

## Ti64 components fabricated using L-PBF processing under helium instead of argon



**CHALMERS**  
UNIVERSITY OF TECHNOLOGY

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Making our world more productive



## Linde/Chalmers partnership



**CHALMERS**  
UNIVERSITY OF TECHNOLOGY

# GDC Additive Manufacturing AM Lab in Munich – Capabilities



**Purpose:**  
In-house process development  
Part production

**Features:**

- Build surface 250\*250\*350mm
- 400W Fiber Laser, focus Ø 100 µm



**Purpose:**  
Process development  
Internal training

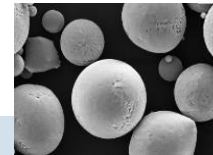
**Features:**  
Build surface Ø300\*400mm  
500W Fiber Laser, focus Ø 100-500 µm



**Purpose:**  
Process development  
Internal training

**Features:**  
Build surface Ø100mm  
200W Fiber Laser, focus Ø 50 µm

6 Technology experts  
3 PhD students  
1 Marketing/Partner management  
1 Engineering

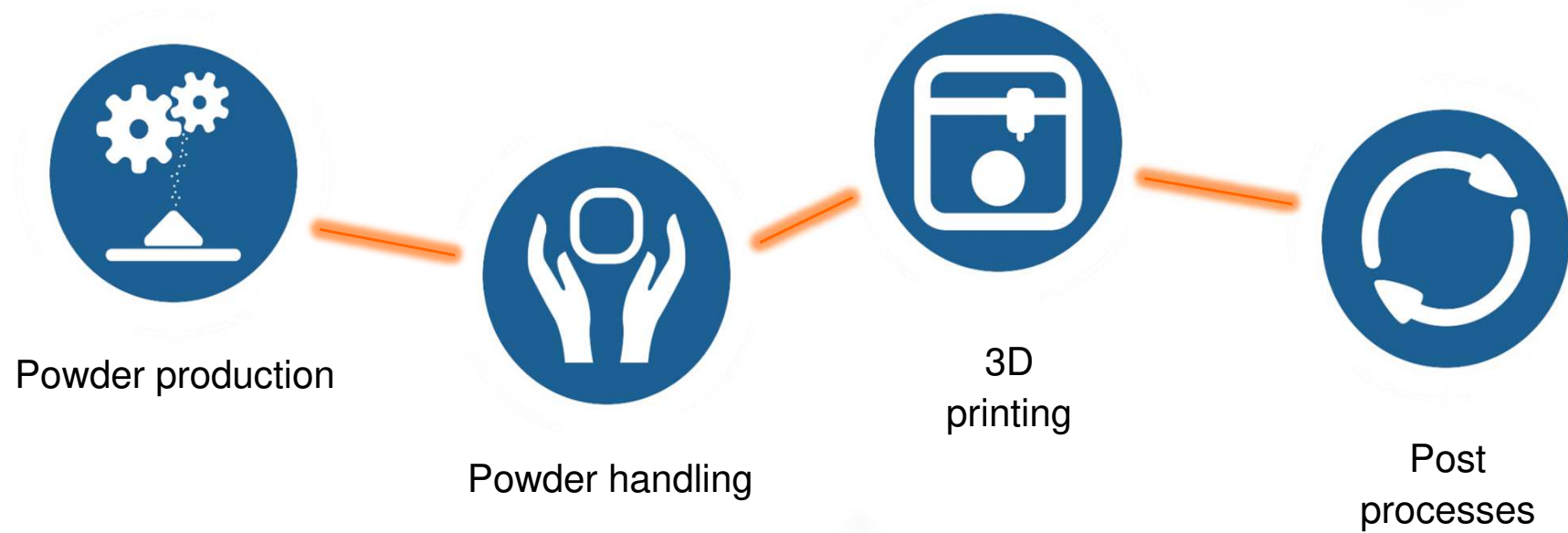


**Analytic:**

- Powder characterisation (SEM, CAMSIZER X2, KarlFischer Titration, Revolution)
- Metallography lab
- Chemical Analysis (Leco HNO)
- Gas Analytic (Gas Chromatography, ADDvance O2 precision)



