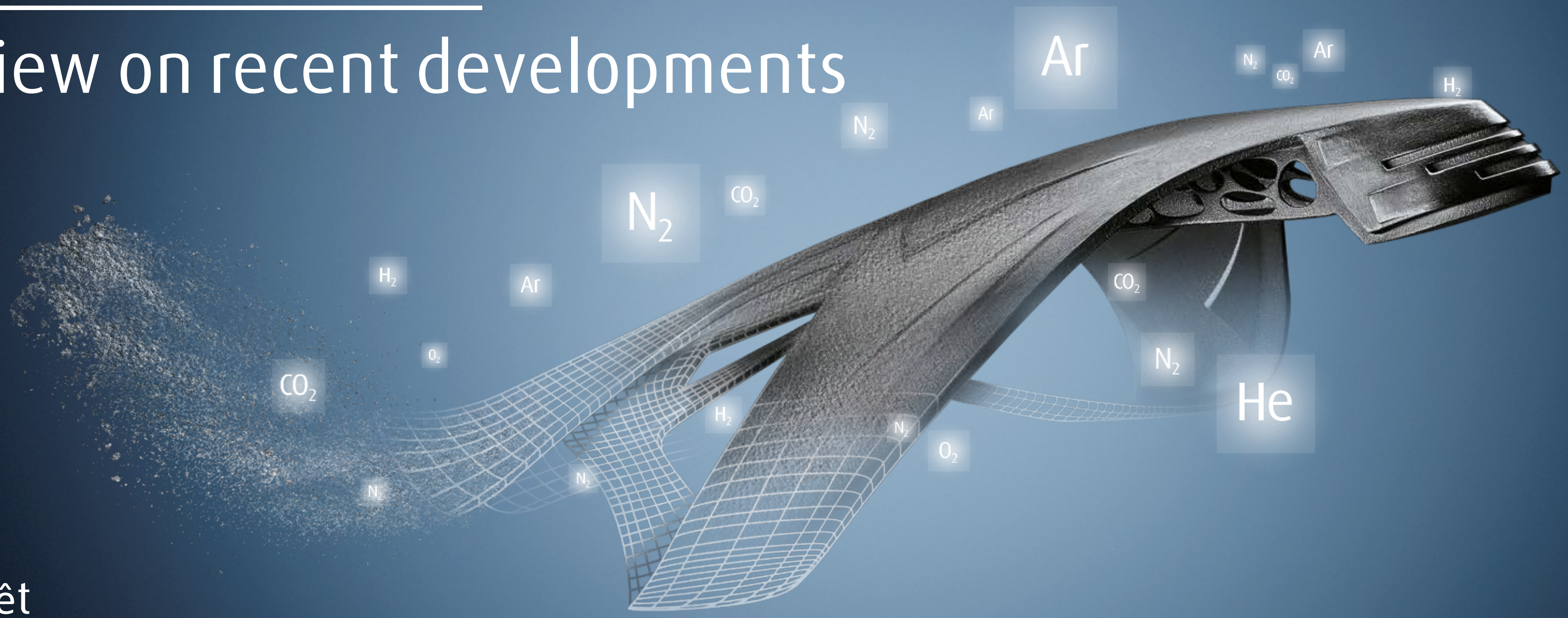
# AMTC 2021

## New Material Solution

## Overview on recent developments

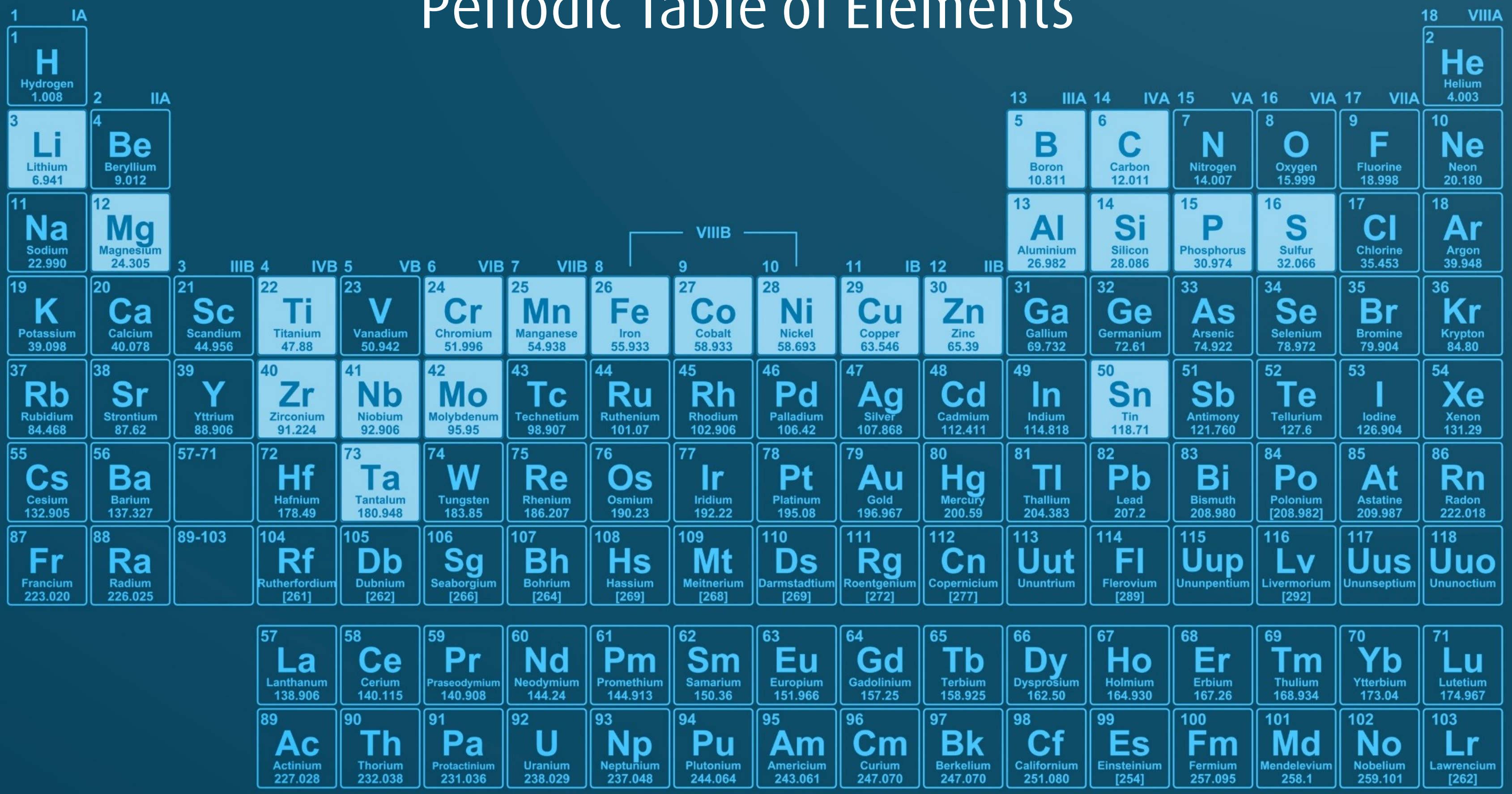



Pierre Forêt
October 2021

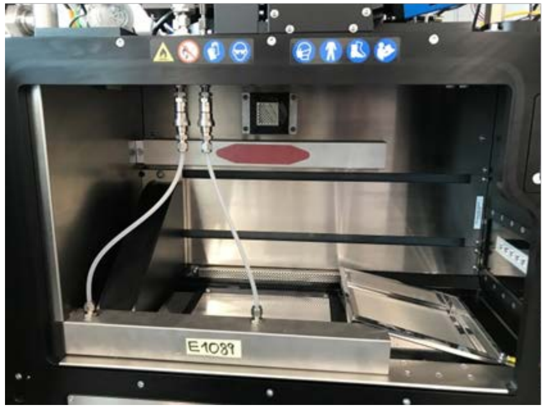
Making our world more productive

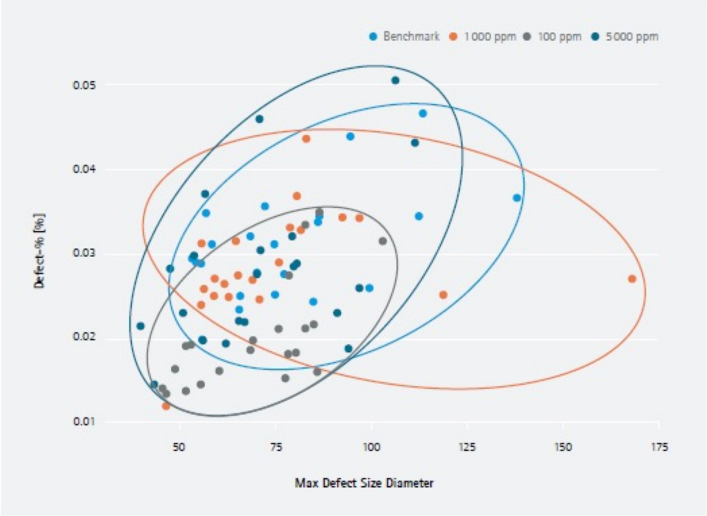
# AlSi10Mg | IN718 | A2000 series | Nitinol

## Periodic Table of Elements

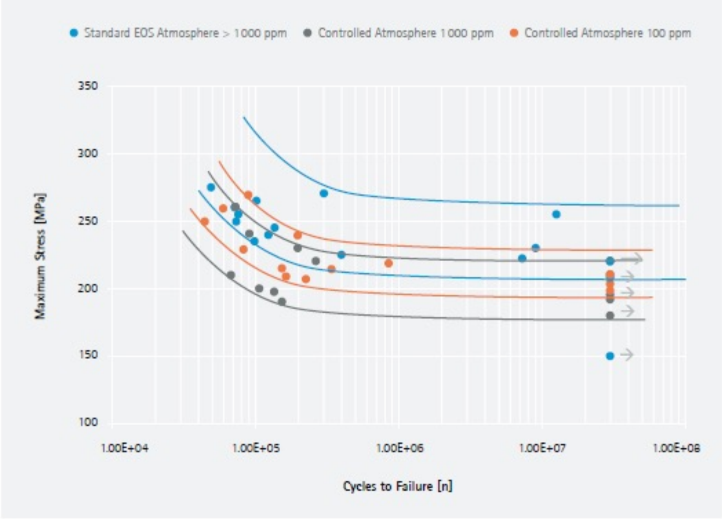


# Al Linde and EOS leverage ADDvance $O_2$ precision technology for AlSi10Mg study

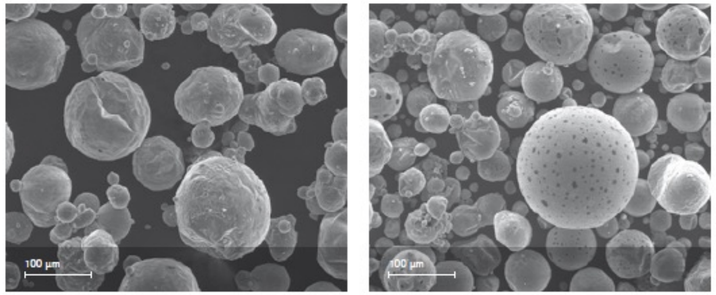



