Annealed titania nanotubes: Wettability and corrosion behavior of modified Ti-6Al-4V

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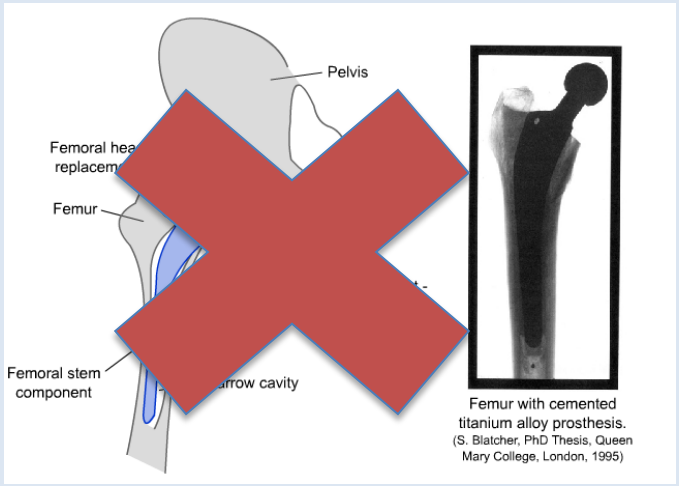
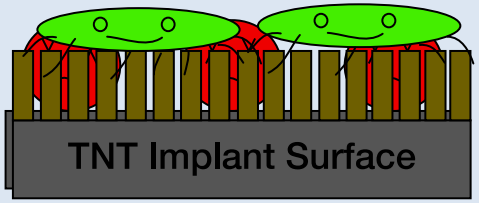
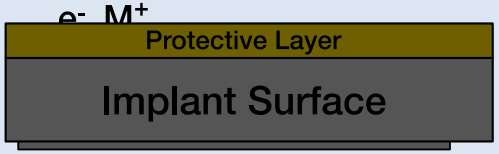
Introduction

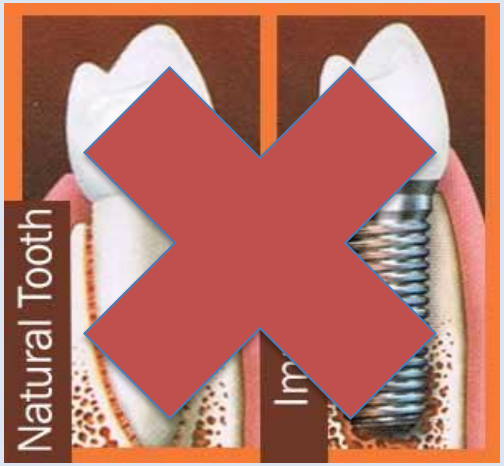


Osseointegration



Corrosion





Tribological

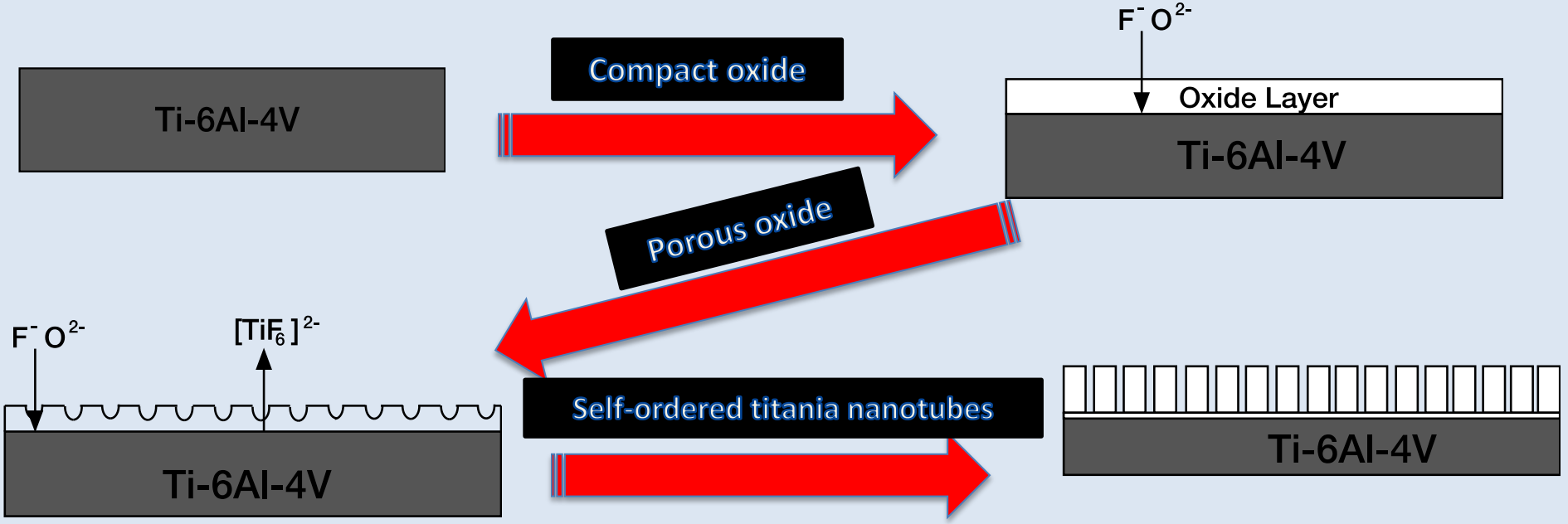
Paupore 2013

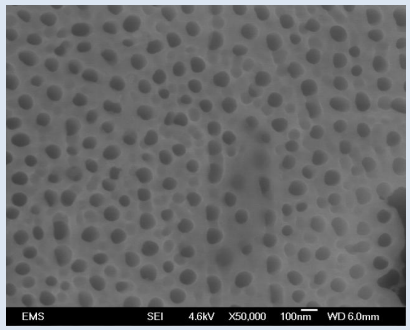
Mechanical

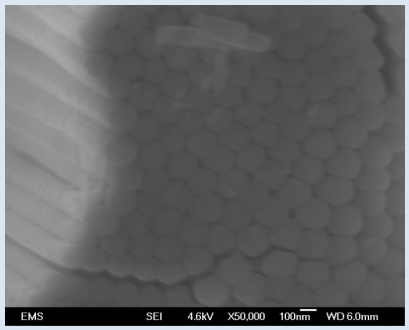
Della Valle 2009

Surface Treatments: Electrochemical Anodization

Anodic Polarization: 60V, 2h (ethylene glycol + 4vol% d.i. water + 0.2 wt.% NH_4F)