## AM value chain



## Content



- How He improves the process stability in comparison to Ar, for Ti64 alloy
  - Jobs with EOS M290 printer & Pure He
  - Jobs with TP 3000 printer & Pure He
  - Jobs with EOS M290 printer & Ar-He mixtures

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# Parts production



- Parts production:

- Process gas

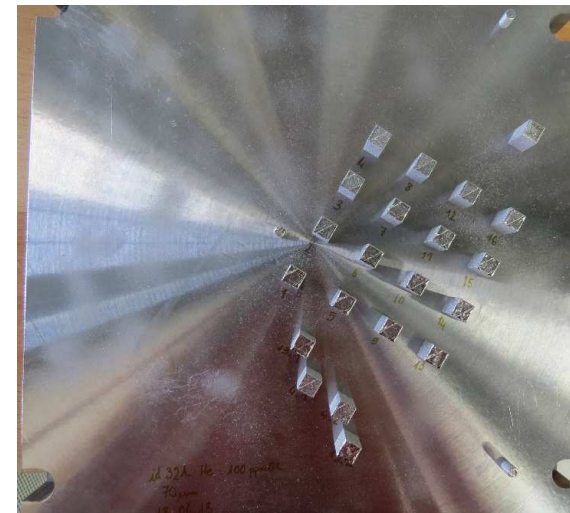
- Argon 5.0 or Helium 4.6

- 100 ppm O2 maintained during the job

EOS M290 and ADDvance® O2 precision

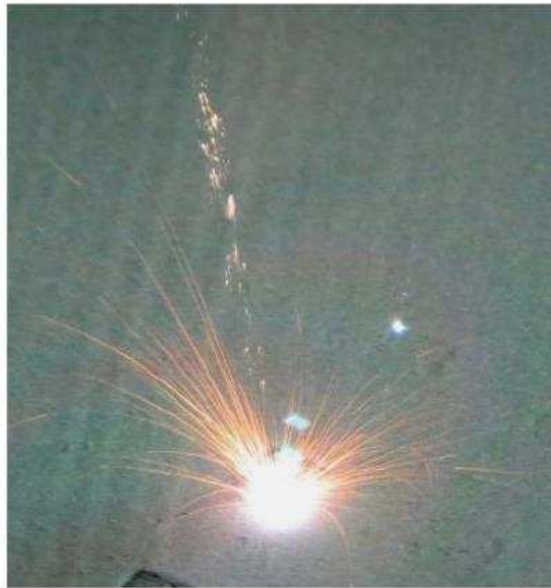


ADDvance® O2  
precision



Build platform 250mm\*250mm

# Process Observations



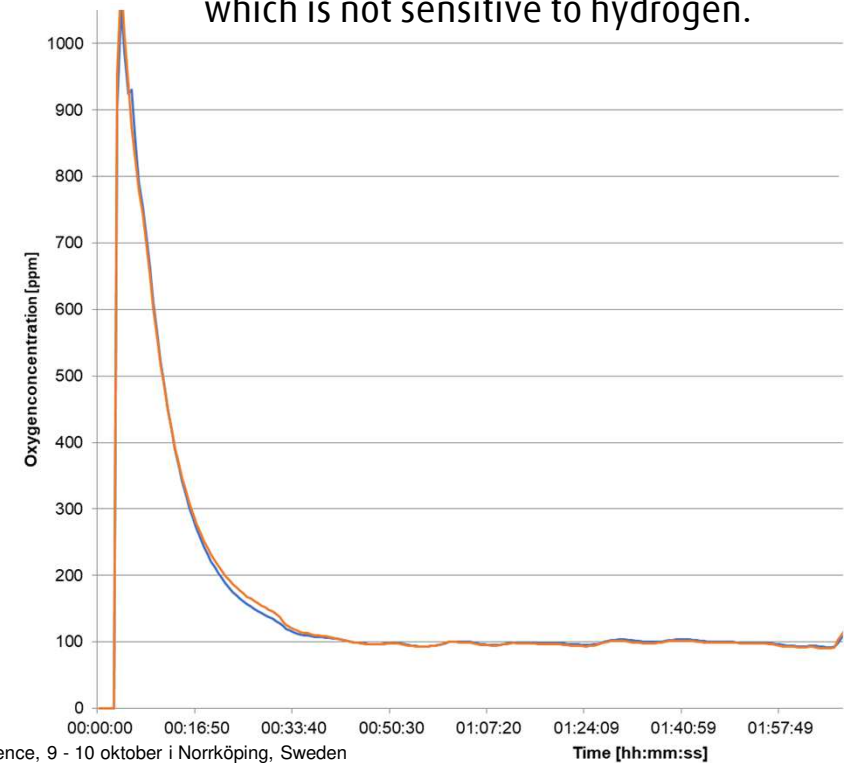
Argon



Helium

*Canon PowerShot SX50 HS camera disposed in front of the L-PBF machine's window on its front door*

- ADDvance®O2 precision into controlled mode
  - to ensure a residual level of 100 ppm O<sub>2</sub>.
  - The system features an electrochemical cell which is not sensitive to hydrogen.