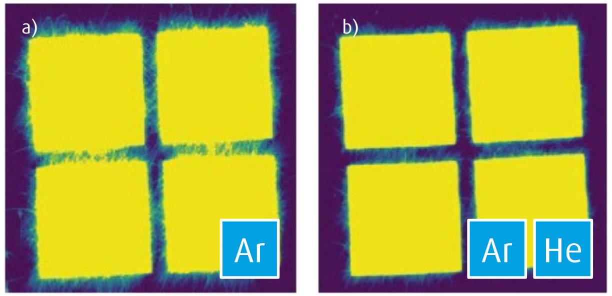

Defect percentage and maximum defect size depending of the oxygen level. Each dot represents one density cube.




Fatigue results for specimens

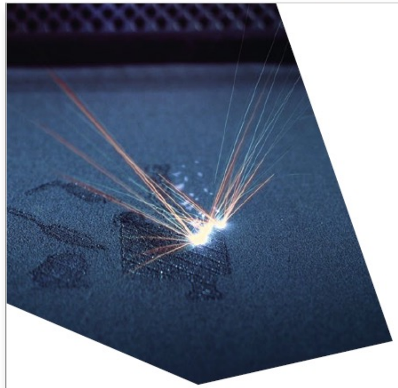



SEM images (500 X) of powder particles collected in the suction nozzles after the build for the EOS standard atmosphere condition (left) and for a process gas atmosphere with 5000 ppm of residual oxygen (right).




