Magnesium Elektron

SERVICE & INNOVATION IN MAGNESIUM

Development & Cold Spray of High Strength Magnesium Alloy Powders

Rajiv Tandon, Deepak Madan

Victor Champagne*, Matthew Trexler*, Blake Barnett*

CSAT Meeting

Oct 30-31,2012

* *Army Research Laboratory, Aberdeen Proving Ground, MD*

LUXFER GROUP

ENVIRONMENTAL • HEALTHCARE • PROTECTION • SPECIALITY

Acknowledgements and Disclaimer

Deepak Kapoor and Jim Wejsa
- U.S. Army Research, Development, and Engineering Center, Picatinny Arsenal, NJ.

Kyu Cho
- U.S. Army Research Laboratory, Aberdeen Proving Ground, MD

Disclaimer: The views, opinion, and conclusions made in this presentation are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the U.S. Army or the U.S. Government. The U.S. Government is authorized to reproduce and distribute this presentation for Government purposes.

AGENDA

- Introduction To Magnesium Elektron Powders
- Objectives for Cold Spraying Mg Alloy Powders
- Preliminary Results of Cold Spray Trials
- Summary and Conclusions

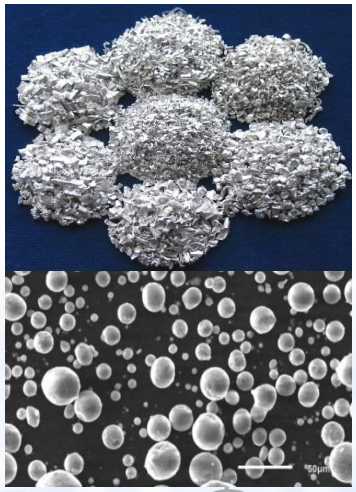
AGENDA

- Introduction To Magnesium Elektron Powders
- Objectives for Cold Spraying Mg Alloy Powders
- Preliminary Results of Cold Spray Trials
- Summary and Conclusions

Magnesium Elektron Operations

MAGNESIUM ELEKTRON

- **Magnesium Casting Alloys**
- **Magnesium Wrought Products**
- **Magnesium Powders**
- **Magnesium Recycling**

