Anodization As A Low Cost, Scalable, and Tunable Nanoscale Manufacturing Technique

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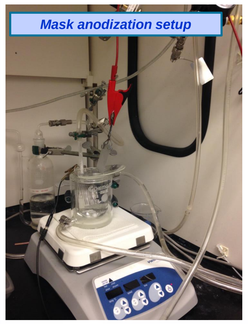
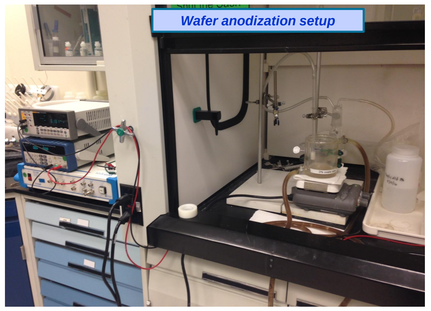
We explore the application of anodization of aluminum as a low cost, efficient, and highly scalable technique useful not only for manipulation of macroscopic properties of materials, but also as a starting point for the creation of nanoscale metallic structures. Using simple chemical setups and software controls, we have been able to selectively anodize aluminum, without affecting underlying substrate. This process has yielded alumina samples suitable for further development.

Anodization lab

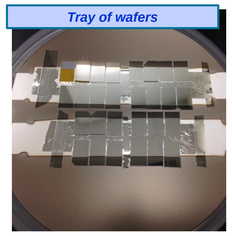


- 2 separate anodization setups.
- Chiller
- Jacketed beaker
- Stir/hotplate
- Power supply
- Voltmeter
- Bubbler
- Laptop

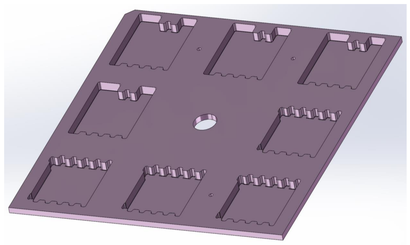


Digital microscope (Keyence) and balances used were in other lab

Substrates



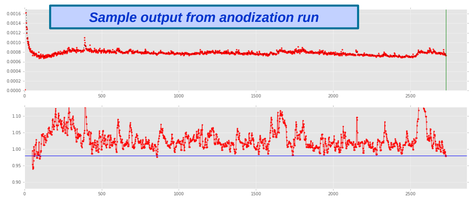
Wafers of metal “sandwiches”. Aluminum atop tungsten, titanium, and base layer of silicon or sapphire.



CAD render of the mask (vias not displayed)

Electronic Control

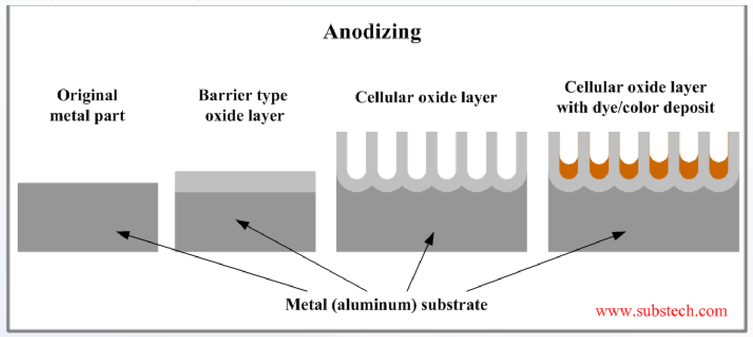
- A Python script controls the experiment
- Interfaces with the equipment, shuts power off based on either current drop or time elapsed.



- Utilises tkinter, matplotlib, and numpy for easy usability and a simple GUI
- Ensures repeatability
- Maximizes productivity

Anodization and its applications

- A method of modifying metals that has been used since 1923, when it was particularly useful as a corrosion barrier.
- Electrochemically accelerated form of oxidation, which occurs naturally
- Oxide layer formed by anodization is as much as 3 orders of magnitude thicker than the layers found naturally.



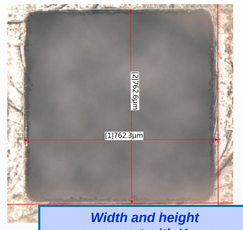
Due to the acidic conditions in the anodization bath, micropores can be formed from the dissolution of the aluminum oxide at surface defects, such as grain boundaries.

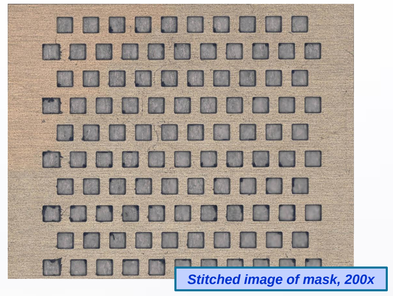
Application 1: Creation of porous templates as templates for catalysis of carbon nanotube growth. Metal is electrodeposited in the pores, allowing planarized growth of the nanotubes on the surface of the template.

Application 2: Processing machined aluminum masks for use in a plasma spray process. The anodization ensures that the material adheres only to the substrate, and not to the mask.

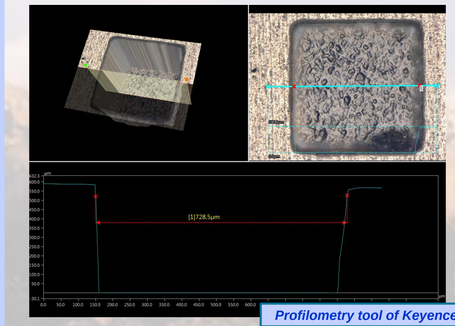
Image source: http://www.substech.com

Microscopy and Analysis



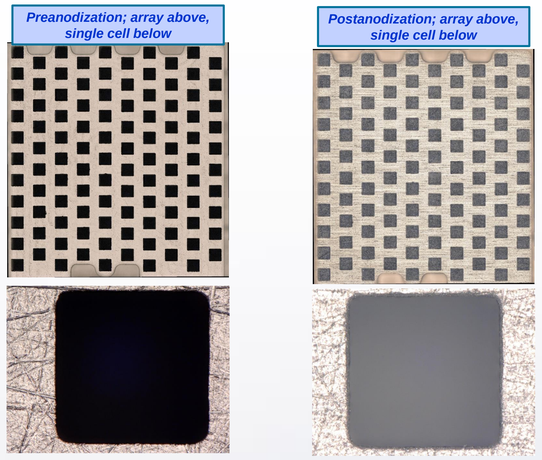


- Used Keyence digital microscope and its accompanying software suite to do visual analysis of pre and post anodization samples.
- Determined optical dimension measurements were not precise enough to measure film growth- produced results that were neither consistent nor in line with 720 rule.
  - Profilometer was no better
  - Film growth per side is on order of 1/100 of via width
- Weight was used in conjunction with the approximate measurements made by Keyence to yield more accurate and precise measurement.



The 720 rule
For 1 mil of oxide growth, we need 720 Amp minutes per square foot

Results



- Developed a process that produces consistent results, with minimal need for human monitoring
- Demonstrated ability to control the relative growth/shrinkage of the dimensions of the masks (application 2). Have confirmed full anodization of surfaces.
- Establishment of an appropriate metric for characterizing the film growth in masks. Also established that visual measurements were ineffective.
- Wafers have also been shown to be successfully anodized. Further work on these has not yet been fully explored; at the time of the making of this poster, an upstream issue was discovered in the structural integrity of the wafers.

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