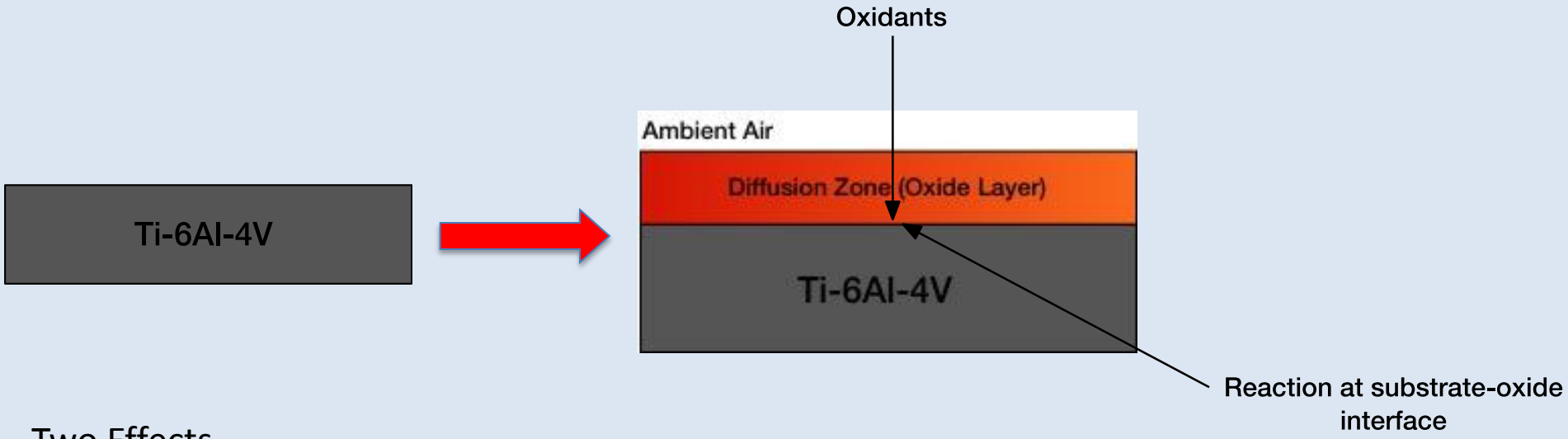






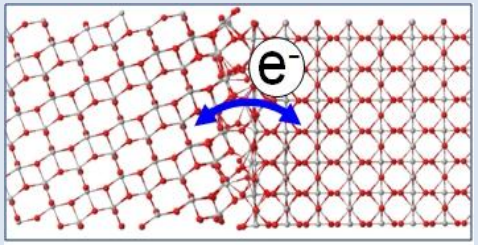
Surface Treatments: Thermal Oxidation

Thermal Oxidation: 600°, 3h (Ambient Air)

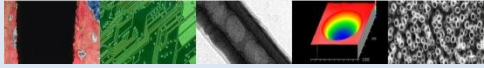


Two Effects

1. Growth of the compact oxide layer
2. Polycrystalline titanium dioxide (anatase/rutile)



(Garcia & Deskins 2012)



Objectives/hypothesis

1. Evaluate the hydrophilic behavior of treated titanium alloy substrates over 25 days
2. Evaluate the electrochemical impedance and corrosion/passivation behavior of treated titanium alloy substrates in cell culture medium at physiological temperature
3. Evaluate the osteoblast adhesion response to treated titanium alloy substrates

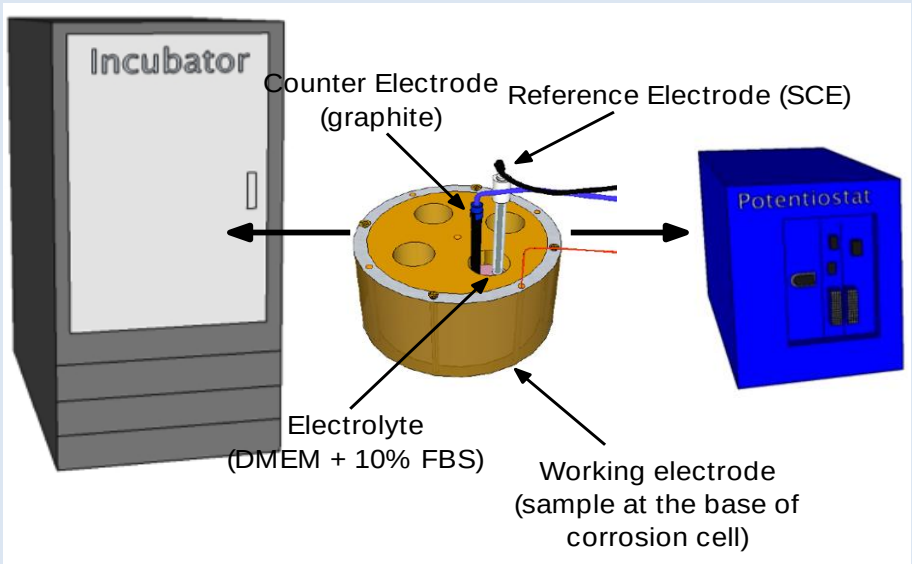
Experimental design

Surface Modifications (Ti-6Al-4V discs)

- Polished (Smooth)
- Thermally Oxidized (TO) 600° C, 3h
- Anodized (Ad) 60V, 2h
- Anodized 60V, 2h + Thermally Oxidized 600° C, 3h (Ad+TO)

Surface Characterizations

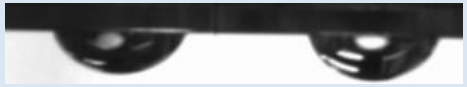
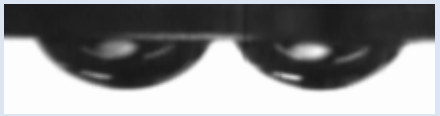
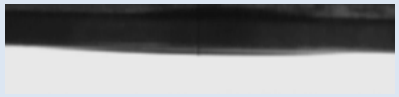
- Water Contact Angle Aging
- Fourier Transform Infrared Spectroscopy
- Field Emission Scanning Electron Microscopy
- Brunauer-Emmett-Teller Surface Area



