Processing and Characterization of Hierarchical Surface Coatings for Titanium Implants

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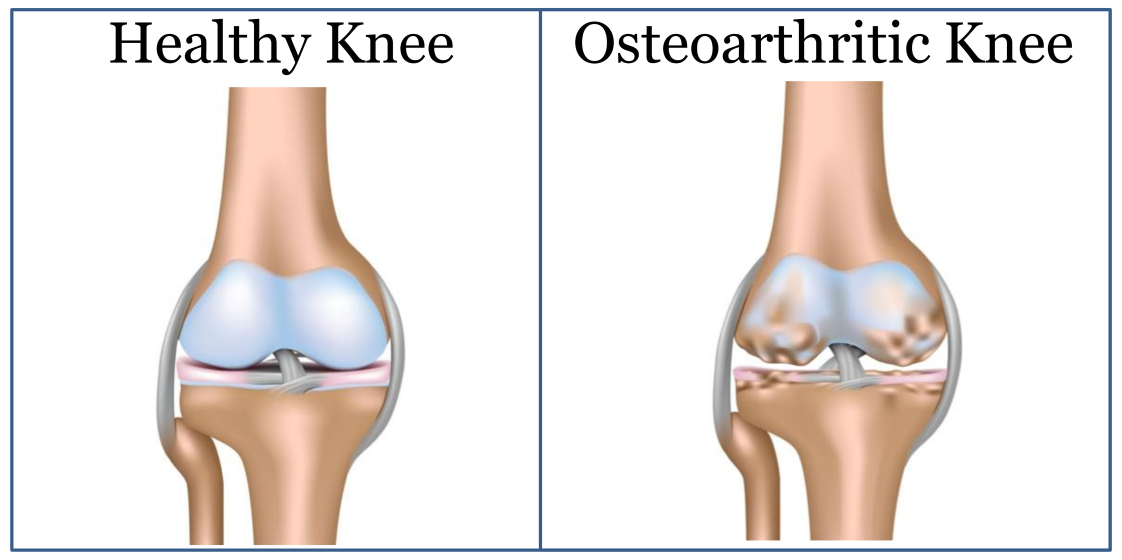
Introduction

- ❖ Osteoarthritis - degradation of cartilage and bone
  - Affects 27 million Americans
  - Costs U.S. $89.1 billion per year



[1]

- ❖ 285,000 total hip and 600,000 total knee replacements completed each year in the U.S. [2]
- ❖ Titanium metal used as implant biomaterial in replacement surgeries because:
  - Good mechanical properties
  - High strength-to-weight ratio
  - Corrosion resistance
  - Excellent biocompatibility [3]

Project Objective

- ❖ To increase integration between bone and implant:
  - Micro-scale surface features foster bone ingrowth [4]
  - Nano-scale surface features increase osteoblast function [5]
  - Combine both features into single hierarchical coating to further improve osseointegration

Procedure

1. Laser Deposition ➔ produces microgrid
2. Cleaning with wirebrush treatment
3. Anodic Oxidation ➔ produces nanotubes
4. Cell Culture for cell morphology and cell viability

❖ Steps characterized by contact angle, scanning electron microscopy (SEM), cell morphology and cell viability ❖