EOSTATE Exposure OT picture. 4 cubes with a) argon b) argon/helium process gas mixture

# Al Linde and EOS leverage ADDvance $O_2$ precision technology for AlSi10Mg study



Whitepaper

This whitepaper provides insight into:

- → Processing of AlSi10Mg
- → Atmospheric monitoring and optimization with Linde's ADDvance® $O_2$ precision
- → Use of EOSTATE Exposure OT with argon-helium process gas

The Influence of Process Gas on Additively Manufactured AlSi10Mg

By
M.Sc. Manuel Walter
Process Technology Engineer
EOS GmbH
Dr. Dominik Bauer
AM Expert – Linde GmbH

How residual oxygen influences the processing of AlSi10Mg and its material quality

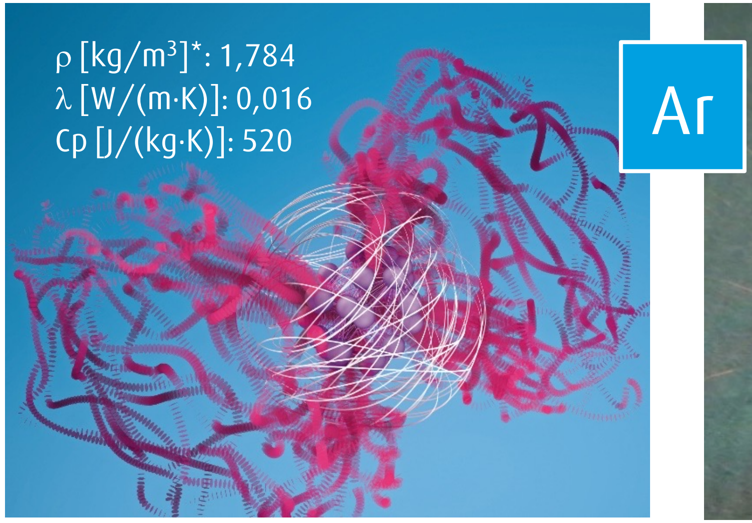
EOS and Linde combined their expertise to jointly undertake research in the field of additive manufacturing and material-gas interaction. The aim of this study was to investigate the influence of the oxygen concentration on the properties of AlSi10Mg. The influence of impurities in the process gas on the quality of the additively manufactured material was analyzed, as well as the influence on the process itself.

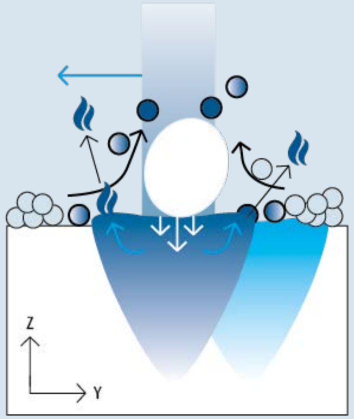
The results presented in this paper demonstrate which oxygen levels are acceptable for the processing of AlSi10Mg and show how the equipment can be further optimized for specific applications.

The results highlight that:

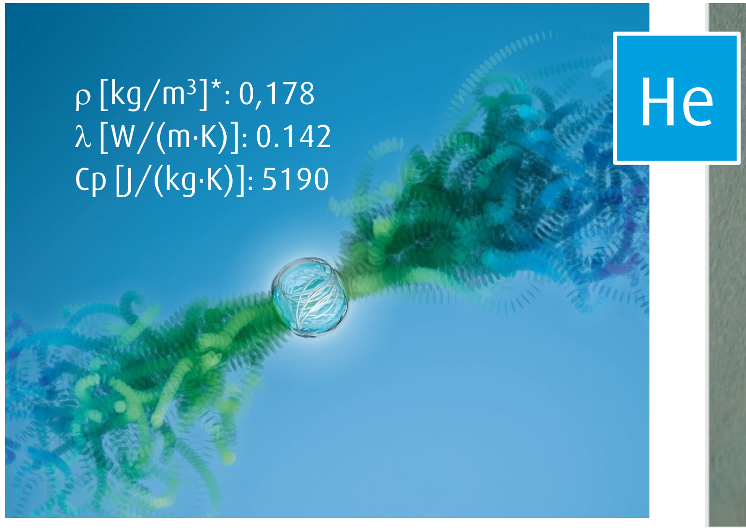
- The EOS M 290 with the EOS Aluminium AlSi10Mg powder and process parameters enable a high-quality, reproducible final part
- An oxygen content below 1000 ppm needs to be maintained during processing to prevent increasing the number and size of pores, ensure high part density and required mechanical properties
- Powder aging is reduced by keeping the O level below 1000 ppm which enables more frequent reuse of the powder
- The position of the oxygen sensor influences the measurement, with a sensor placed near to the powder bed giving optimal measurement

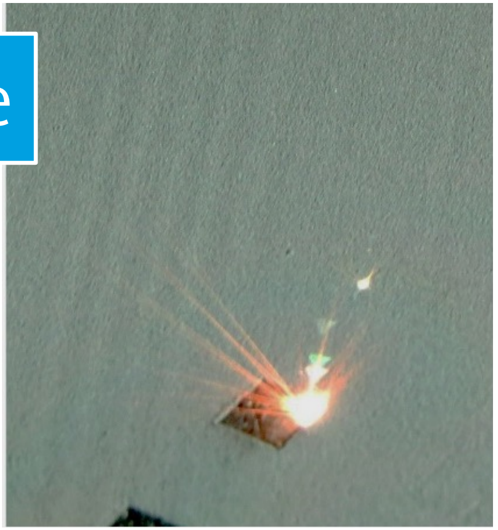
# Ni IN718 - Reduction of process by-products.