Corrosion Tests

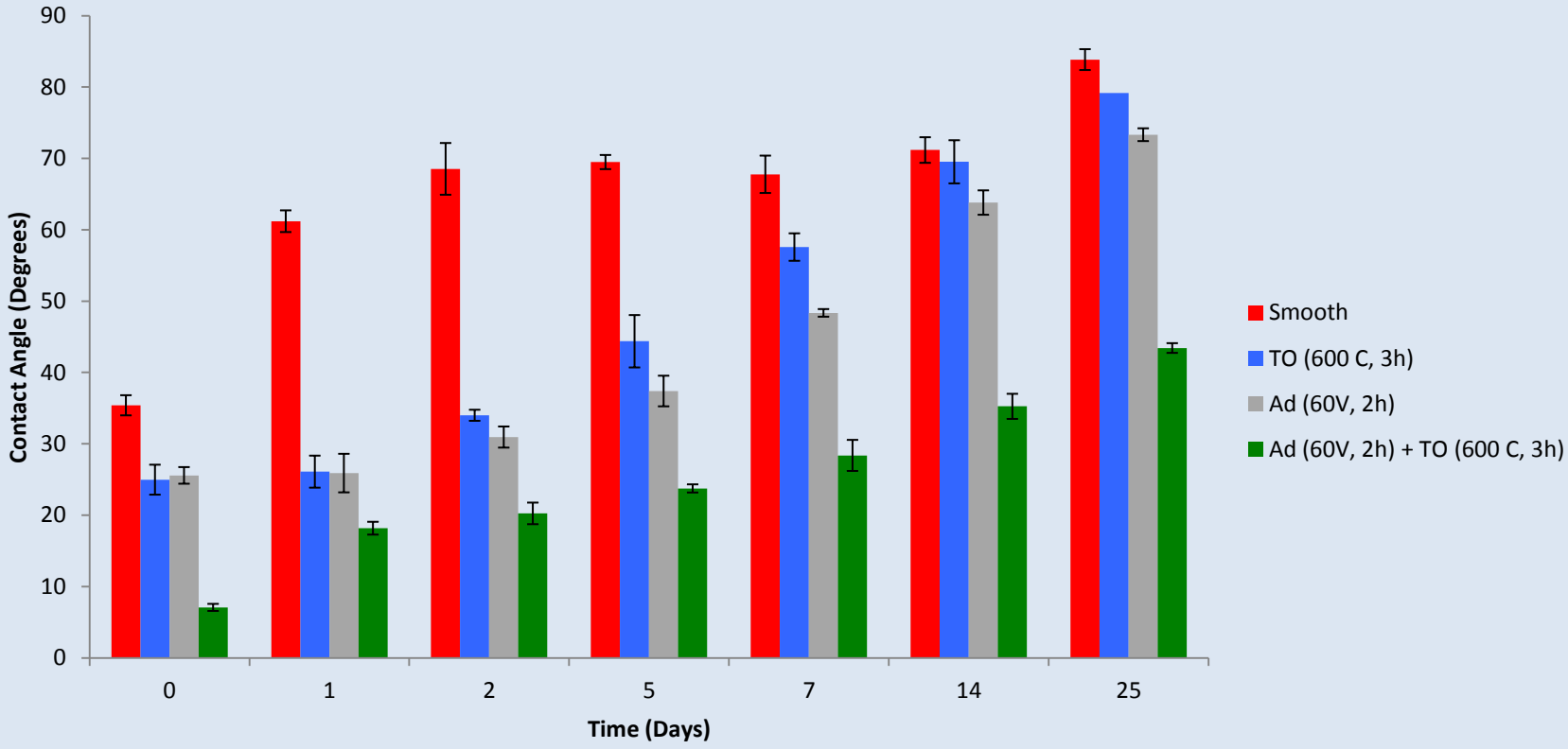
1. OCP (1h)
2. EIS (± 10 mV from OCP)
3. Potentiodynamic (-1V vs. SCE-1.8 V vs. SCE)

Results: WCA

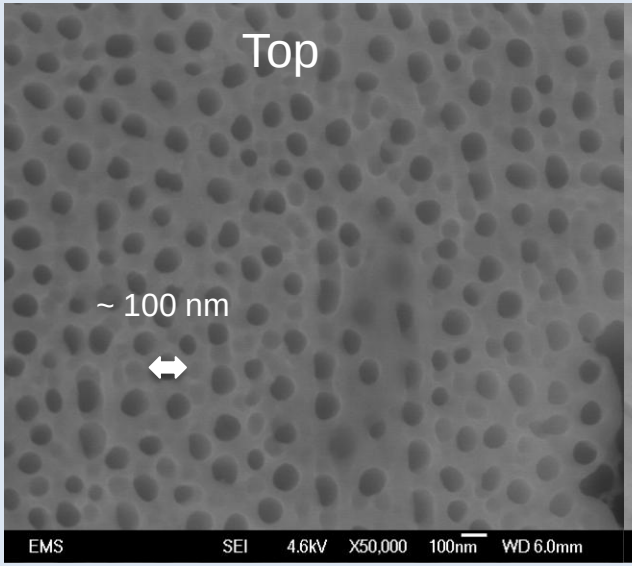
	Day 0	Day 7	Day 14	Day 25
Smooth				
Annealed 600º C, 3h				
Anodized 60V, 2h				
Anodized 60V, 2h + Annealed 600º C, 3h				