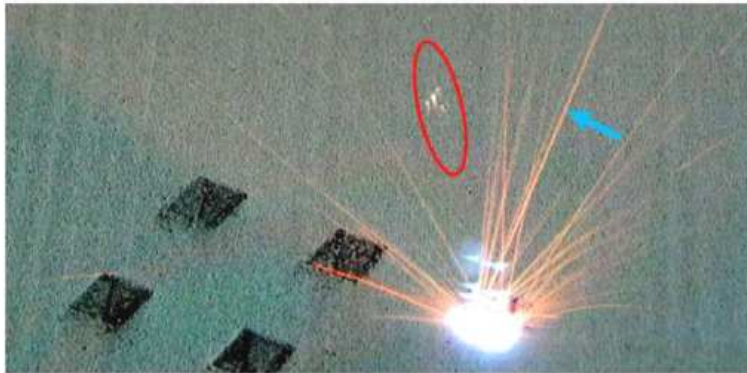




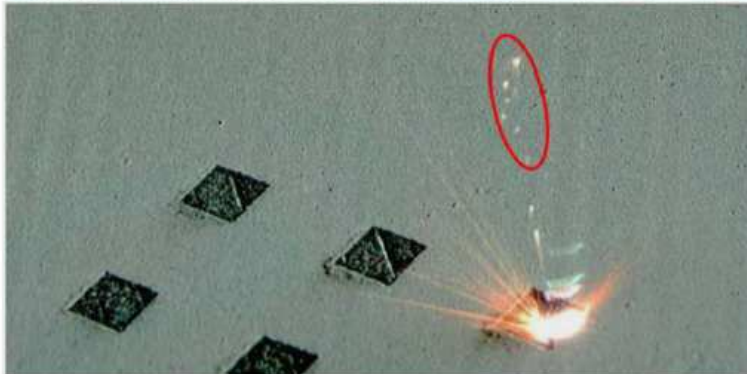
# Process Observations



Argon

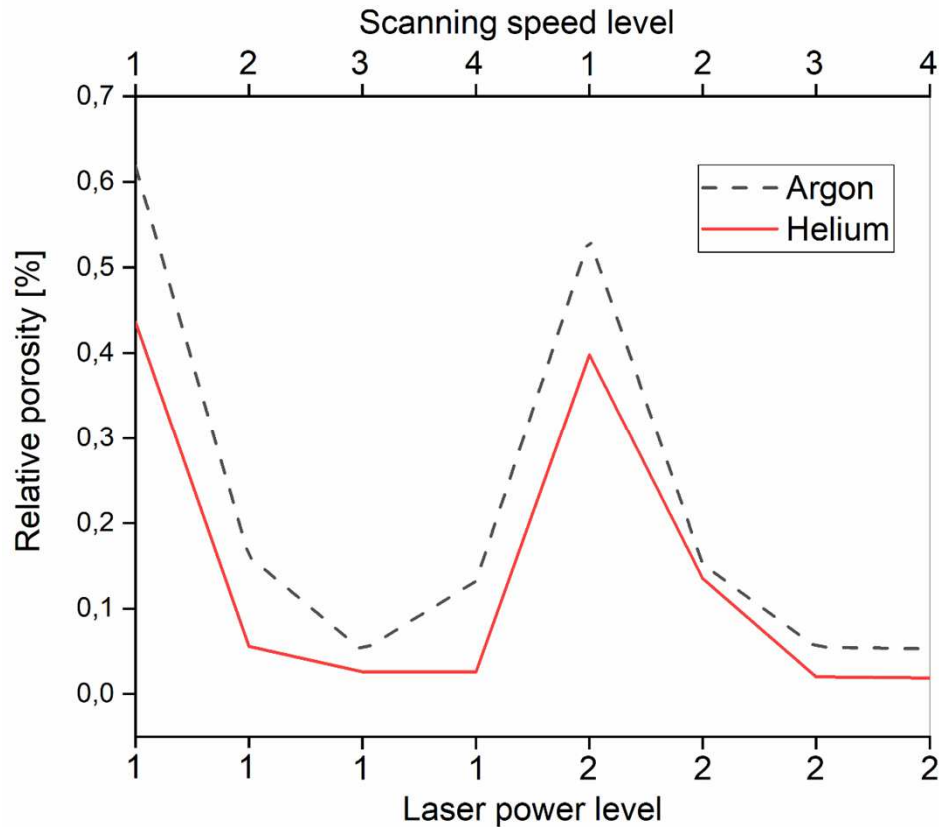


Helium



- Under He
  - Less convection-driven projections
