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מוסד הטכניון למחקר ופיתוח בע"מ

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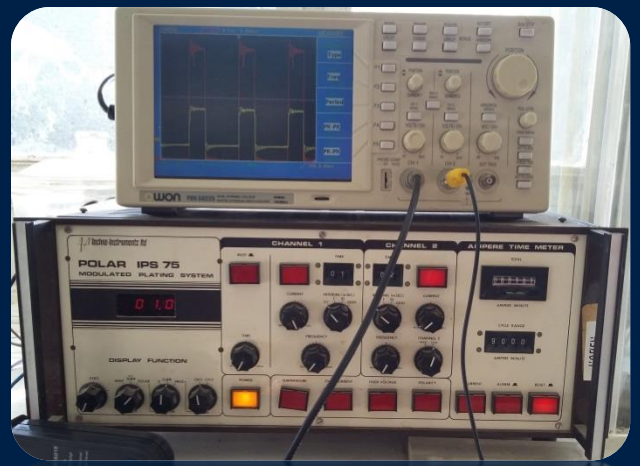
מכון המתכות הישראלי

Development of electro polishing (EP) process for Ti-6Al-4V ELI parts made by electron beam melting additive manufacturing (EBM-AM) technology using environmental friendly electrolyte



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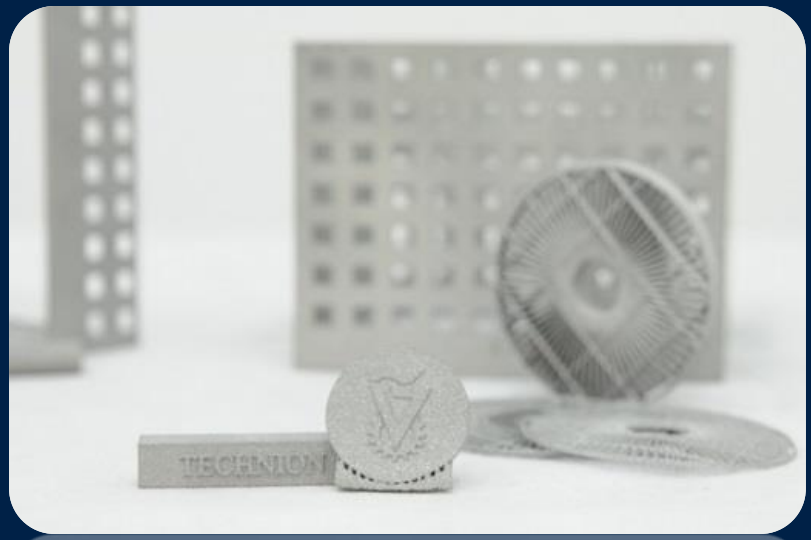
- Additive manufacturing provides prototyping and production of lightweight but extremely strong components, with option for complex geometry, that are used in commercial and military aircraft, space applications, missiles, as well as engine components and accessories for the aerospace industry.



Introduction

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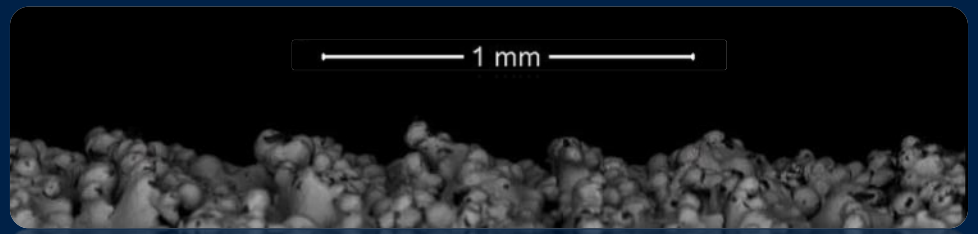
- Ti-6Al-4V ELI parts which are manufactured by additive manufacturing exhibit very good mechanical properties but they are suffering of low surface quality that reduces their geometrical accuracy and induces the friction coefficient. These rough surface features can serve as stress concentration and fatigue crack initiation sites because of a deeper notch depth and a sharp radius of curvature.