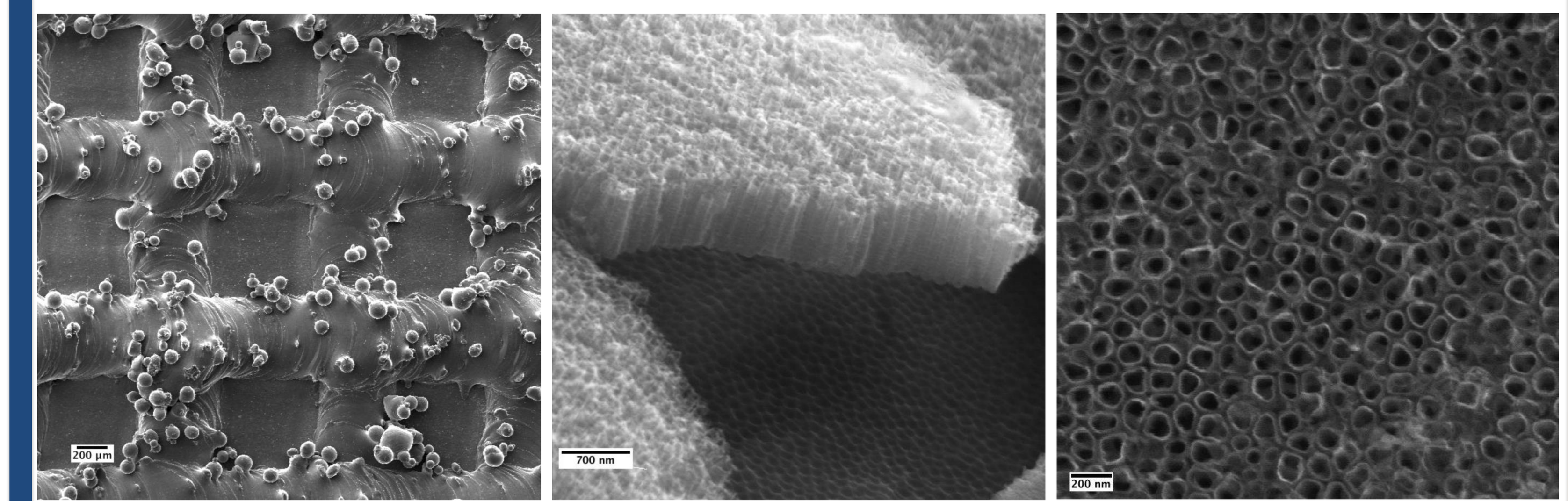
Study Design

GROUP NUMBER	MICRO-GRID	NANO-TUBES	WIREBRUSH CLEANING
1	❖	❖	❖
2	❖	❖	
3	❖		❖
4	❖		

❖ Indicates presence of treatment

Results

Representative SEM Images of Microgrid and Nanotubes

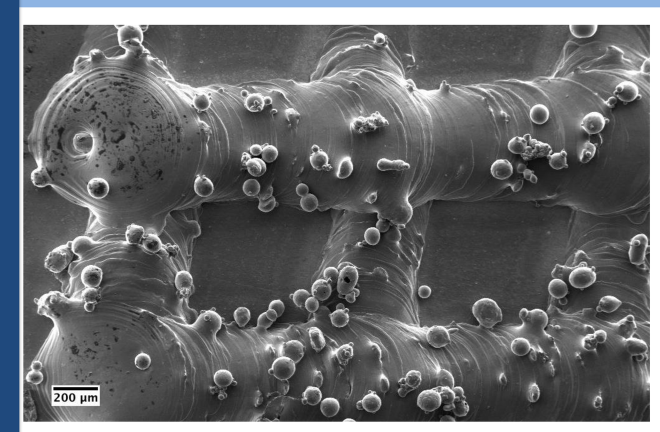


Top-down view of microgrid
Pore size: 600µm ± 20µm

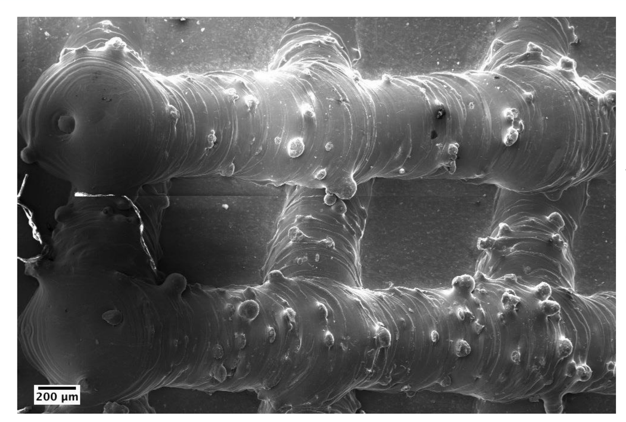
Side view of nanotubes
Nanotube length: 714nm ± 34nm