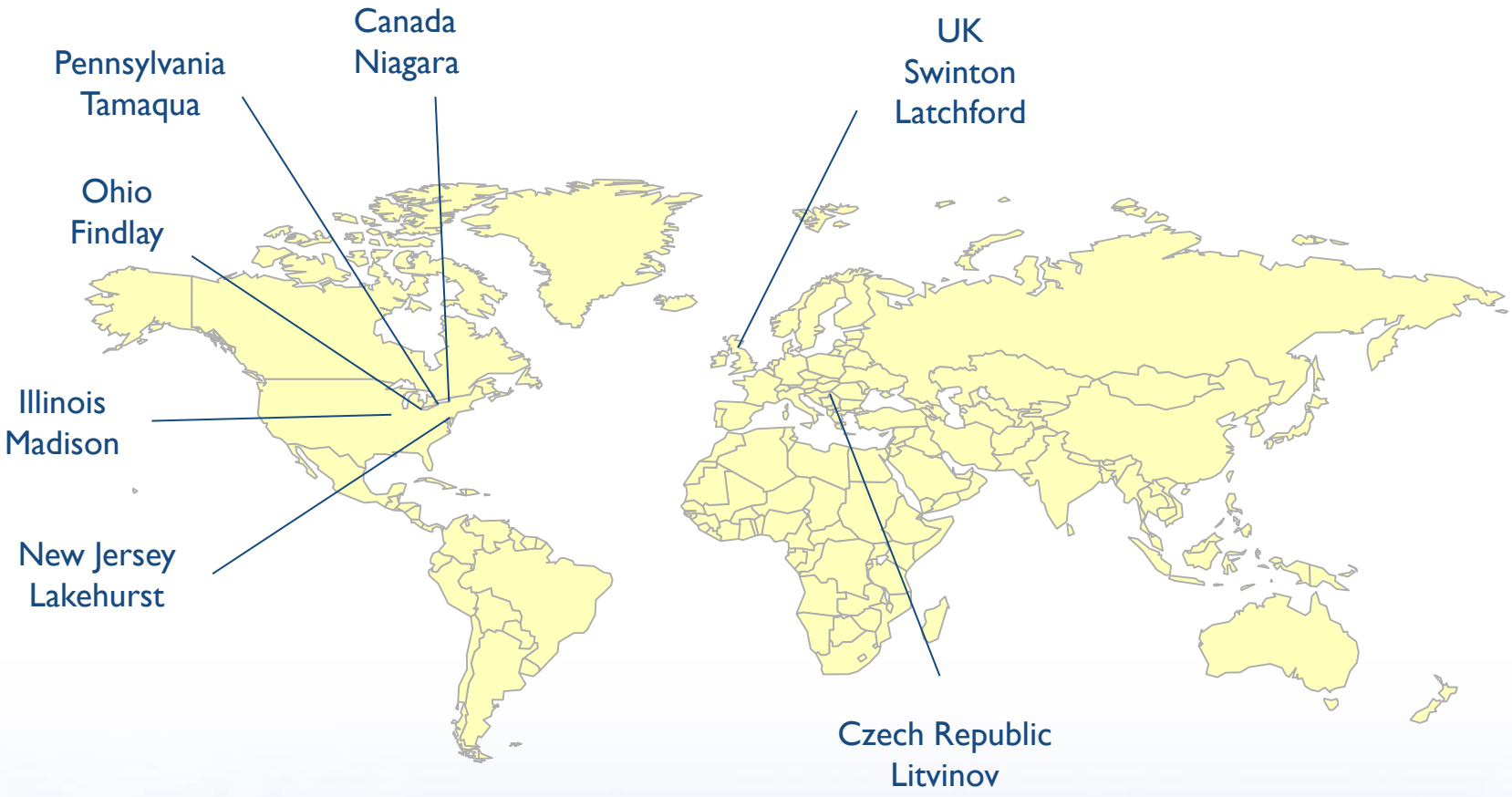


ENVIRONMENTAL • HEALTHCARE • PROTECTION • SPECIALITY

Magnesium Elektron

SERVICE & INNOVATION IN MAGNESIUM

Magnesium Elektron Facilities

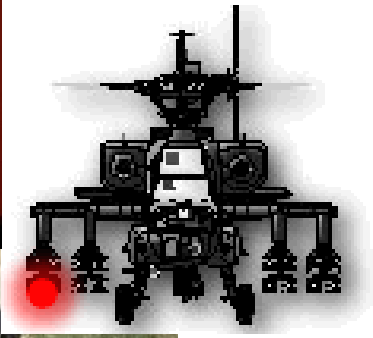


Magnesium Elektron
High Performance Mg Casting Alloys

Lockheed Martin F-22, F-35

Boeing AH64 Apache

Elektron 21



Elektron WE43

ENVIRONMENTAL • HEALTHCARE • PROTECTION • SPECIALITY

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

Approved for public release

Magnesium Elektron Powders

- Three Manufacturing Plants

  Reade Manufacturing Co. (NJ)

  Hart Metals Inc. (PA)

  Niagara Metallurgical Products (ON)

- World's Leading Supplier of Ground and Atomised Magnesium Powders
- Critical supplier to the U.S. Department of Defense