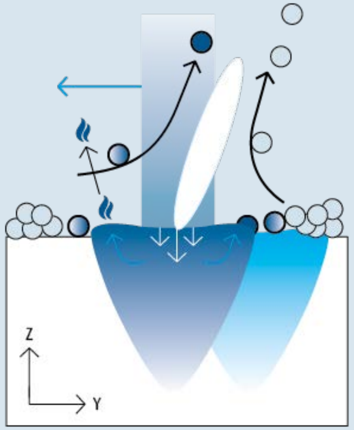



- Recoil pressure leads to process by-products
- Fumes are generated



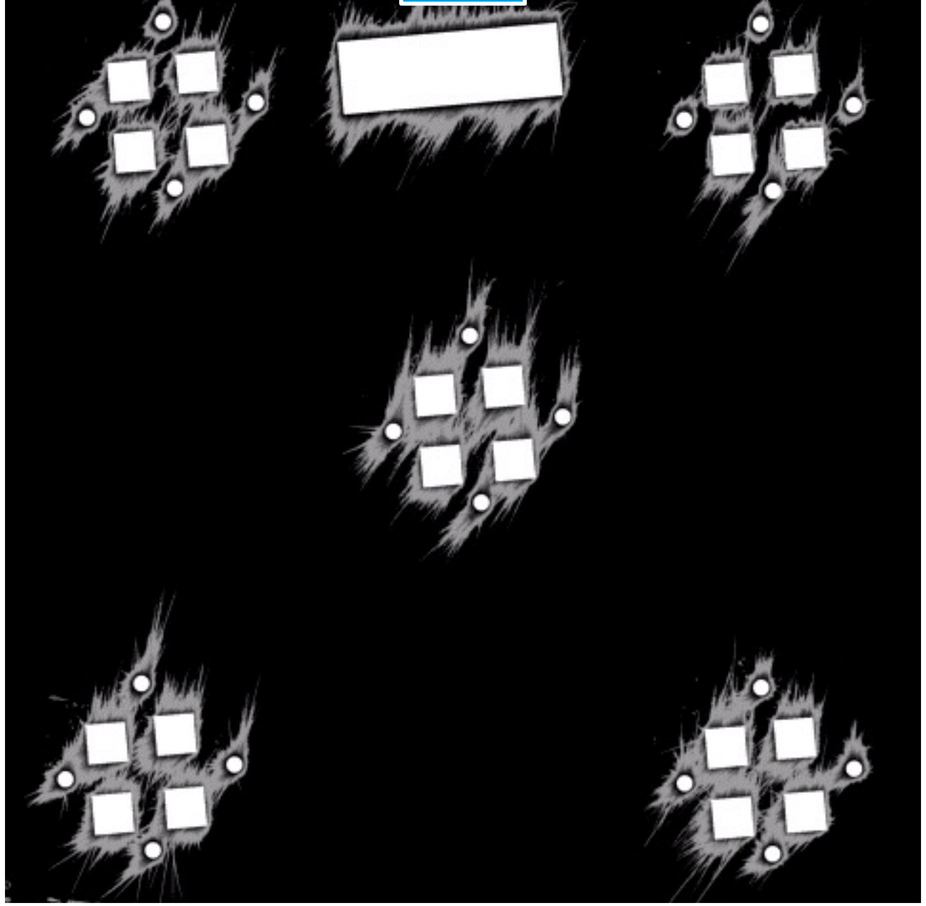



- Recoil pressure is reduced leading to less process by-product ejections
- Less fumes are generated

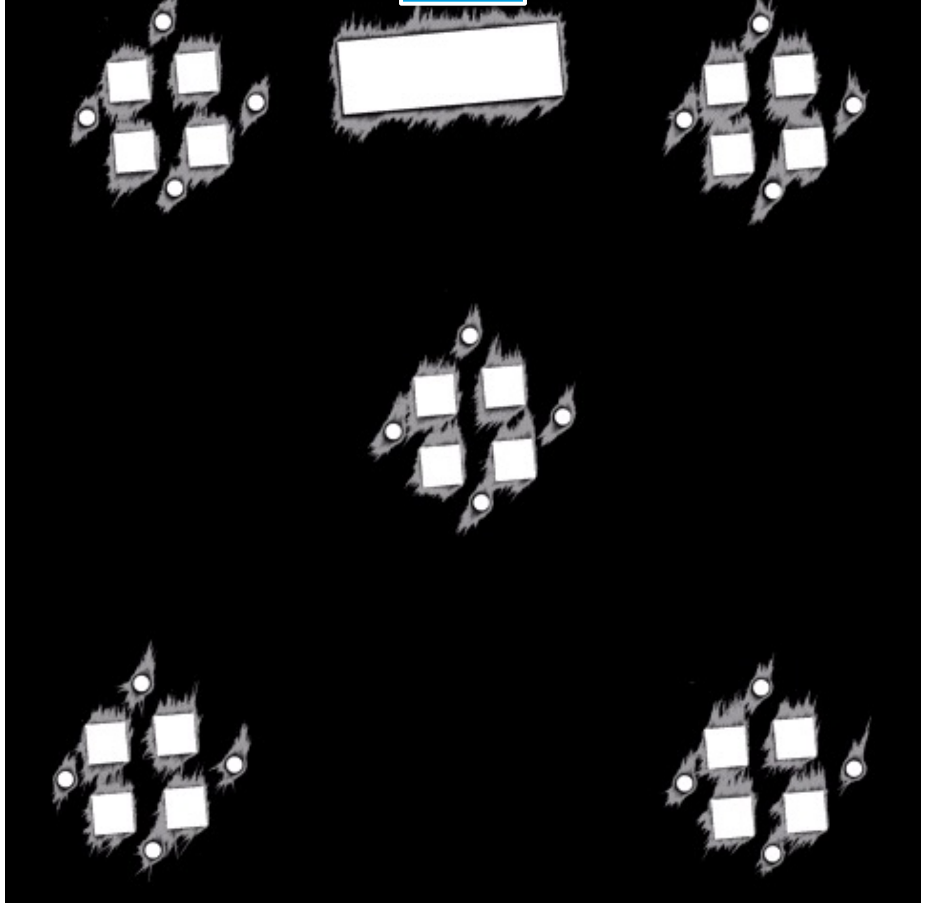
Ni

# IN718 - Reduction of process by-products.

Ar

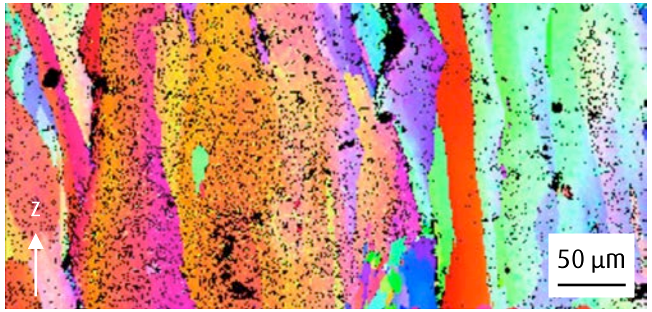


He



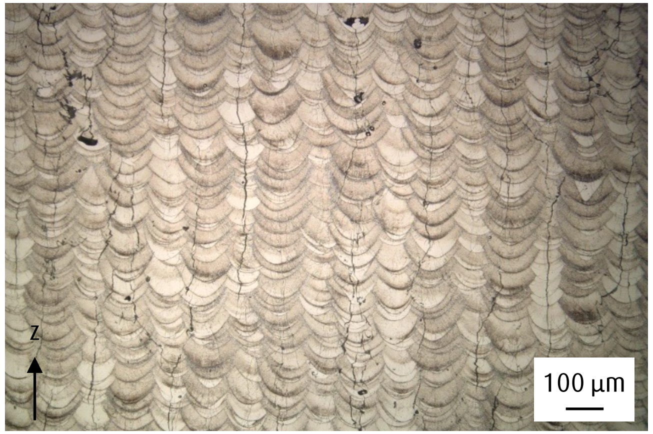
# GasAlloy-X: Approaches to design new high-strength aluminium alloy for PBF-LB/M

