4-11-2011

Minimization of Surface Impurities in Anodized Aluminum

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Abstract

Anodized aluminum is commonly used to create wear-resistant parts for process tools used in the semiconductor industry. Sinc microchips require high purity manufacturing environments[1], surface impurities on tooling needs to be minimized.

It has been determined that anodized aluminum parts are one source of contamination. This project investigates the source of trace elements in anodized aluminum 6061 parts and ways to reduce them.

Disciplines

Materials Science and Engineering

Minimization of Surface Impurities in Anodized Aluminum

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I. Introduction

Anodized aluminum is commonly used to create wear-resistant parts for process tools used in the semiconductor industry. Since microchips require high purity manufacturing environments [1], surface impurities on tooling needs to be minimized.
It has been determined that anodized aluminum parts are one source of contamination. This project investigates the source of trace elements in anodized aluminum 6061 parts and ways to reduce them.

II. Background

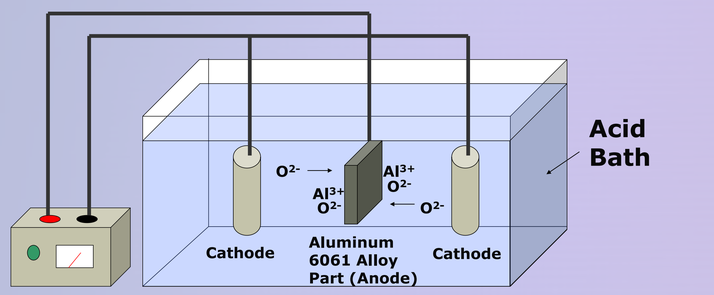
NxEdge, the project sponsor, uses aluminum 6061 T6 alloy for their wafer manufacturing components. The composition of this alloy (in wt%) is as follows [2]:

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	V
0.650	0.350	0.30	0.05	1.00	0.023	0.05	0.08	0.04	0.01

Many of these elements are considered contaminants in the semiconductor industry.

Anodizing

NxEdge uses Type III hard anodizing on many products.
- Negative charge carried by oxygen from cathode to part
- O^{2-} combines with Al^{3+} to neutralize and form Al_2O_3
- Type III – oxide is grown relatively thick (25-50 µm)
- Hot water bath to seal porous alumina surface



Pros of Anodizing:
- Robust and corrosion resistant surface
- Resistant to abrasion
- Thermally and electrically insulative

Cons:
- Impurities from acid bath
- Alloy elements act as impurities and cause discontinuities in oxide

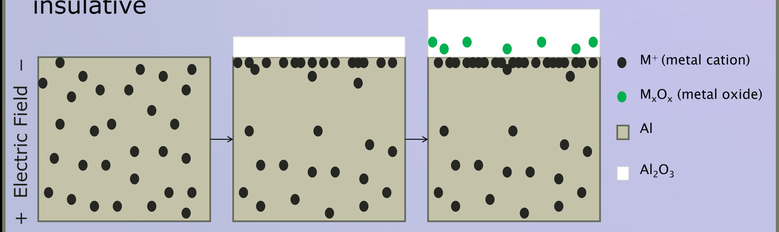
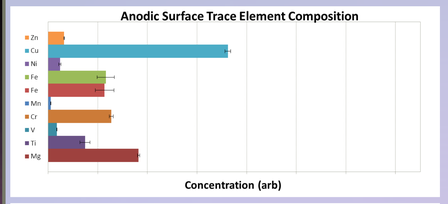
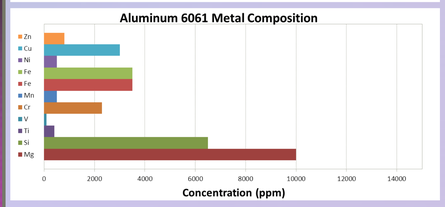


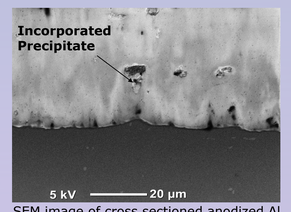
Diagram showing the migration of highly mobile metal cations collecting at the interface before incorporating with the oxide during anodizing.

III. Approach

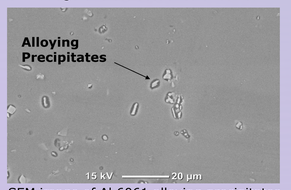
Preliminary Characterization
Scanning Electron Microscopy (SEM)
Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS)







SEM image of cross sectioned anodized Al



SEM image of Al 6061 alloying precipitates

- Negligible variation in trace element concentration between 6061 samples at various steps in anodizing process, strong correlation between substrate and oxide

Methods – Three methods to reduce trace elements were developed based on preliminary characterization.