  - Shorter and less curved bright trajectories
  - Smaller interaction spot

# Relative porosity [Light Optical Microscope]



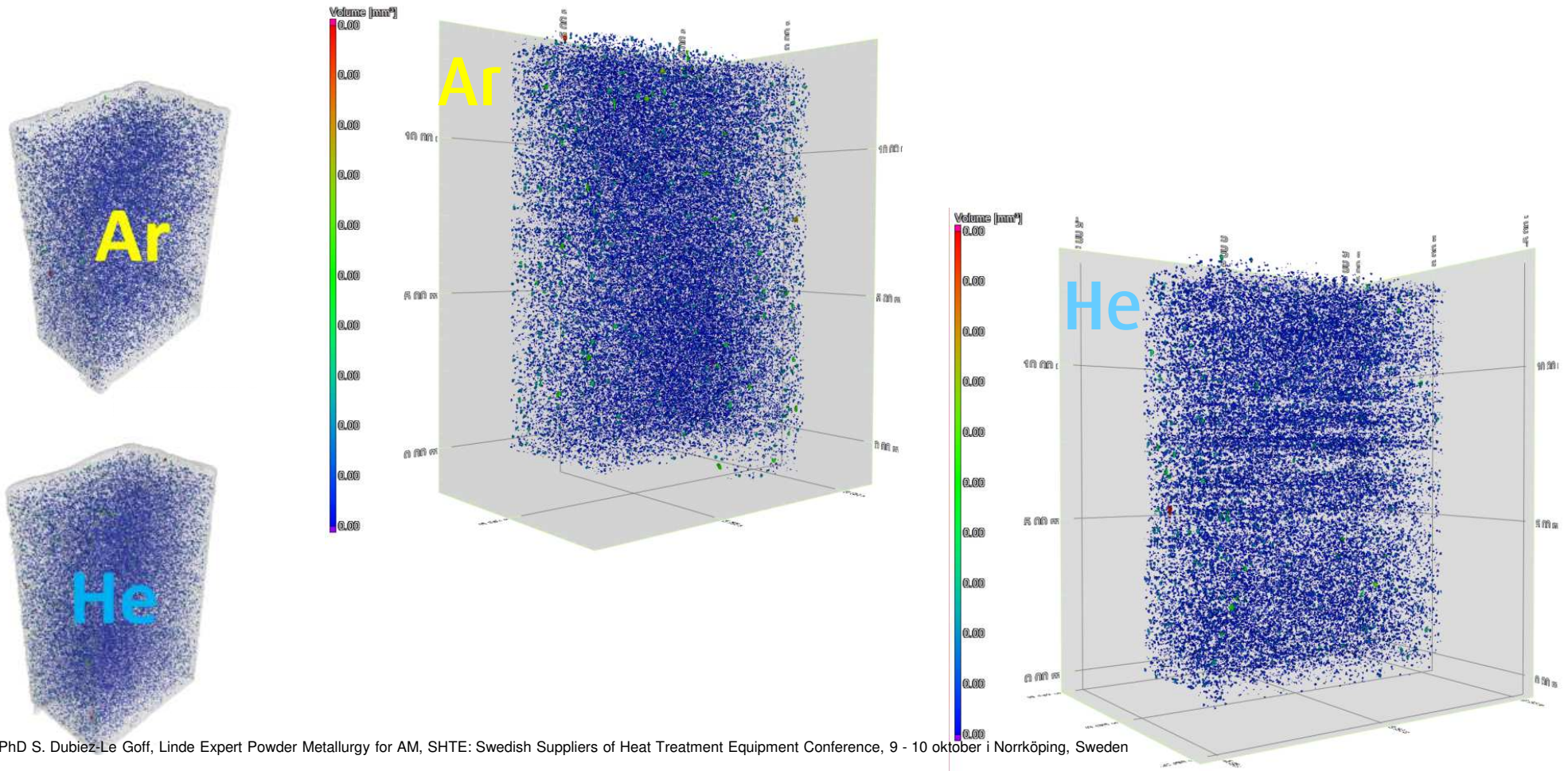
- For a given set of parameters:
  - Higher density in Helium than in Argon