Surface Profile of EBM-AM Ti-6Al-4V ELI part

Material	Maximus Roughness Ra (μm)	Mean Fatigue Life (cycles)
Cast Ti-6Al-4V ELI	10	40000
Rolled Ti-6Al-4V ELI	1	167000
EBM Ti-6Al-4V ELI	130	30000
EBM Ti-6Al-4V ELI + finish	5	50000
LBM Ti-6Al-4V ELI	40	60000
LBM Ti-6Al-4V ELI + finish	8	80000

Effect of surface roughness on fatigue life:
Chan, Kwai S., et al. "Fatigue life of titanium alloys fabricated by additive layer manufacturing techniques for dental implants."

*LBM – Laser Beam Melting

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- For many applications such roughness is inappropriate, and Ra values of as low as 2 µm or less are often required (particularly in the aerospace industry). It is necessary to develop a technique to achieve the required surface quality of EBM parts. But because complex geometry of printed parts, simple abrasive polishing processes are impractical. Therefore, development of a reliable electropolishing process for EBM-AM parts is the key for the high surface finish.

- Conventional electropolishing processes for titanium usually use aggressive electrolytes that contain very toxic and strong acids which reduce the formation of oxide layer that forms in the presence of oxygen. Most of electrolytes contain perchloric acid or hydrofluoric acid which are extensively regulated. For this reason, an electro-polishing process for EBM-AM Ti-6Al-4V ELI parts, with environmental friendly electrolyte, is in development in the Israel Institute of Metals (IIM).

Hazards:
Health
Flammability
Reactivity

Perchloric Acid

Hydrofluoric Acid

Electrolyte base for IIM process

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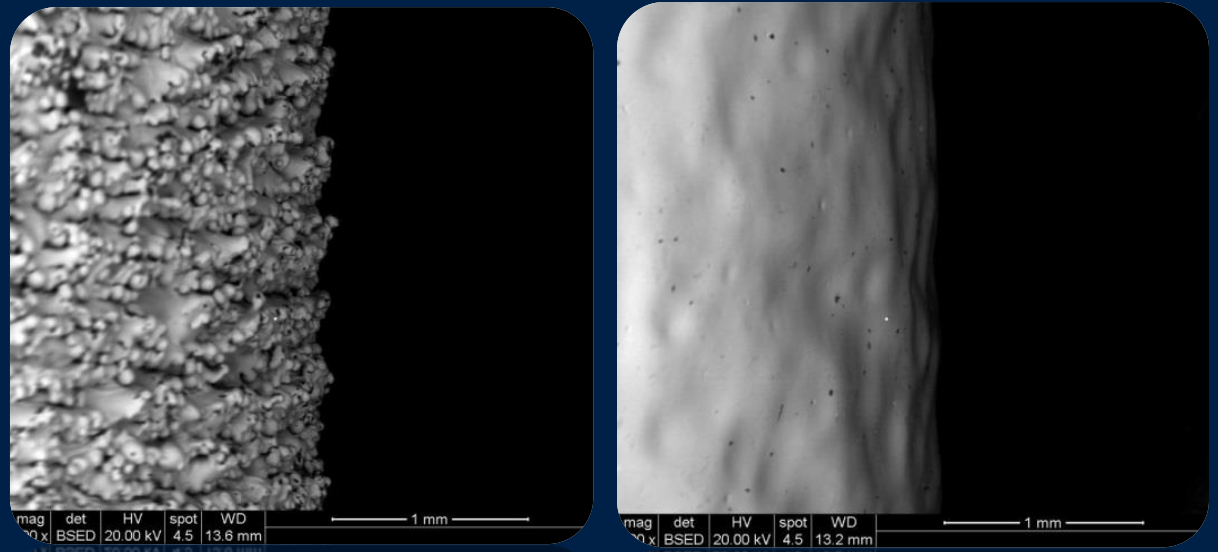
- Till this moment we achieved 88% roughness loss, up to 6 μm (Ra), with 1/4 mm width reduction. The process was carried in moderate temperature and last no longer than one hour. No special protective equipment was used to maintain the electropolishing setup.