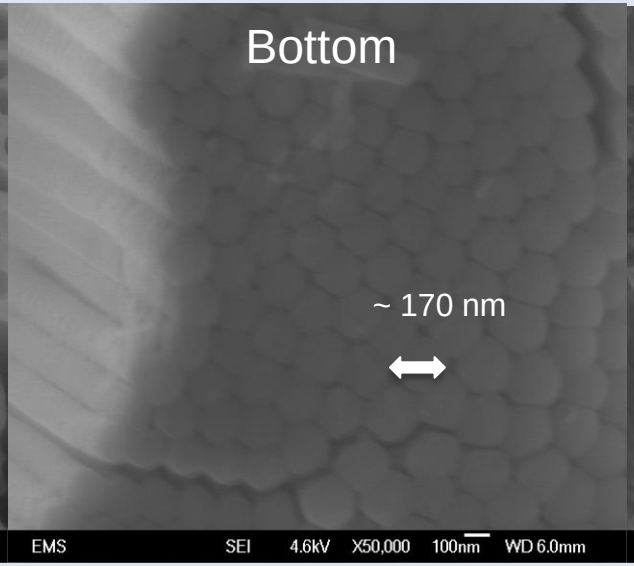
Results: WCA

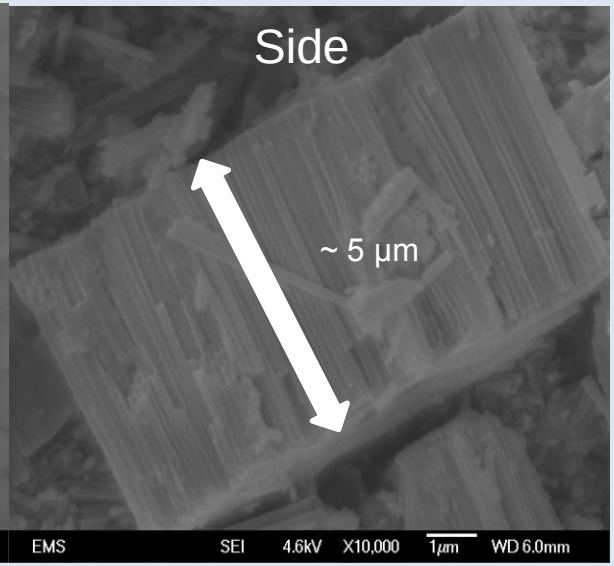
- WCA: Ad+TO<Ad<TO<Smooth
- Ad+TO showed increased wettability over 25 days of aging ($p<0.001$)

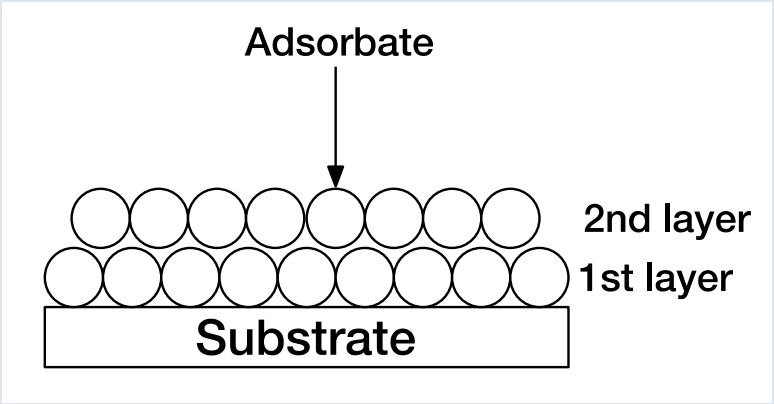


Results: FESEM, BET



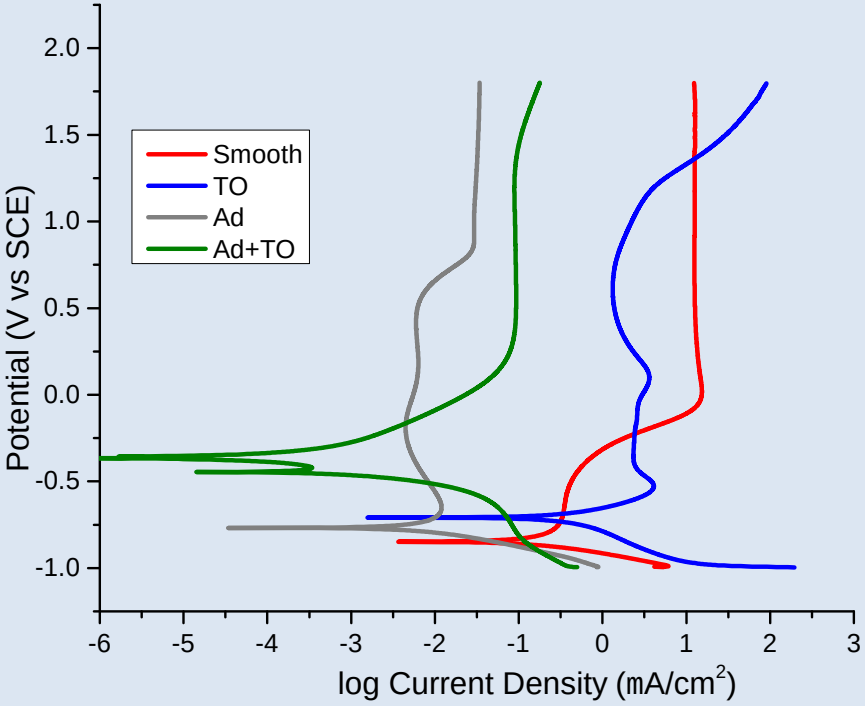




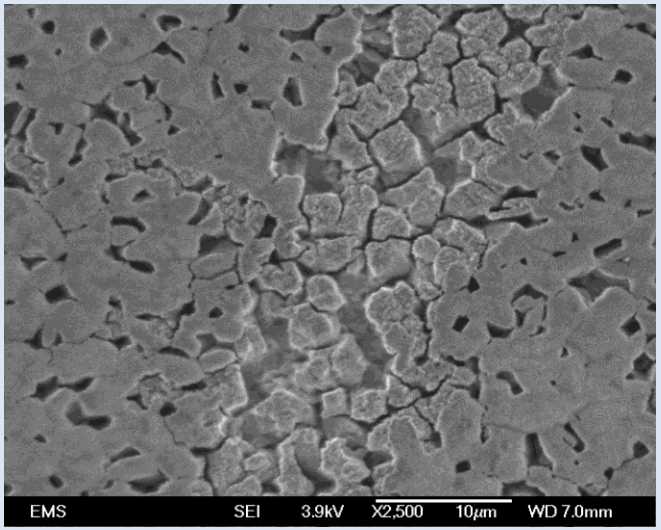


- Used Krypton gas as adsorbate
- For anodized samples, SA= 0.33 m^2/g (correlation = 0.998)
- Based on mass of sample and exposed area to the electrolyte, corrosion SA~300 cm^2