## Relative porosity [micro-CT]



- micro-CT system:
  - Yxlon FF35 CT
    - Acceleration voltage: 160 kV
    - Current: 150 A
    - integration time of 3 s for 2880 projections.  
Minimum voxel size: 5,6  $\mu\text{m}$ .

# Relative porosity [micro-CT]



## Content



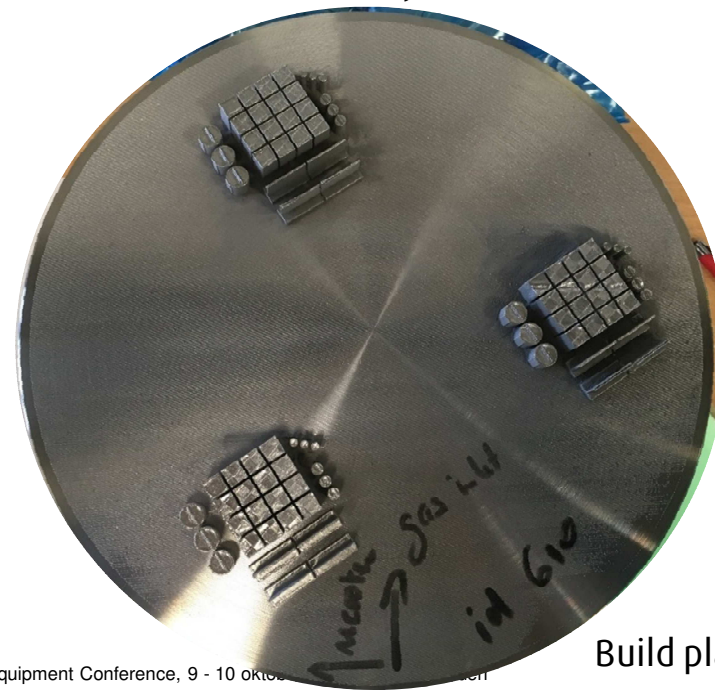
- How He improves the process stability in comparison to Ar, for Ti64 alloy
  - Jobs with EOS M290 printer & Pure He
  - Jobs with TP 3000 printer & Pure He
  - Jobs with EOS M290 printer & Ar-He mixtures