Markets & Applications

POWDER METALLURGY

FLAMELESS RATION HEATERS

PHARMACEUTICAL

CHEMICAL SYNTHESIS

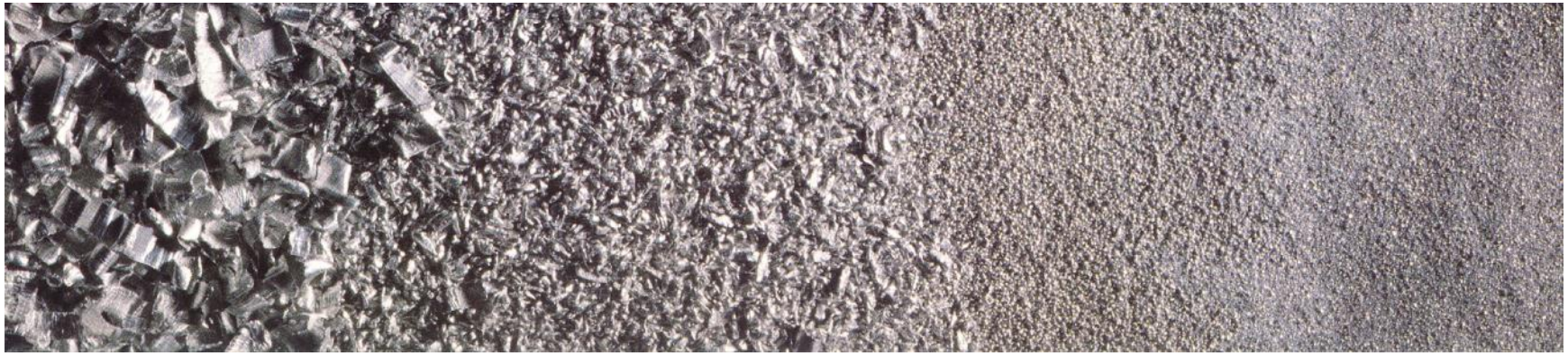
MELTING APPLICATIONS

WELDING

SPECIALTY PYROTECHNICS

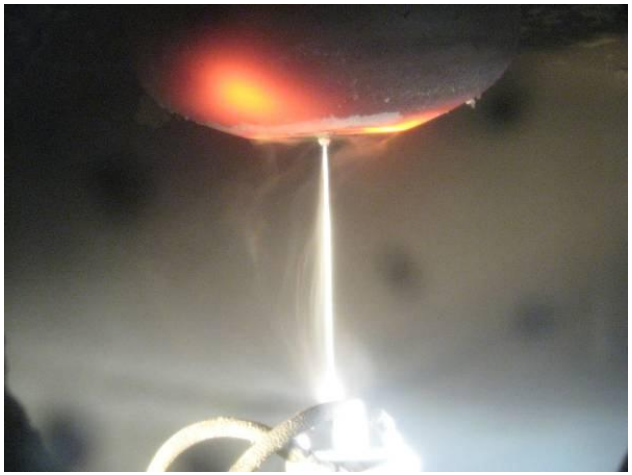
Ground Magnesium Metal & Alloy Powders

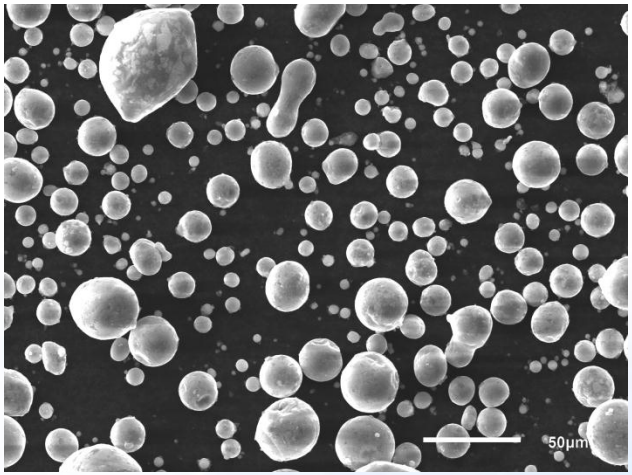
INGOTS → CHIP → GRIND → SCREEN → GROUND POWDER



- Wide Range of Ground Powder Sizes
  - Chips, Granules, Coarse Powders, Fine Powders
- Particle Shape Control
  - Turnings, Flake, Irregular, Ellipsoidal Shapes
- Variety of Powder Grades Available
  - Pure Magnesium Powders: Standard & Ultra-High Purity
  - Magnesium Alloys: Mg-Al, AZ91, AZ31, Elektron 43, and Elektron 21