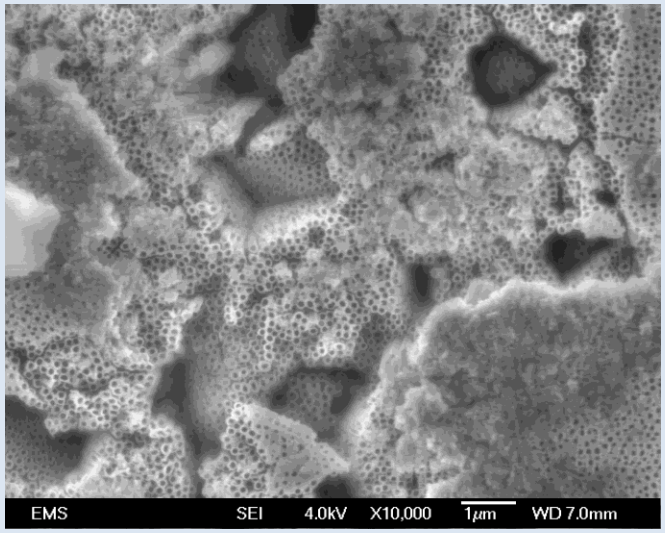
Results: Potentiodynamic



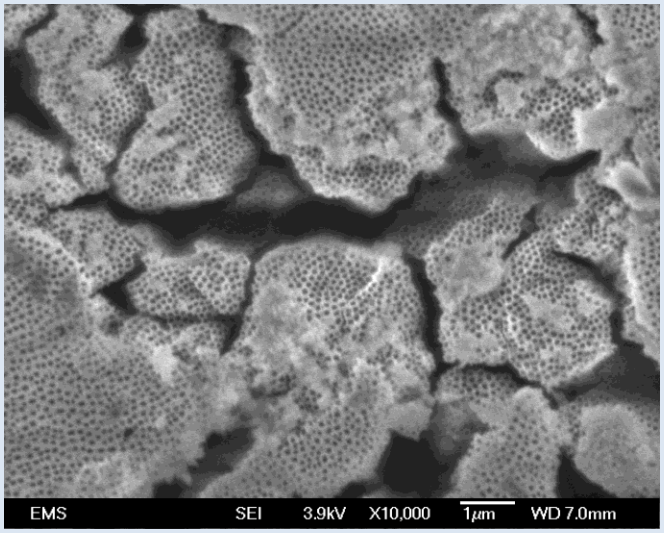
Ad+TO



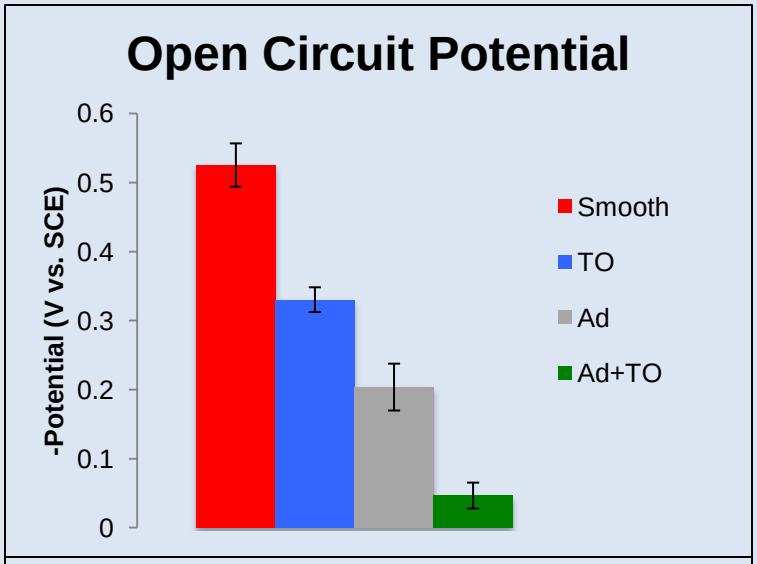
Ad

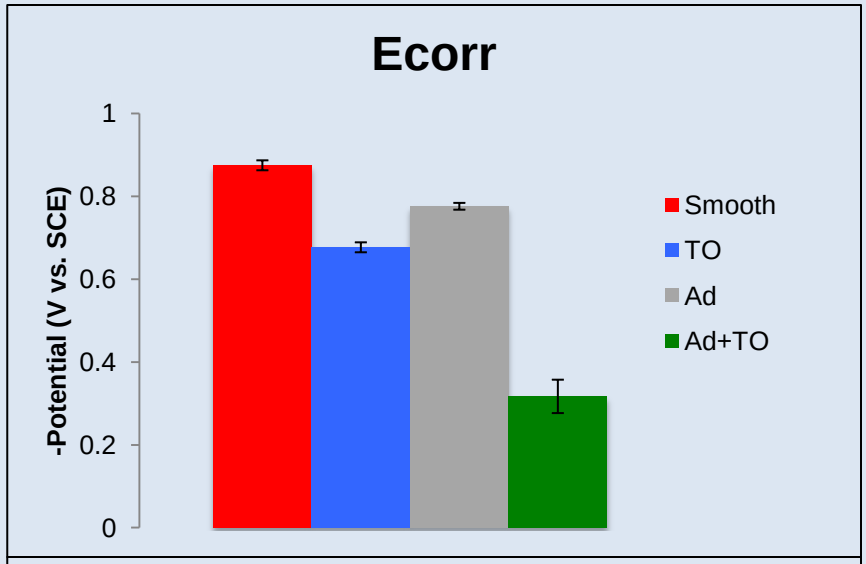


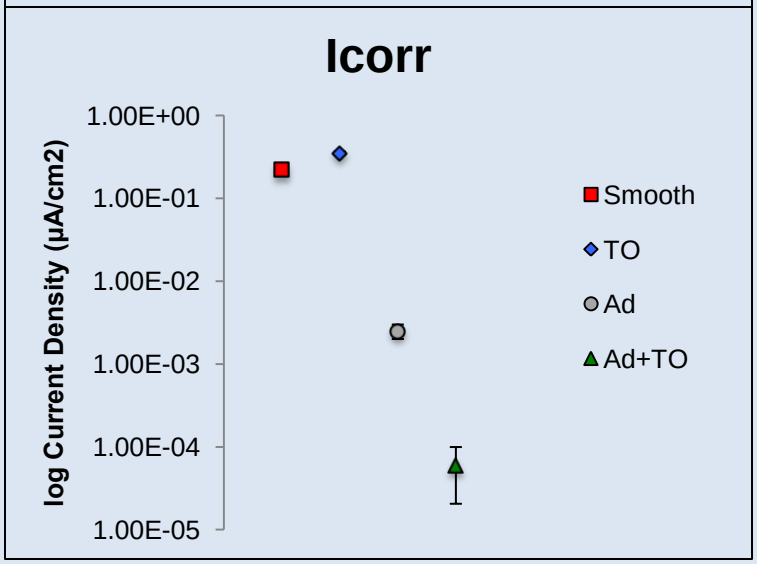
Ad+TO

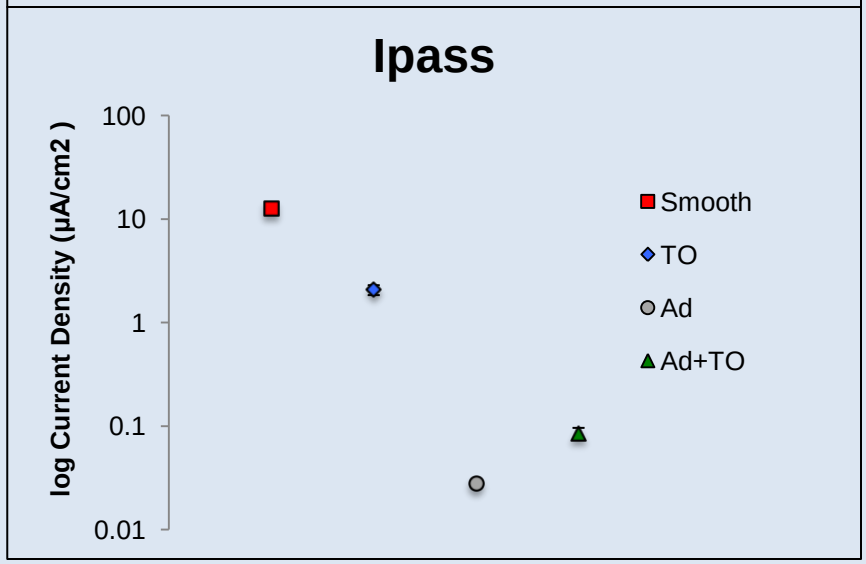


Results: OCP, Potentiodynamic

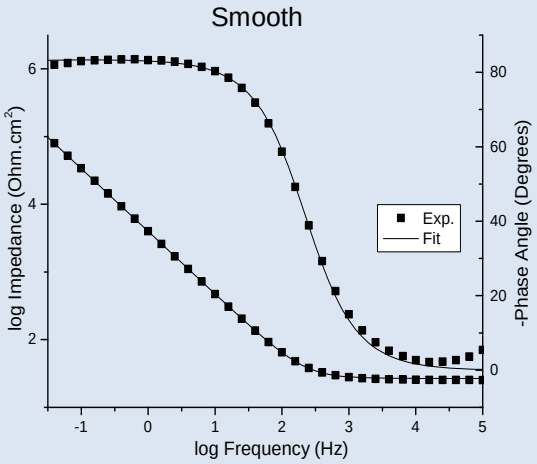


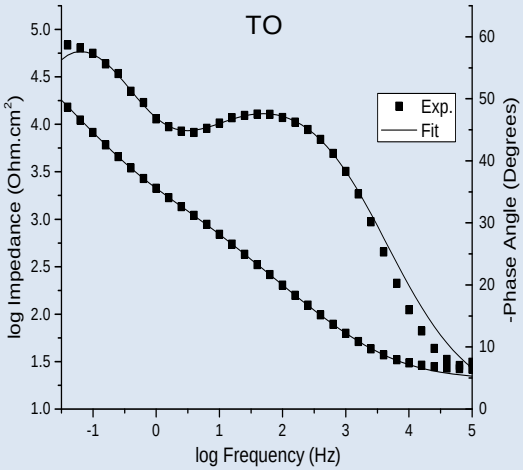