# Parts production



## – Parts production:

- Process gas
  - Argon 5.0 or Helium 4.6
  - Un-controlled jobs

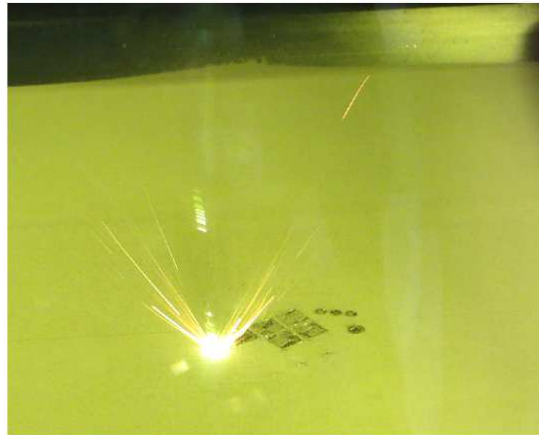


Build platform Ø300

# Process Observations



Argon  
1000 ppm uncontrolled



Helium  
1000 ppm uncontrolled

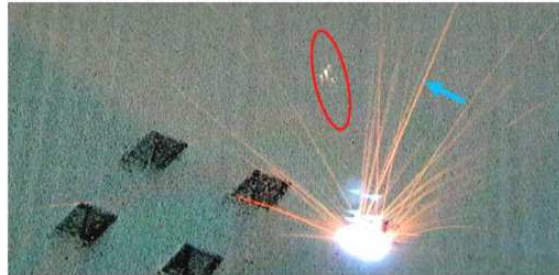


# Process Observations

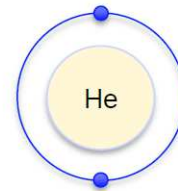
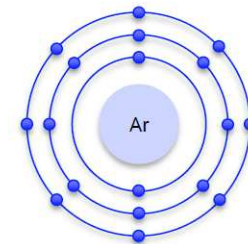
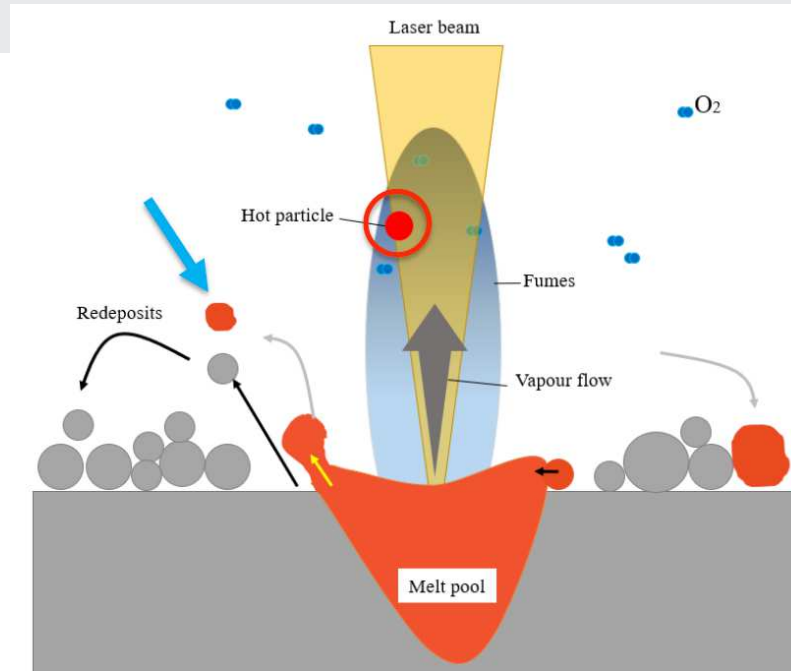
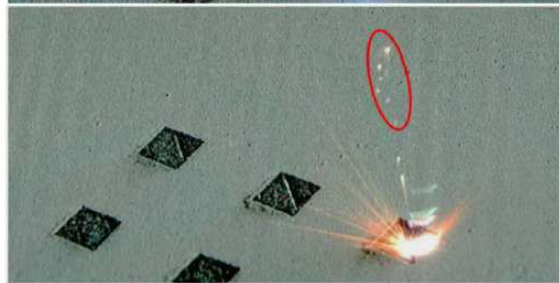
## Interpretation



Argon



Helium



Density [kg/ m<sup>3</sup>]:

1.62

0.16

Thermal conductivity [W/(m·K)]:

0.016

0.142

Specific heat capacity [J/(kg·K)]:

520

5190

- Under He
  - Less convection-driven projections
  - Shorter and less curved bright trajectories
  - Smaller interaction spot