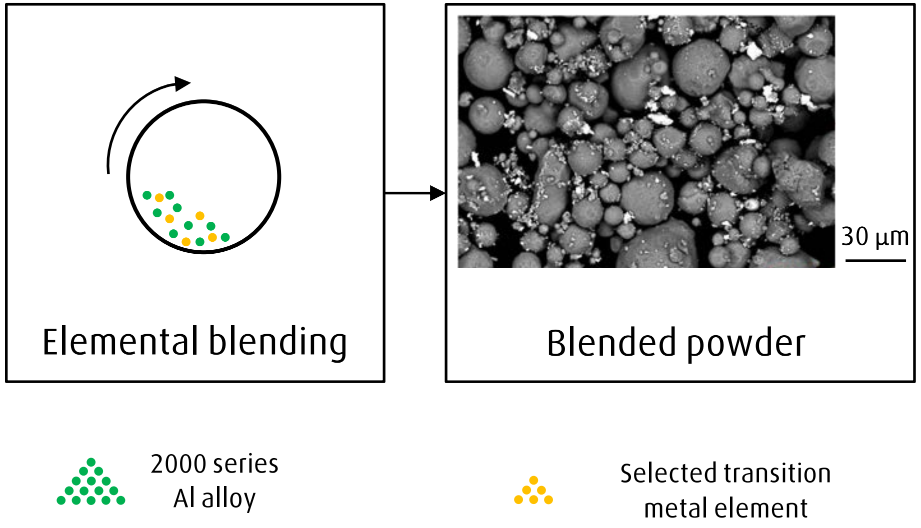
Al

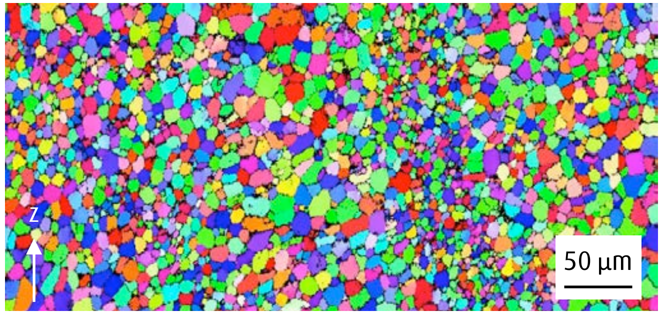



Pure 2000 series Al alloy in PBF-LB/M:

- Affected by hot cracking
- Elongated large grains

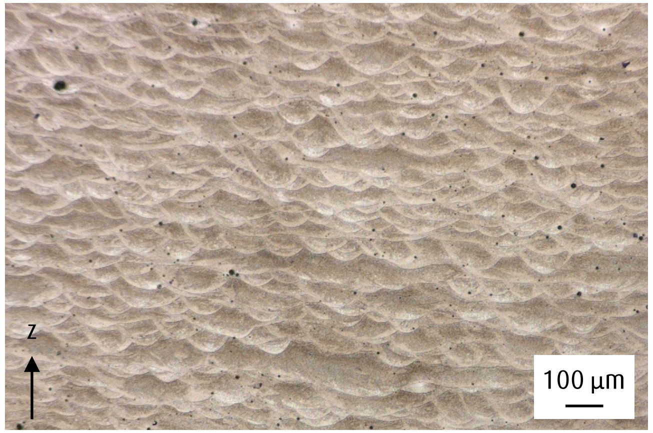



Project 2000 series Al alloy in PBF-LB/M:

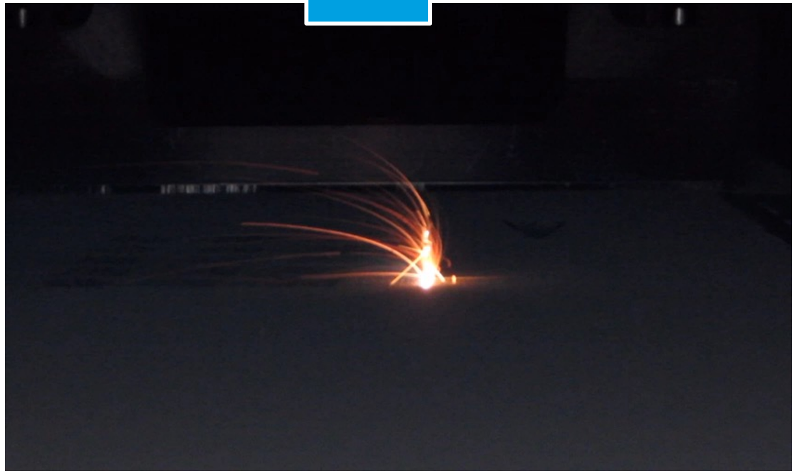
- No hot cracking
- Equiaxed sub-micron grains