Top-down view of nanotubes
Nanotube diameter: 88nm ± 6nm

Wirebrush Treatment

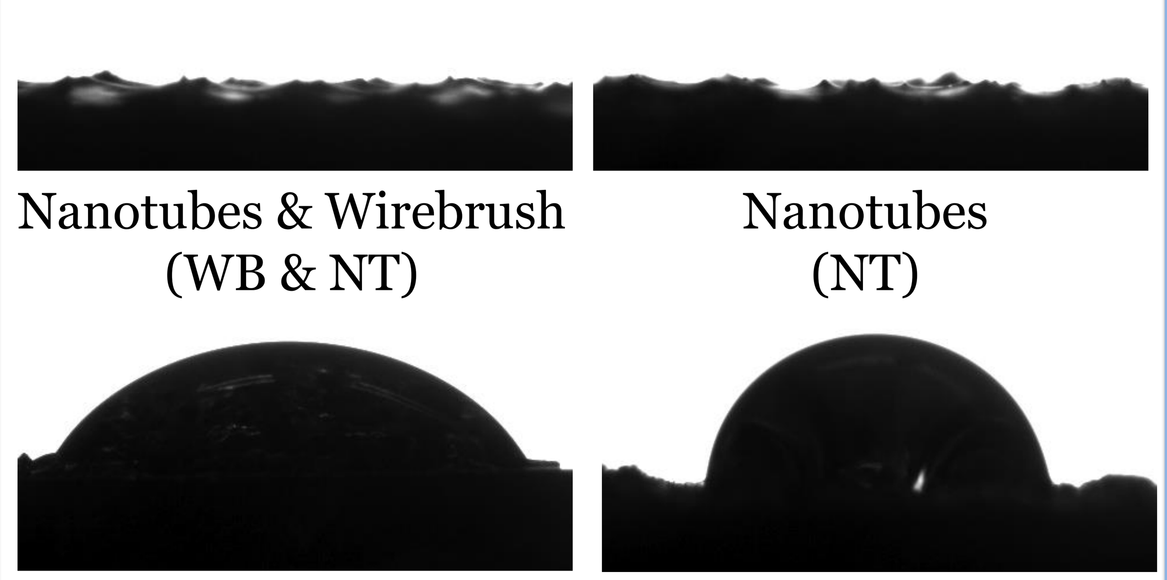


As Deposited



After Wirebrush Treatment

Contact Angles



Nanotubes & Wirebrush (WB & NT)

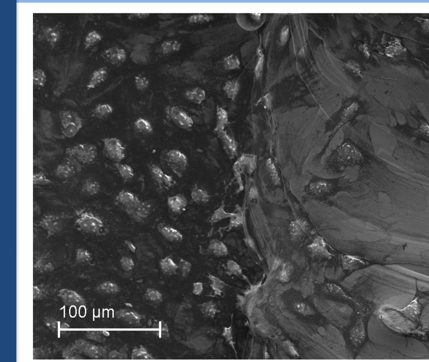
Nanotubes (NT)

Wirebrush (WB)

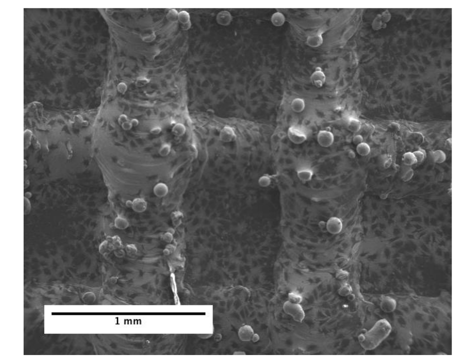
No Treatment

Average Contact Angles (degrees)	
NT & WB	N/A
NT	N/A
WB	57.2 ± 1.4
No Treatment	74.5 ± 4.9