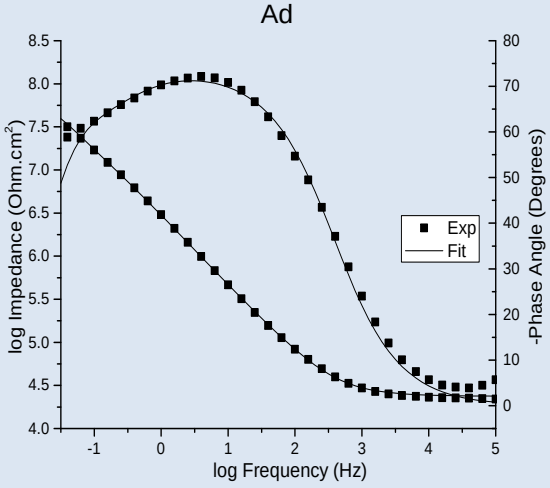


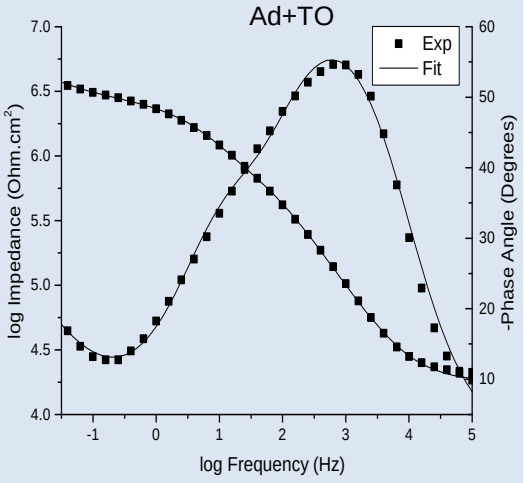


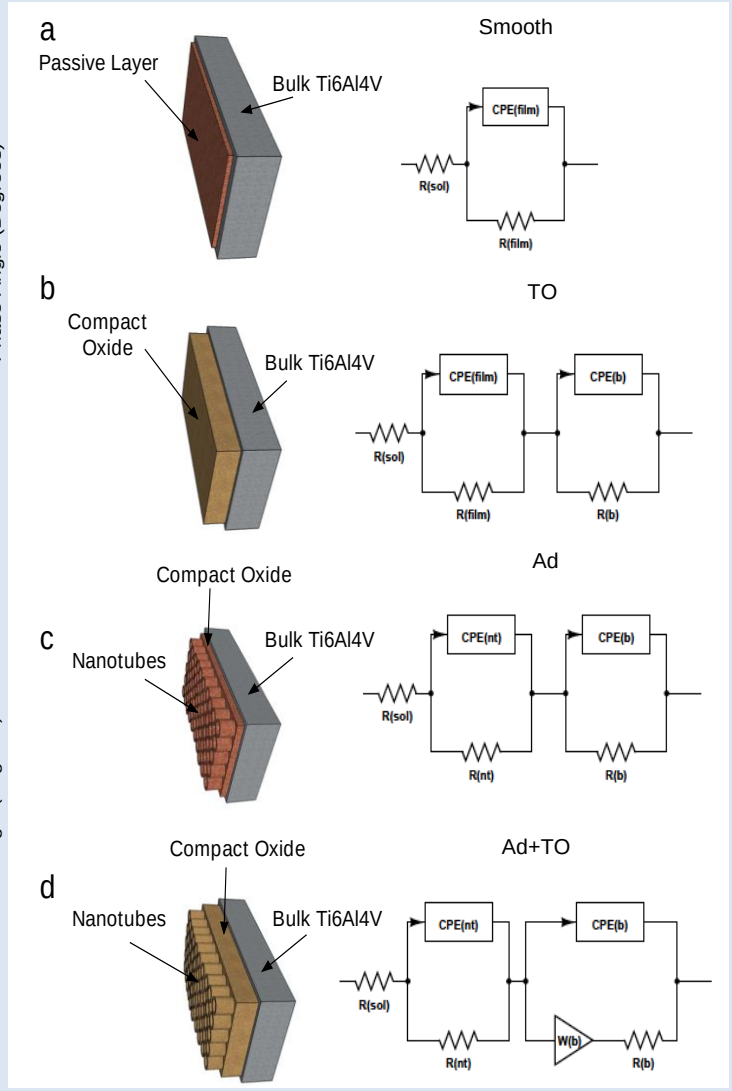
Results: EIS Modeling



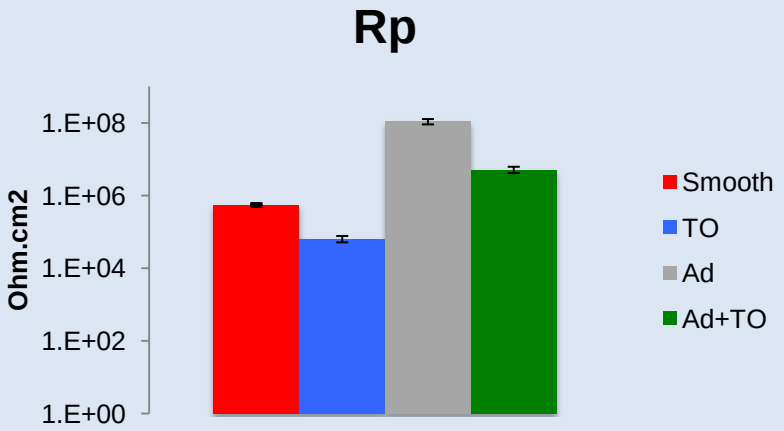


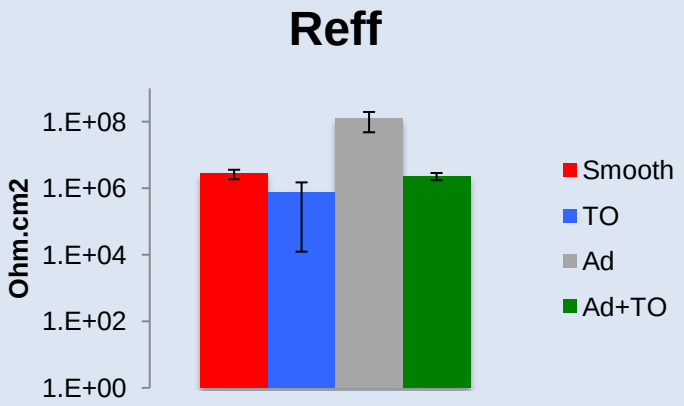


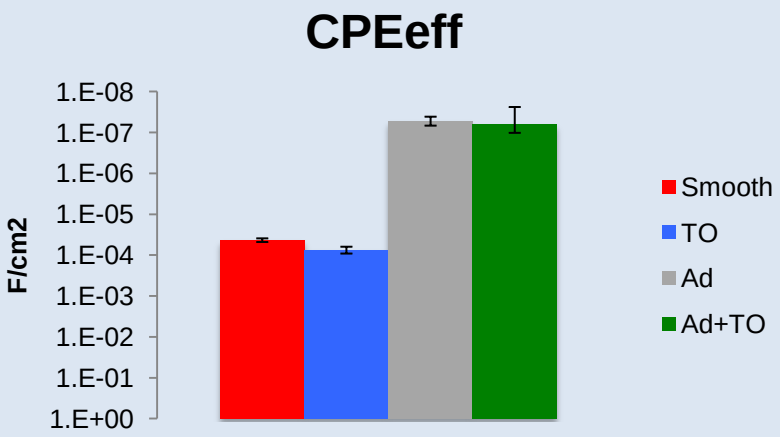




Results: EIS

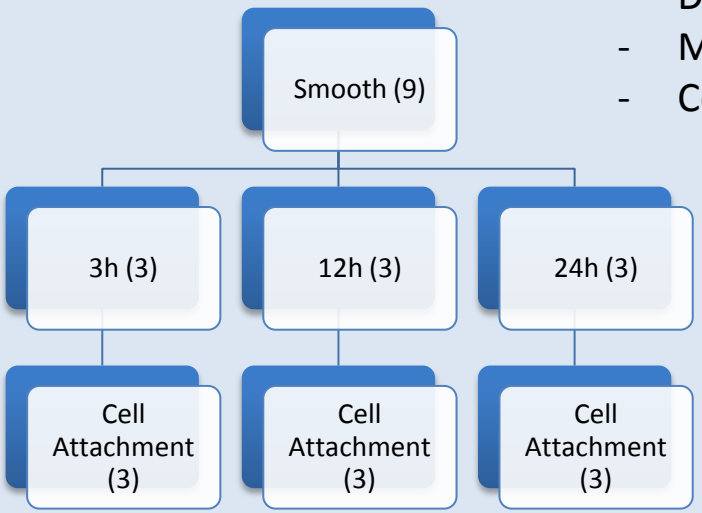

Rp
Ohm.cm2
1.E+08
1.E+06
1.E+04
1.E+02
1.E+00
Smooth