Scanning electron microscope images of as printed (left) and electropolished (right) samples (BSED, magnification X100)

Electropolished EBM-AM Ti6Al4V samples (bright part)

Present Research

Future Goals

1. Improve electropolishing efficiency for simple geometry parts: maximum roughness reduction with minimum width loss.
2. Build a new electropolishing cell for scale up and future research.
3. Develop ability to finish internal and external features.
4. Analyze EP surface morphology and contaminations.
5. Develop a simulation model for prediction of counter electrode (cathode) shape that will be applicable with complex geometry of specific part.
6. Use EBM-AM process to produce a counter electrodes from Ti-6Al-4V ELI with desired shapes and high surface area.

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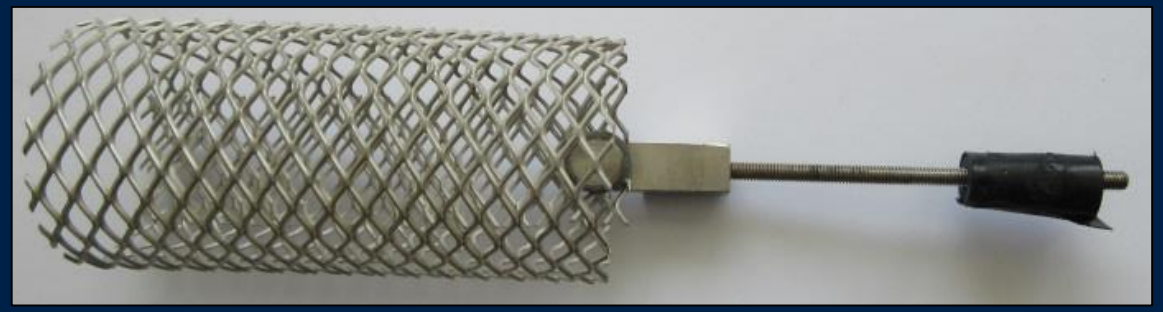
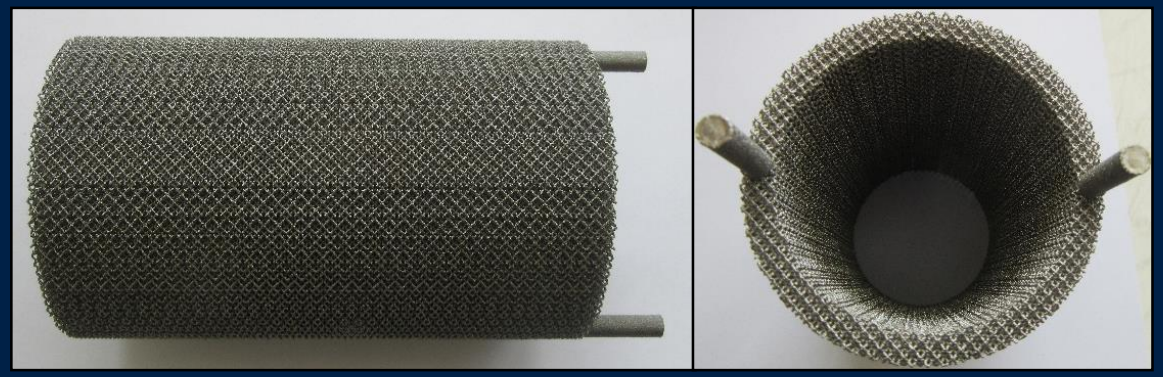
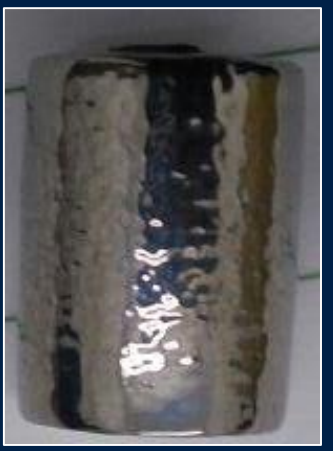


Previous counter electrode made from Ti mesh



First EBM-AM Ti-6Al-4V ELI printed counter electrode
with extremely high surface area (IIM)

RESULTS



Scoop