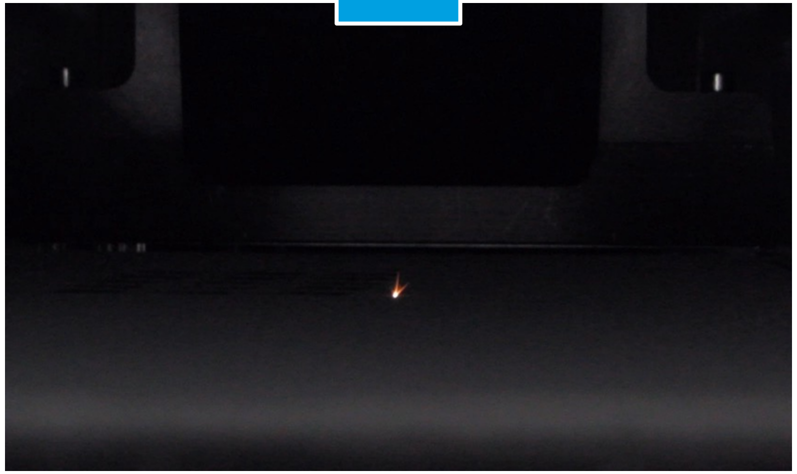
Al

# GasAlloy-X: Influence of Ar, He and $CO_2$ on process by-products

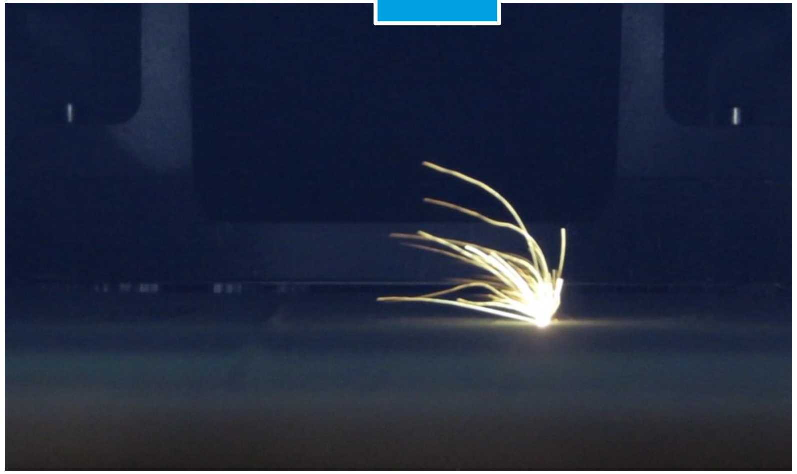
Ar



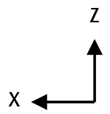
He



$CO_2$



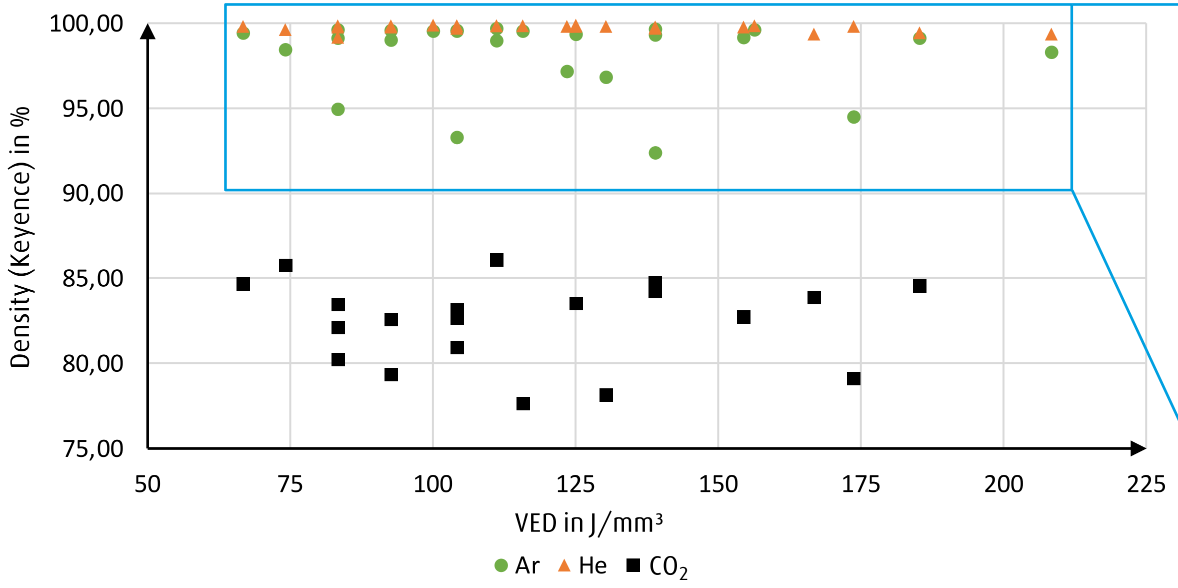
x = gas flow direction, z = build direction

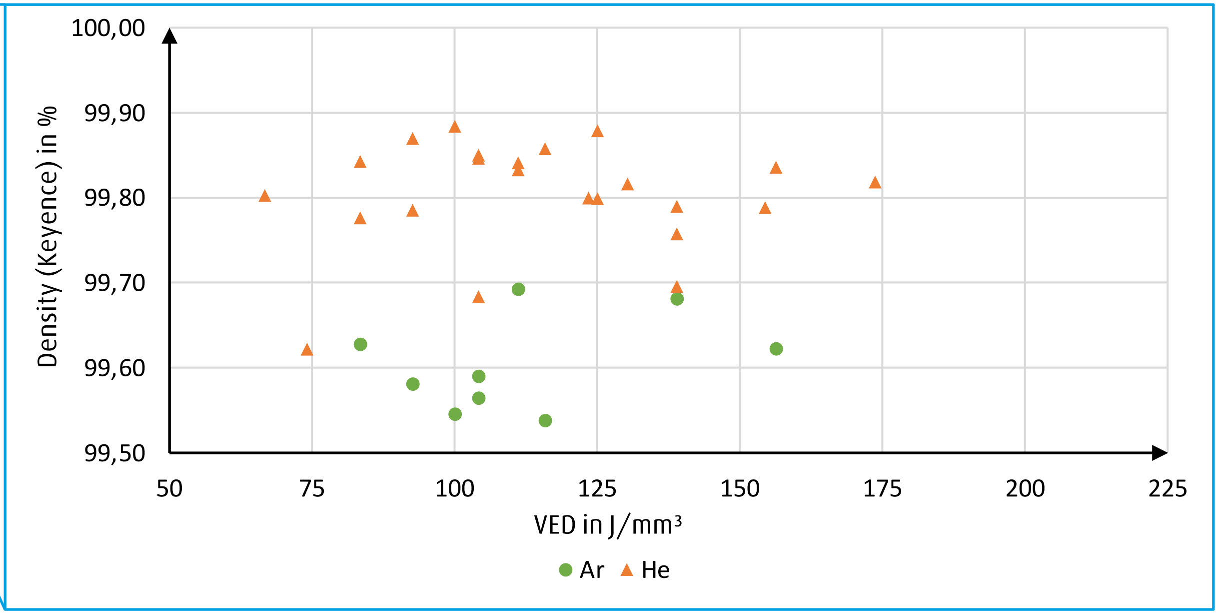


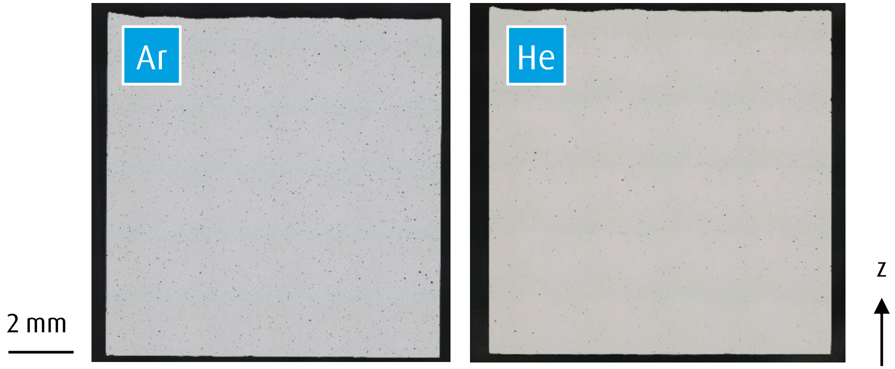
# Al GasAlloy-X: Influence of Ar, He and $CO_2$ on the properties of the printed parts