TO
Ad
Ad+TO

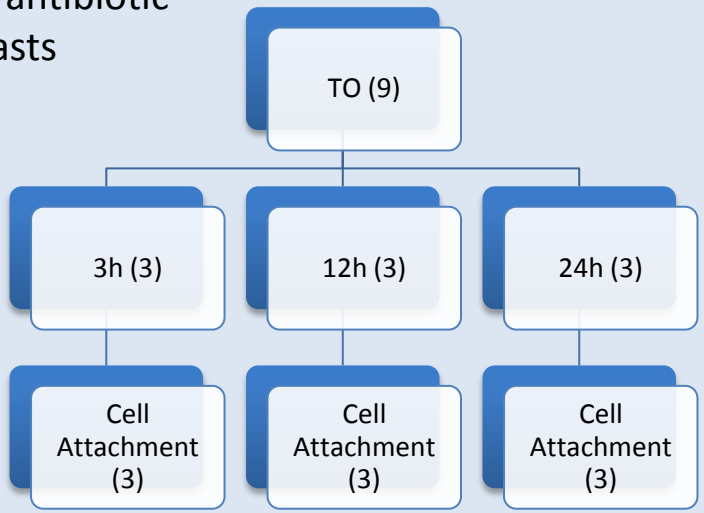

Reff
Ohm.cm2
1.E+08
1.E+06
1.E+04
1.E+02
1.E+00
Smooth
TO
Ad
Ad+TO

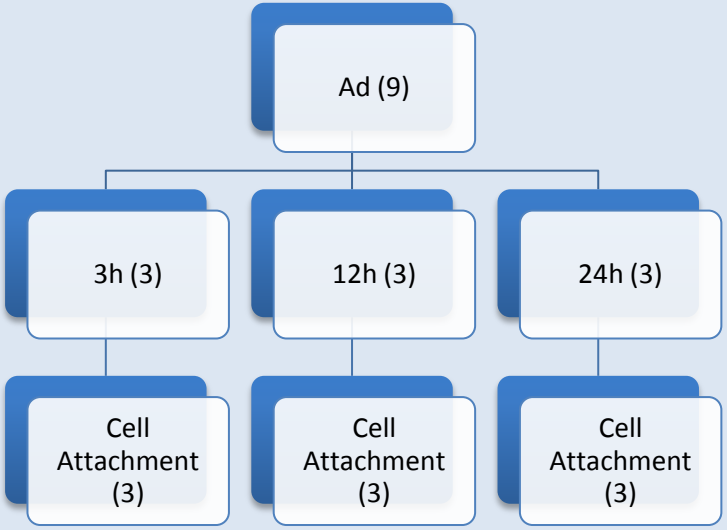

CPEeff
F/cm2
1.E-08
1.E-07
1.E-06
1.E-05
1.E-04
1.E-03
1.E-02
1.E-01
1.E+00
Smooth
TO
Ad
Ad+TO

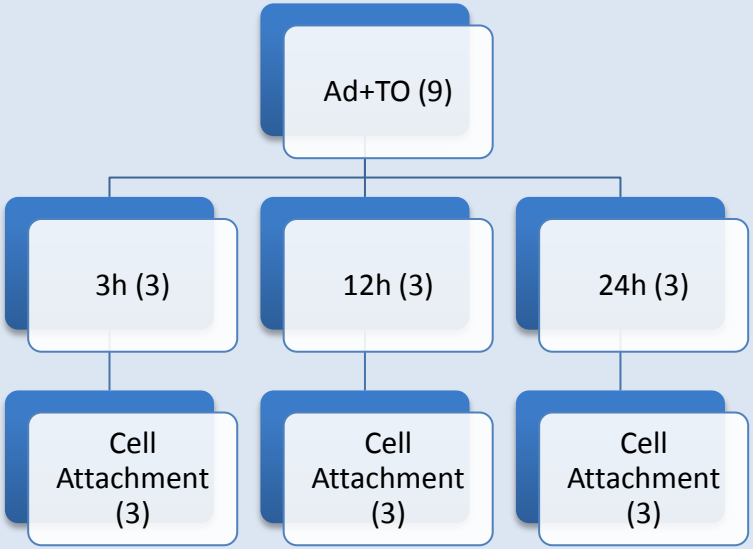
Progresses: Cell Culture

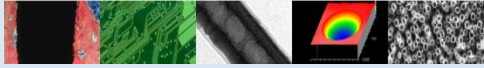
- 36 discs total
- DMEM + 10% FBS + 1% antibiotic
- MC3T3-E1 Pre-Osteoblasts
- Cell attachment assay











Future work

- Optimize nanotube dimensions and annealing temperature/duration for corrosion resistance
- Optimize nanotube dimensions and annealing temperature/duration for osteogenic response: adhesion, proliferation, differentiation
- Understand the effect of spontaneous voltages on cellular viability with titania nanotubes