Atomized Pure Magnesium Powders





PURE Mg INGOTS

↓

MELT

↓

ATOMIZE

↓

SCREEN

↓

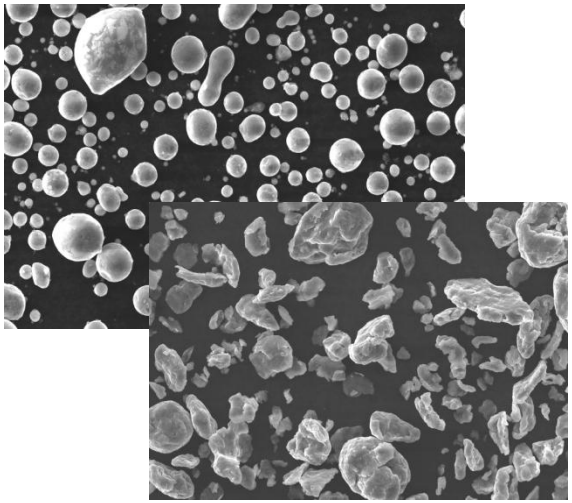
ATOMIZED POWDER

- Proprietary Technology
- Recent Capital Expansion
  - State-of-the-Art Instrumentation
  - Advanced Automation
  - More Environmentally Friendly
- Range of Sizes
- Spherical Powder Shape

Pilot Atomizer for Magnesium Alloys

- New pilot atomizer
  - For alloy powder development
  - Scalable system
  - 50 to 125 lbs. Batch
- Funded by U.S. Army and Magnesium Elektron
- Examples of alloy powders being developed
  - AZ91, AZ31, ZE41 & ZE43
  - Elektron 21
  - Elektron 43 & WE43
  - Other High Performance & Custom Alloys

Potential Applications



Cold Spray & Additive Manufacturing Applications

Lightweight P/M Components

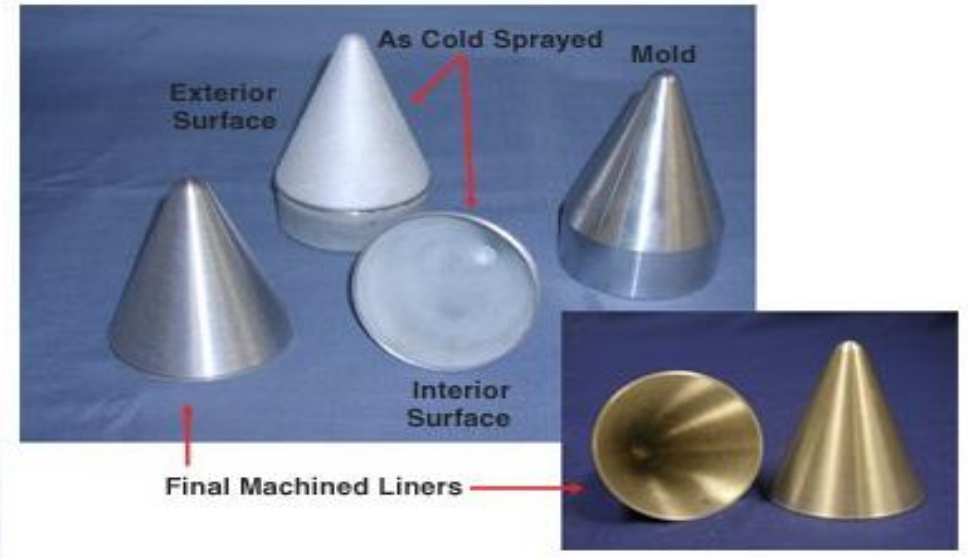
Energetics

AGENDA

- Introduction To Magnesium Elektron Powders
- Objectives for Cold Spraying Mg Alloy Powders
- Preliminary Results of Spray Trials
- Summary and Conclusions

