Andrew Feldman

A DEVICE FOR GROWING PATTERNED ANODIC OXIDE FILMS ON TITANIUM

(6.UAP THESIS PROPOSAL)

Anodization is an industrially important process for applying aesthetic, protective, or functional surface modifications to metal surfaces, via electrochemical oxidation of the surface metal. Commonly anodized metals include (but are not limited to) Aluminum, Titanium, and Niobium, for reasons having to do with the physical characteristics of native oxide layers on these metals. Commonly, the anodization process requires a metal part to be submerged in an electrolyte bath and connected to the anode (positive terminal) of a voltage source. The anode tends to convert some of the metal atoms at the part’s surface to positive ions, and when the cathode is submerged as well, it generates negative oxygen ions that diffuse through the solution and neutralize the metal ions, forming the “anodic oxide layer” on the metal part.

Owing to the porosity of anodic oxides formed under the proper conditions, anodized metal surfaces can absorb and lock in pigments. Anodized and dyed Aluminum surfaces are responsible for the brilliant matte or smooth surface coloration on Apple’s line of iPods and newer iPhones, as well as many other metal products such as carabiners and Aluminum water bottles. Companies such as Superior Metal Technologies claim that anodization of Aluminum produces strong, wear-resistant protective layers with corrosion resistance superior to that provided by paint. Aluminum anodization is also used to change the chemical behavior at the surfaces of metals, and the growth of structured porous anodic oxide layers has been studied as a technical for fabricating “nano-pillars” with useful optical properties.

I am designing an etchant-free, mask-free, CNC process for applying patterned anodization to metal surfaces. Instead of submerging the entire metal part in a liquid electrochemical cell, I am modifying a low-cost CNC drawing machine\* to “paint” narrow lines of anodic oxide onto the metal using an electrolyte-soaked, fine-tipped brush or marker connected to a voltage source. In this way, the electrochemical reaction is localized to the minute region where the brush or marker contacts the metal part. In this system there are four important degrees of freedom: the X and Y coordinates of the brush/marker, the contact-state of the marker with the part, and the voltage applied by the voltage source. With this system working, the next step would be do develop a simple CAM program that converts a bitmap representing the desired pattern and thickness of anodic oxide to a sequence of control codes for the CNC machine.

Ultimately a system such as this could be used for any suitable electrochemical reaction involving a variety of metals. Titanium anodization is of interest for my current work because oxide thickness is an important process parameter for anodization, and Titanium (as well as the more expensive Niobium) is unique in that the color of its oxide allows one to roughly estimate the oxide film thickness with the naked eye owing to thin-film interference effects. So testing the CNC anodization system on Titanium allows me to easily and cheaply verify that the resulting anodic oxide film thickness meets spec. Aesthetically appealing anodic oxide films can be produced on Titanium without the need for electrolytes containing sulfuric acid, which are necessary for Aluminum anodization.

\*I have not yet purchased a CNC drawing machine. I had purchased a low-cost Solidoodle 3D printer prior to beginning this work, so if the CNC drawing machine exceeds my budget I may use the Solidoodle’s 3-axis stage instead.

<find final version of proposal>

The first electrolytic deposition tip was a crayola marker soaked and baking soda and fed with a wire from the power supply. The improved resolution tip is a tube with a small slice of felt.

The Titanium plate also needs to have a wir back to the power supply and it must be fixed to the base of the print surface. In my first setup, I held the Titanium plate to the print surface using two strips of double-sided tape; in between the strips of double-sided tape, I slid a stripped wire which would be held in contact with the Titanium plate.

The electrochemical potential source is a 30V power supply modulated by a PWM signal from a microcontroller. The high voltage modulator filters the PWM signal and feeds it into an op-amp amplifier running off of the 30V rail, which allows the microcontroller to control the source’s output from roughly zero to thirty volts. In practice, the source plateaus at several volts and and 20-something volts respectively, with a very nonlinear response in between. The output voltage is thus not proportional to the PWM duty cycle and it is necessary to calibrate the duty cycle-output voltage relationship to allow precise control.