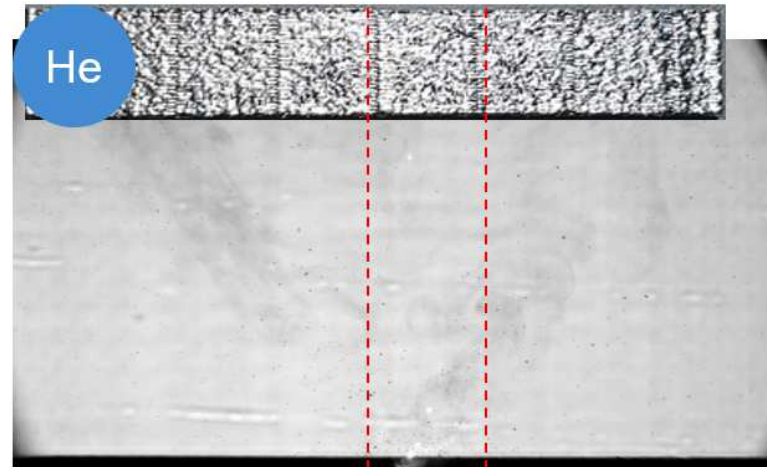
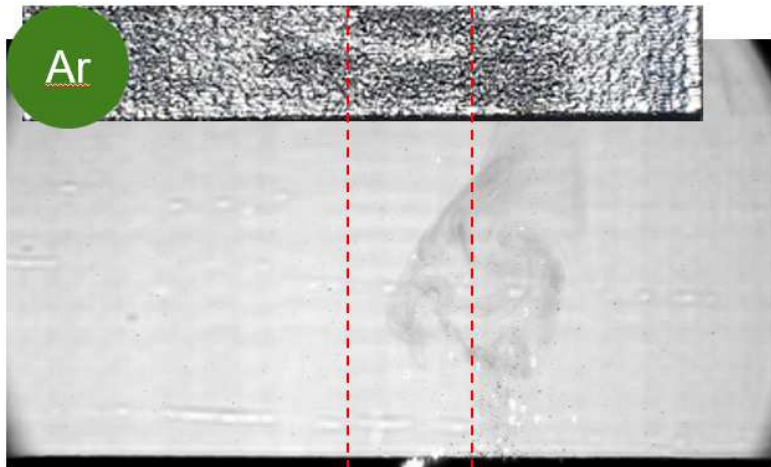
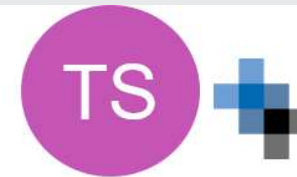


# Process Observations

## Complementary analyses by Schlieren imaging



Project Reference  
Influence of shielding gas on LPBF process



Material: Ti6Al4V, Scan speed: 1,000 mm/s, Layer: 30  $\mu$ m, Specimen: cube  
Inert gas: **Argon** (no flow, just atmosphere)

Material: Ti6Al4V, Scan speed: 1,000 mm/s, Layer: 30  $\mu$ m, Specimen: cube  
Inert gas: **Helium** (no flow, just atmosphere)

### Preliminary findings:

- Shielding gas has a significant impact on process dynamics
- Argon process collapses while Helium process remains steady
- Causes for measured effects are currently investigated
- Next steps: Evaluation of Varigon & Argon with 1000 ppm O<sub>2</sub>