Summary

- *Repairing* Mg-based Structures
- *Fabricating* Near-Net Shape Structures

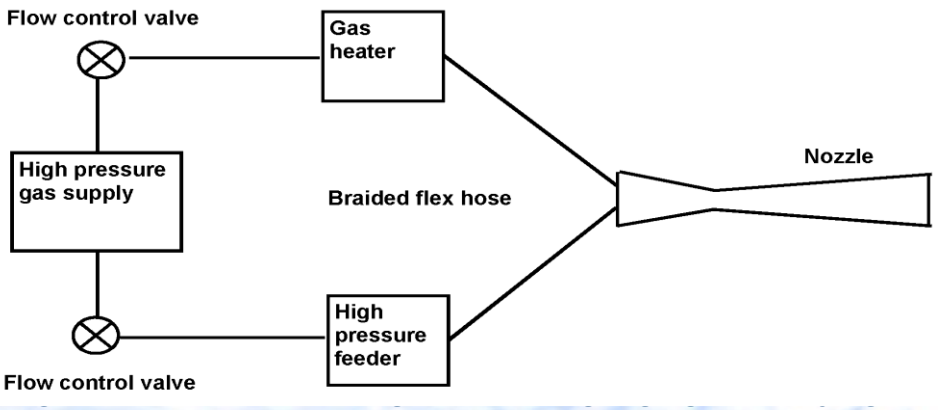


Objectives

- Investigate Ground Mg-Alloy and Atomized Mg-Alloy Powders for Cold Spray
- Process Modeling
- Powder Characterization
- Preliminary Spray Trials
- Results in terms of porosity, deposition efficiency (DE) & hardness
- Process optimization results
  - AZ31B ground and WE43 atomized at different temperatures/pressures

CGT Kinetics 4000 High Pressure Cold Spray System

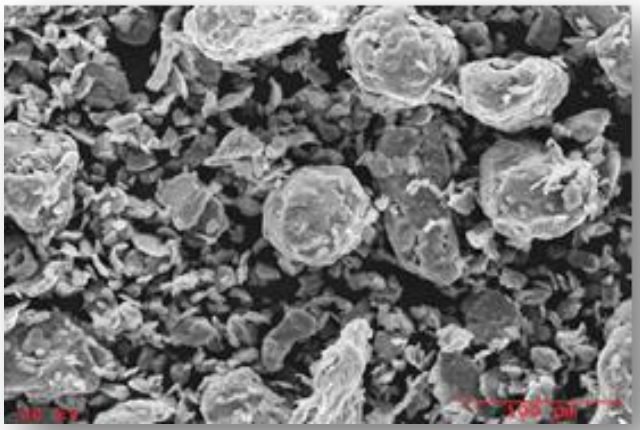
Operating Parameter	Value
Gas Pressure	250 – 580 psi
Gas Temperature	30 - 800 °C
Gas Flow	50 - 200 SCFM
Powder Flow	10 – 50 gram/minute
Particle Exit Velocity	500 - 2000 meter/second



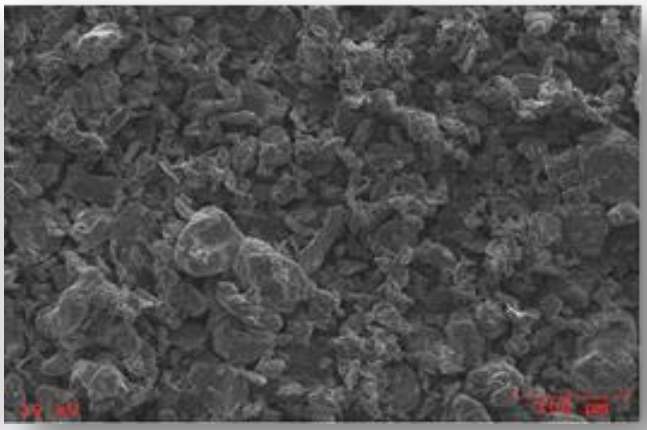
Polymer De Laval Cold Spray Nozzle

Approved for public release

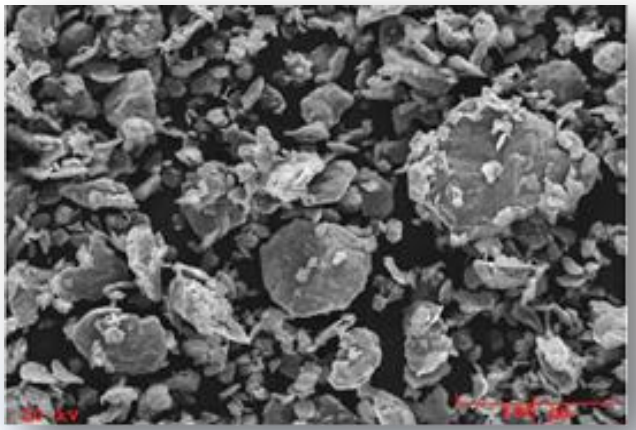
Morphology of Ground Magnesium Alloy Powders