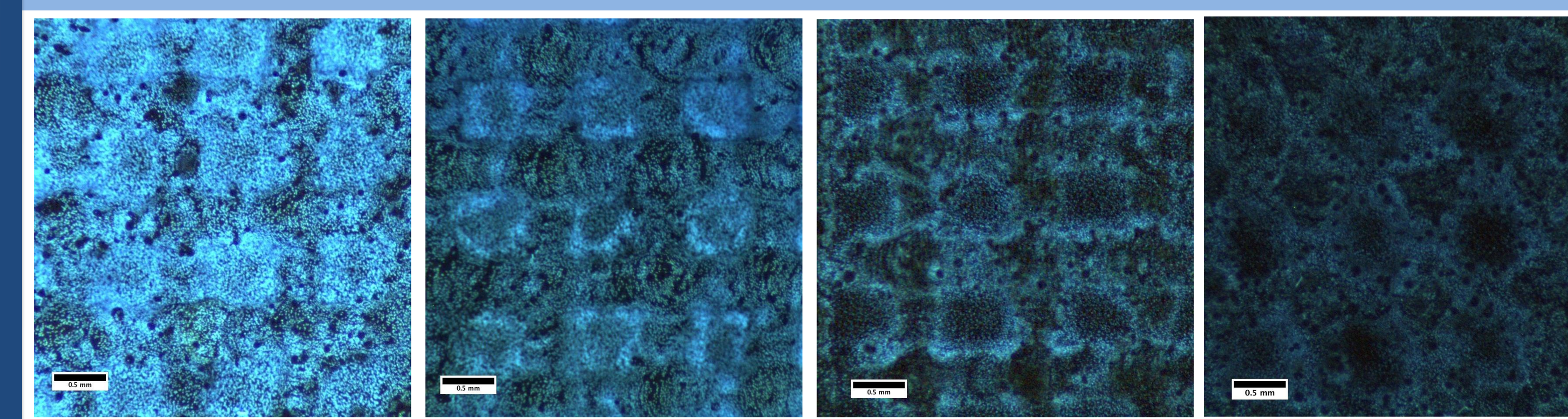
Representative Cell Morphology SEM Images



- ❖ Mouse pre-osteoblast cells
- ❖ 10^5 cells seeded per sample
- ❖ Incubated for 4 hours before imaging



Cell Viability



WB & NT | NT | WB | No Treatment

❖ 10^5 mouse pre-osteoblasts seeded per sample, cultured for 4 days, then fluorescently stained for live cells

Conclusions

- ❖ Wirebrush treatment was able to dramatically decrease unmelted laser deposition particles.
- ❖ Wirebrush treatment or the presence of nanotubes considerably lowered contact angle.
- ❖ Osteoblasts on all samples showed signs of both cell adhesion and spreading.
- ❖ Samples with nanotubes had significantly greater cell densities compared to samples with no nanotubes.
- ❖ Samples that underwent wirebrush treatment had greater cell densities compared to samples without wirebrush treatment.

References

1. American Academy of Orthopaedic Surgeons. (2011). OrthoInfo. *Total Knee Replacement*. Retrieved June 27, 2013, from http://orthoinfo.aaos.org/topic.cfm?topic=A00389.
2. Arthritis Foundation. (2008). Osteoarthritis Fact Sheet. *Disease Center, Osteoarthritis*. Retrieved June 24, 2013, from http://www.arthritis.org/files/images/newsroom/media-kits/Osteoarthritis_fact_sheet.pdf.
3. Liu X. Y., et al. *Mater. Sci. Eng. Rep.* 2004: 47, 49–121.
4. Kohal, R. J., et al. *Dent Mater.* 2013: *29*(7), 763-776. doi: 10.1016/j.dental.2013.04.003.
5. Sista, S., et al. *J Biomed Mater Res A.* 2013. doi: 10.1002/jbm.a.34638

Acknowledgments

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