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# Parts production



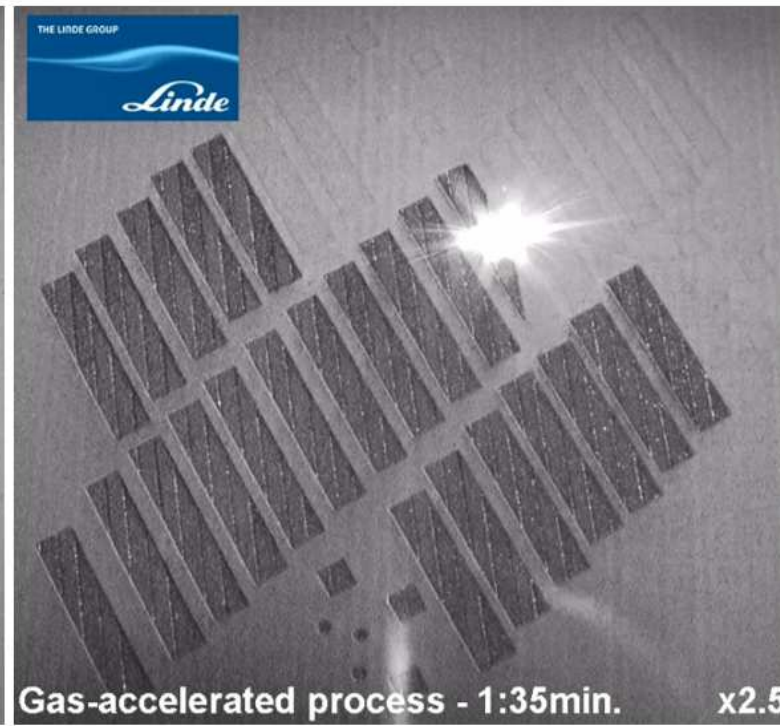
**EOS M290 and ADDvance® O2 precision**



ADDvance® O2  
precision

- Parts production:
- Process gas
  - Argon 5.0 or Helium 4.6 and Ar-He mixtures
  - 100 ppm O2 maintained during the job

# Process Observations



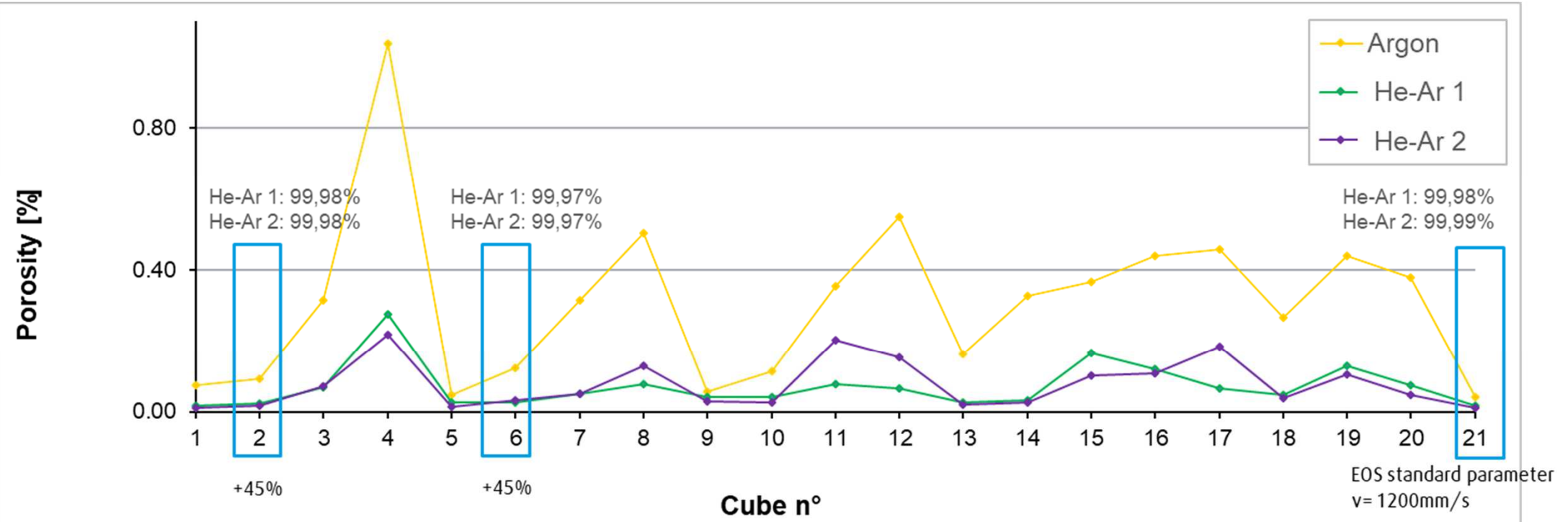
# Productivity Improvement



- Selection of 2 Helium-Argon mixtures
- Increase of laser power and scanning speed
- Control of oxygen levels at 100ppm via ADDvance O2 Precision®

## Conclusions :

- Helium-Argon mixtures yield lower porosity
- Scanning speed can be increased by 45%



## Conclusion



- Helium and Argon-Helium mixtures
- ↗ stability of L-PBF process for Ti-6Al-4V
- ↗ density of L-PBF process for Ti-6Al-4V
  
- ↗ process built rate without compromising the as-built density