œrlikon am

Linde



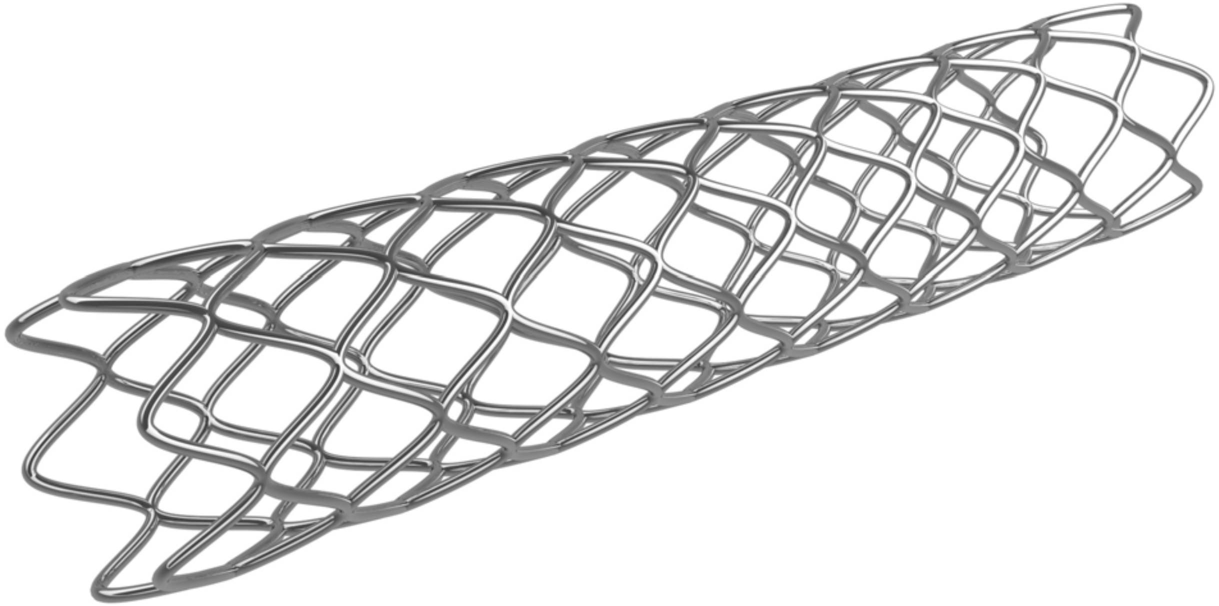



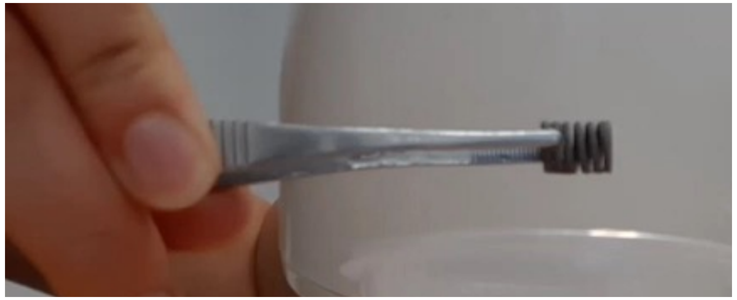

VED = 100 J/mm³

Compared to Ar and $CO_2$, He leads to…

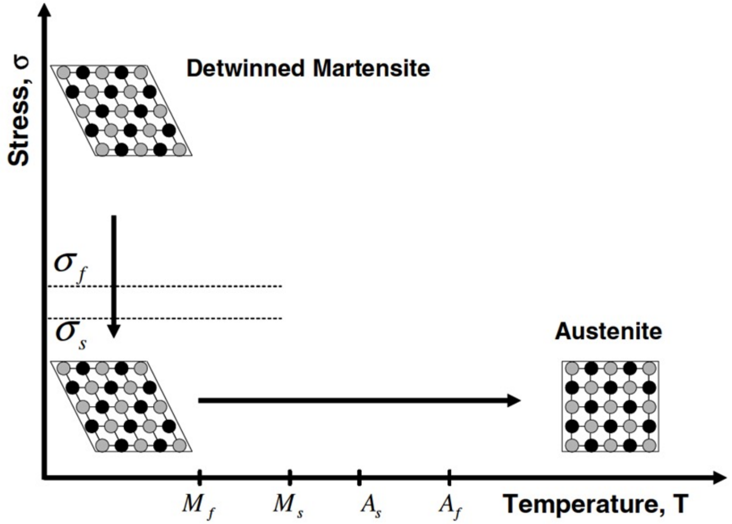
- …consistently high bulk densities (Archimedes and optical)
- …smooth surfaces of the printed parts
- …less visible process by-products

# Nitinol – Shape memory alloy for medical and aerospace applications – Process gas is key





Nitinol 3D printed spring.



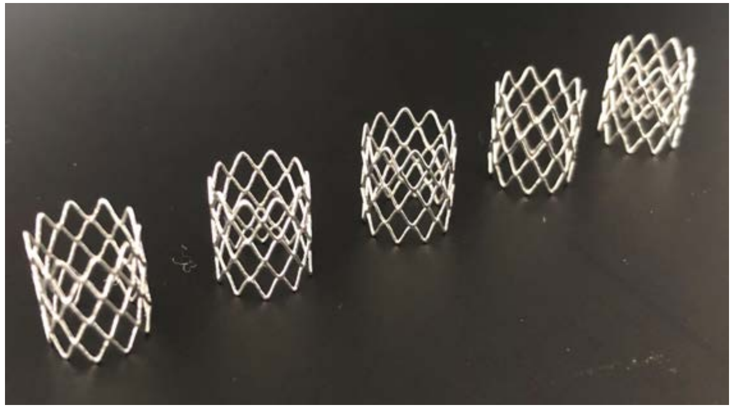

Schematic of the shape memory effect of SMA showing the unloading and subsequent heating to austenite under no load condition

# Ni Nitinol – Shape memory alloy for medical and aerospace applications – Process gas is key

MARLE 3D MEDLAB | Linde

## Problems

- Cold working and machining are difficult because the enormous elasticity of the alloy increases die or roll contact, leading to tremendous frictional resistance and tool wear
- Nitinol is prone to oxidation. The presence of oxygen influences the grain boundary character of the alloy.