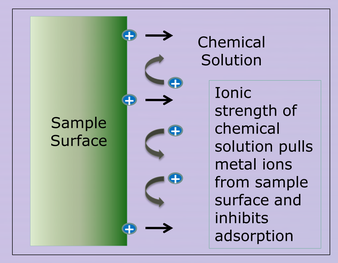
Method 1:
Reduced current density
- Impurities migrate to anodic oxide layer by drift
- Lower current density should lower the drift velocity

v_d = drift velocity
I = current
n = # of ions
q = charge of ions
A = area of cross section

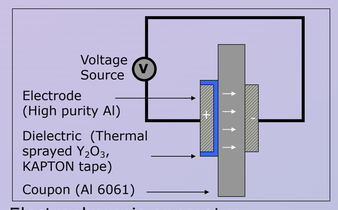
$$v_d = \frac{I}{nqA}$$

Equation representing drift velocity for Method 1

Method 2: Modified Rinse
- Designed to clean semiconductors
- Ultrasonic bath with chemical solution following anodizing and boil seal steps (Process 1) or just boil seal (Process 2)



Method 3: Electrophoresis
- Evidence of ion migration during anodizing
- High electric potentials drive metal cations further into substrate and reduce surface impurities



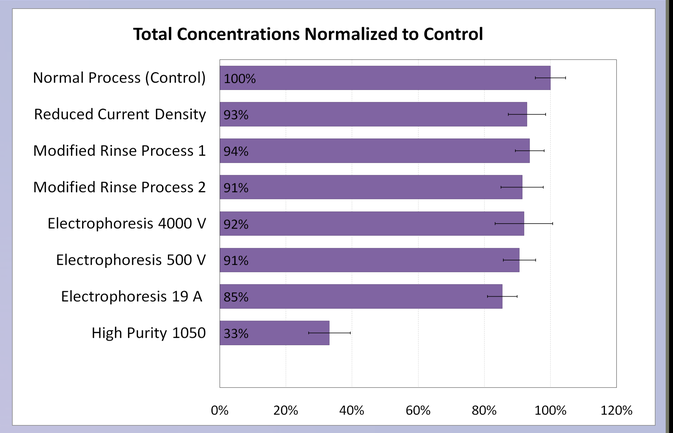
Electrophoresis apparatus

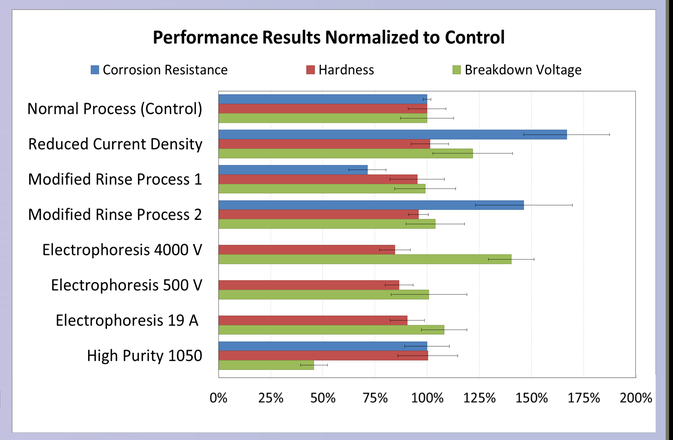
Acknowledgments

Nick Xydas and NxEdge for sponsoring the project, Marc Green at NxEdge for making samples, Chad Watson for his constructive assistance, Dr. Mike Hurley and Dr. John Youngsman for their guidance, as well as Dr. Sean Donovan, Dr. Darryl Butt, Dr. Megan Frary, and Dr. Paul Olin for use of their laboratories and equipment.

V. Results

- Trace elements concentrations to determine method effectiveness
- Concentrations determined using a Newave Research LA-ICP-MS system.
- Minor decreases in total trace elements for all methods
- Corrosion resistance, hardness, and breakdown voltage tested to measure performance
- Reduced Current Density had best results
- High purity Al 1050 series was tested to look for any changes in performance
- Low breakdown for Al 1050 series





VI. Conclusions

- Starting material is the main source of contaminant elements in the anodic oxide layer
- Using a high purity substrate or surface is the most effective method for reducing contaminants
- Prototypes created with Reduced Current Density or Modified Rinse Process 2 remained robust, crucial for reducing rate of contamination
- Using high purity aluminum substrate or coatings may drastically lower impurities while maintaining good hardness and corrosion resistance

VII. Future Work

- Experimentation with various current densities or lower voltages
- Studies on bath life, dilution, and optimization of modified rinse process
- Optimization of parameters for electrophoresis to achieve its full capabilities
- Investigate use of coating with high purity aluminum prior to anodizing

References

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2. "Alcoa Spectrochemical Standards," A. I. S. M. Division, Ed., ed. Pittsburgh, PA, 2004, p. 18.