Multiscale post-processing of metal additive manufactured parts by electro-polishing technology

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Our Mission

Develop green advanced manufacturing technologies meeting the demand of the fourth industrial revolution
Our Expertise

- **Glass Machining**
  - Lab-on-Chip
  - Multilayer chips
  - Micro- to Macro-world interfaces

- **Post-Processing**
  - Multiscale electro-polishing
  - Down to Ra of 50nm
  - Broad range of materials including Titanium

- **Coating**
  - Complex parts
  - Wide range of substrate materials
  - Tuning surface wettability

- **Industry 4.0**
  - Batch Size 1 production
  - Internet of Things (IoT)
  - Ultra low-cost tooling
Glass Micromachining

- Med Tech
- Watch Industry
- Consumer Electronics
- Rapid Prototyping
Electropolishing

Design it

Polish it

Use it

Print it

SLM part

3D printed CE holder

Counter electrode (CE)

Roughness Profile SLM part Ti-alloy

Before EP

After EP
Room Temperature Nanocoating

400 μm through glass via Ni plated

Hydrophilic coating

Hydrophobic coating
Internet of Things

PC, Tablet, Smartphone, ...

IoT Device

Application Code

GeCo Library

Local Access over LAN

Back Office

Remote Data Acquisition
Additive Manufacturing

General functional principle of laser-sintering

Typical metals
- Aluminium alloys
- Cobalt Chrome alloys
- Maraging Steel
- Nickel alloys
- Nickel Chromium alloy
- Stainless steel
- Titanium alloys

Applications
- Aerospace
- Medical
- Automotive
- Lifestyle
- Tooling
- Rapid Prototyping
Additive Manufacturing: Limitations

Staircase effect & semi-melted beads
- Surface quality (1 – 100 µm $R_a$)
- Geometrical accuracy
- Surface defects decrease performance

Solutions to overcome limitations:
- Process control (e.g. re-melting, finer powder)
- Post-processing:
  - Electropolishing ✓ Selective surface smoothing
  - Mechanical polishing ✓ control of micro- and nano-roughness
  - Abrasive flow polishing
Electropolishing Principle

- Workpiece immersed in electrolyte (e.g. sulphuric acid)
- Anodic dissolution of workpiece

\[ M(s) \leftrightarrow M^{+n} + n\text{e}^- \]

Mass transport mechanism:
- Peaks diffuse at higher rates than recesses → anodic leveling
- Random removal of atoms from surface → surface brightening
Electropolishing Limitations

• Acts only on microprofiles (=> requires low initial surface roughness)
• Aqueous acidic solution limits removal of metal species
  ➔ forming TiO₂ layer ➔ stopping removal process
• Acidic electrolytes are very hazardous

Method to overcome limitations

• Pulse Technology ➔ control Nernst diffusion layer
• Water-free electrolytes
Nernst diffusion layer control by pulsed current

- Short pulses → reducing large asperities (> 100 μm)
Pulse Technology
Effect of Pulse Width

\[ \text{Roughness } S_a [\mu m] \]

\[ \text{Pulse Width } [\mu s] \]

\[ S_a = \frac{1}{A} \int \int |Z(x,y)| \, dx \, dy \]
Pulse Technology
Effect of Duty Cycle variation

\[ S_a = \frac{1}{A} \int \int |Z(x,y)| \, dx \, dy \]

Roughness \( S_a \) [\( \mu \text{m} \)]

Duty Cycle [%]
Pulse Technology
Effect of Polishing Time

\[ S_a = \frac{1}{A} \int \int |Z(x,y)| \, dx \, dy \]

Polishing time [min]

Roughness \( S_a \) [\( \mu m \)]
Post-process Metal AM Parts

Roughness Profile SLM part Ti-alloy

Ra 20.5 µm
Rz 72.6 µm

Ra 2.0 µm
Rz 7.2 µm

Ra | Rz before + after EP for various alloys

Ti6Al4V
AlSi10Mg
EOS SS PH1

Ra initial [µm]
Rz initial [µm]
Ra after EP [µm]
Rz after EP [µm]
Case Study Roughness Control

1. Titanium rod
2. ‘Spider-web’ SLM fabricated Ti-6Al-4V parts

**Goal:**
1. reduce semi-melted beads (50 µm - 100 µm)
2. understand global reduction in strut thickness
3. optimize parameters for control of roughness and process time

Ra=1.2µm
Ti-rods

Effect of Polishing Time

Ra \[ \mu m \]

Polishing Time [min]
Ti-Spider Web
Effect of EP on Bead Removal

Unpolished

Polished (35 min)
Polishing of Inner Surfaces

Unpolished

Polished
Conclusions

• Pulse technology is an effective tool to eliminate surface asperities on AM parts
• Surface roughness is reduced typically by a factor 10-20
• Possible to tune the final roughness
• Possible to polish complex shapes
• Possible to polish inner surfaces
Current industrial partners

- posalux
- FlowJEM
- micronit
- PASSIVE ACTION
- Réseau Québec 3D
- Axis Prototypes
- TERRAGON Environmental Technologies Inc.
- Shilps Sciences
- Machine Tool Systems Inc.
- Alphacasting
- AGC ASAHI GLASS
What we offer

- R&D projects
- Continuing education
- Collaborative platforms
- Laboratory analysis
- R&D projects
- Continuing education
- Collaborative platforms
- Laboratory analysis
THANK YOU

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