## Solution

- AM can solve manufacturing challenges for high value products for medical and aerospace applications
- $O_2$ level during printing <10ppm

<1000ppm O2 in the printing chamber

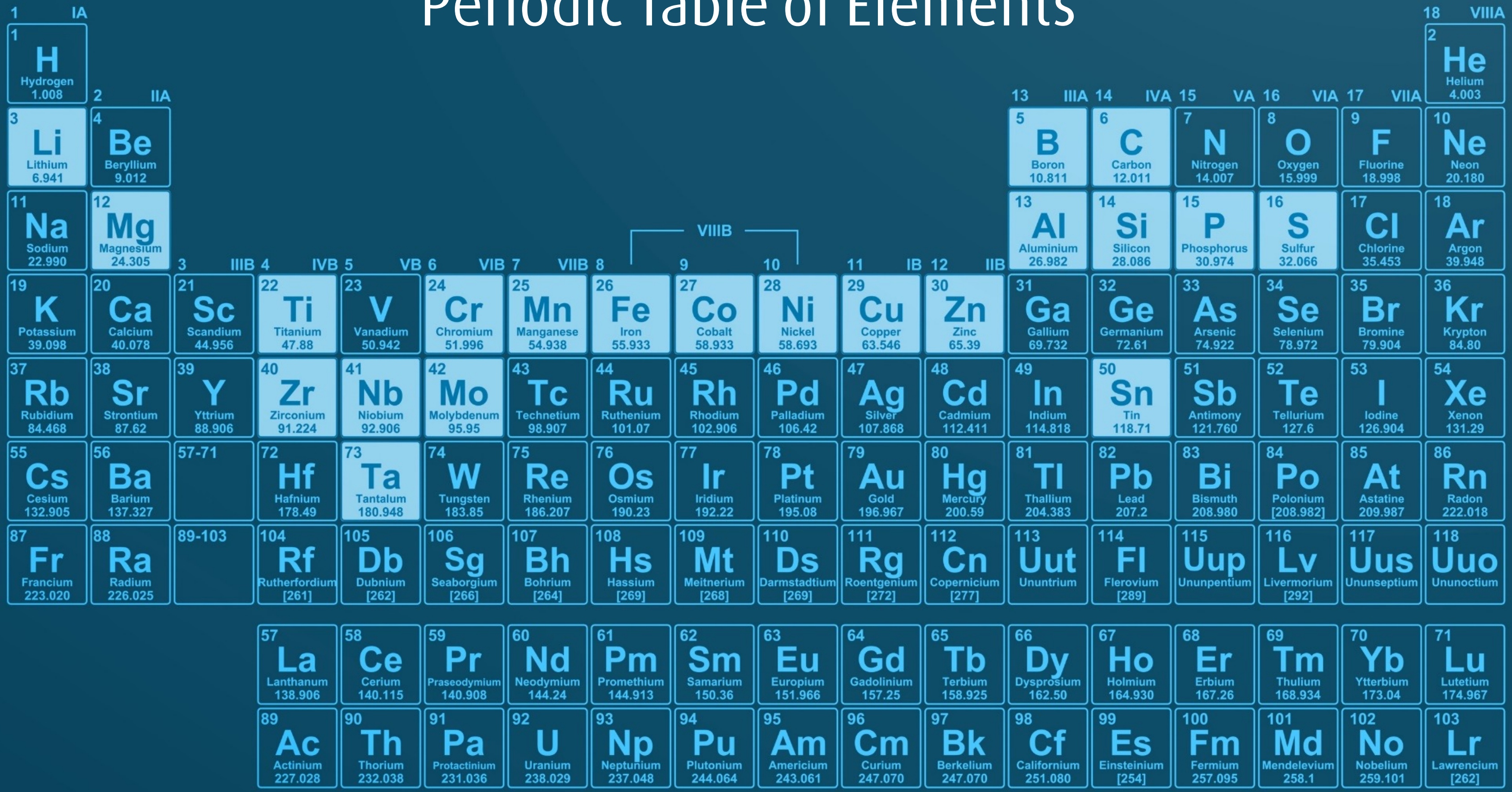
<10ppm O2 in the printing chamber

# Nitinol – Shape memory alloy for medical and aerospace applications – Process gas is key

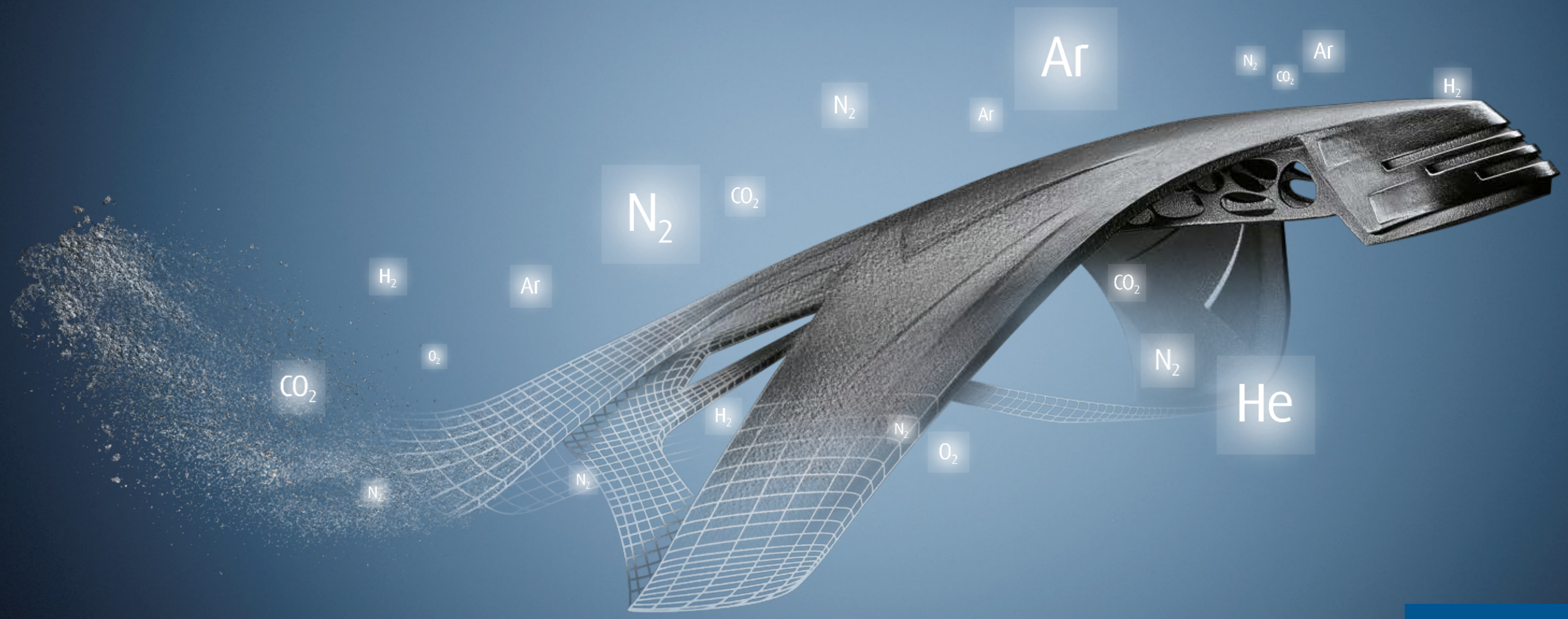
<1000ppm O2 in the printing chamber

<10ppm O2 in the printing chamber

# Periodic Table of Elements



# Thank you for your attention

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Making our world more productive