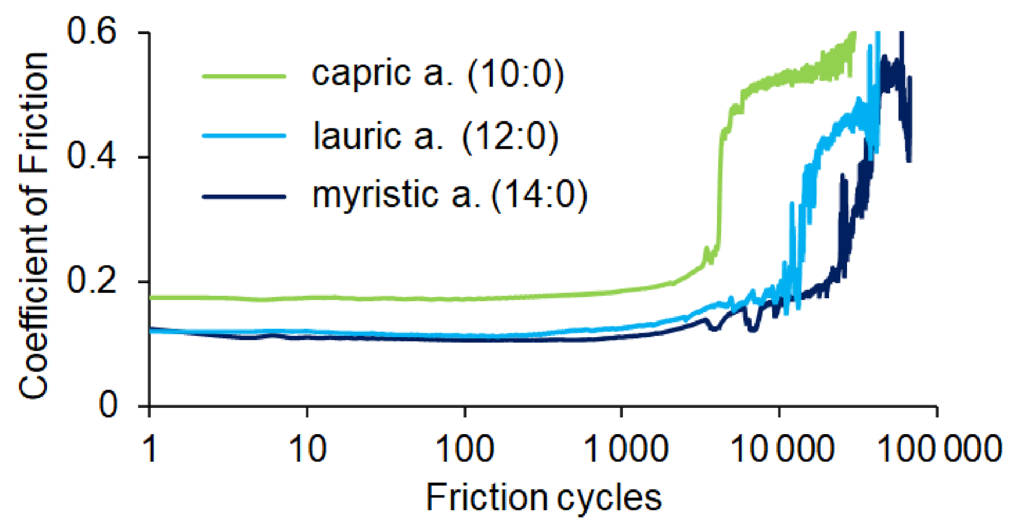

Fig. 4. *Influence of saturated FA on friction tendencies of anodized 6082 alloy under 30 N load and 1500 rpm velocity*

CONCLUSIONS

1. The barrier type PTFE coatings are less tribologically effective than fatty acids, which can form soaps.
2. Large voids on anodized 7075 might help PTFE penetration, but they reduce hardness significantly.
3. Combining the immersion liquid, alloy and anodizing electrolyte can further improve tribological performance.

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