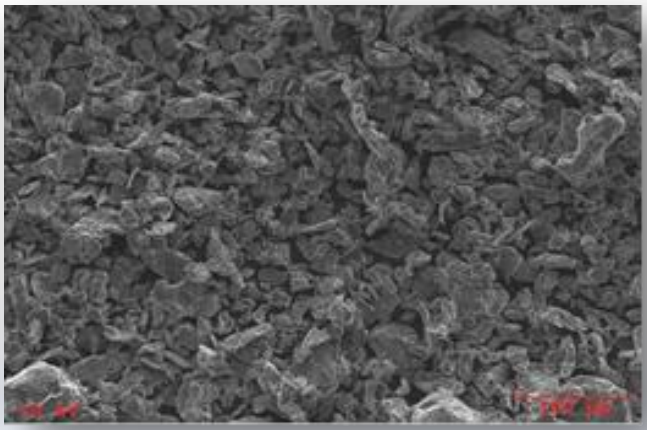
Ground AZ31B -200 mesh



Ground WE43 -230 mesh

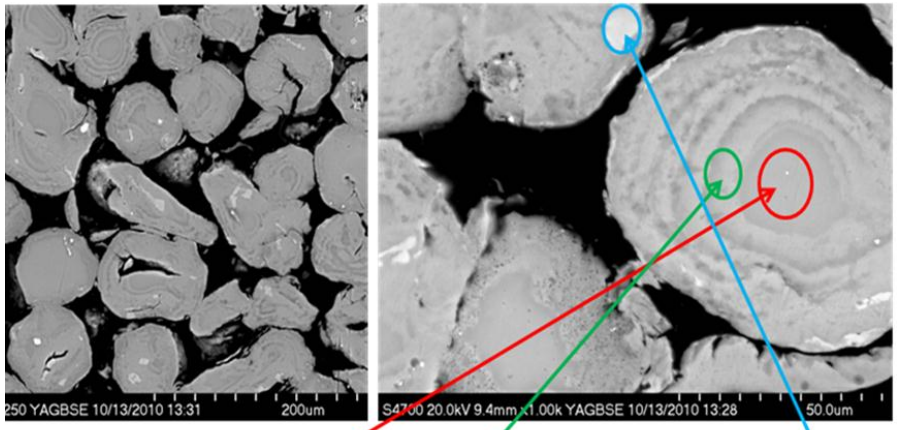


Ground AZ91E -200 mesh



Ground E21 -230 mesh

Cross Section of Ground Magnesium Alloy Powders

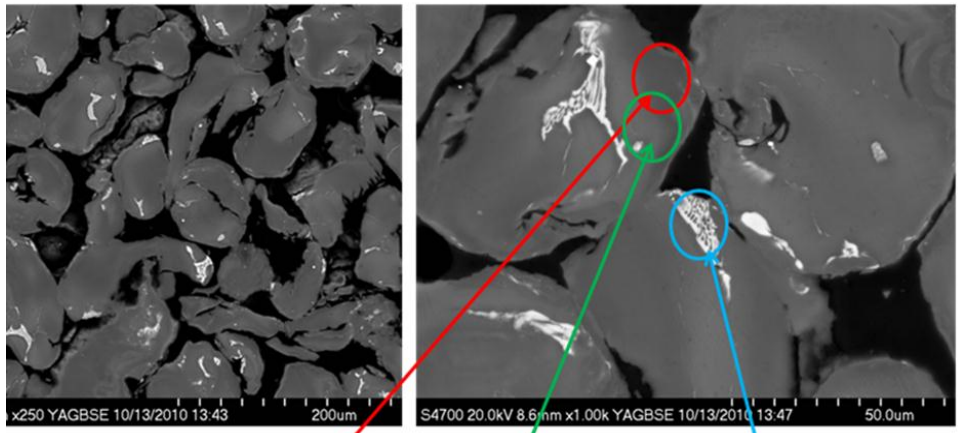


Elem	Wt %	At %
Mg	94.77	95.27
Al	5.23	4.73
Total	100.00	100.00

Elem	Wt %	At %
Mg	92.70	93.38
Al	7.30	6.62
Total	100.00	100.00

Elem	Wt %	At %
Mg	59.45	63.91
Al	34.96	33.86
Zn	5.59	2.24
Total	100.00	100.00

Ground AZ31B



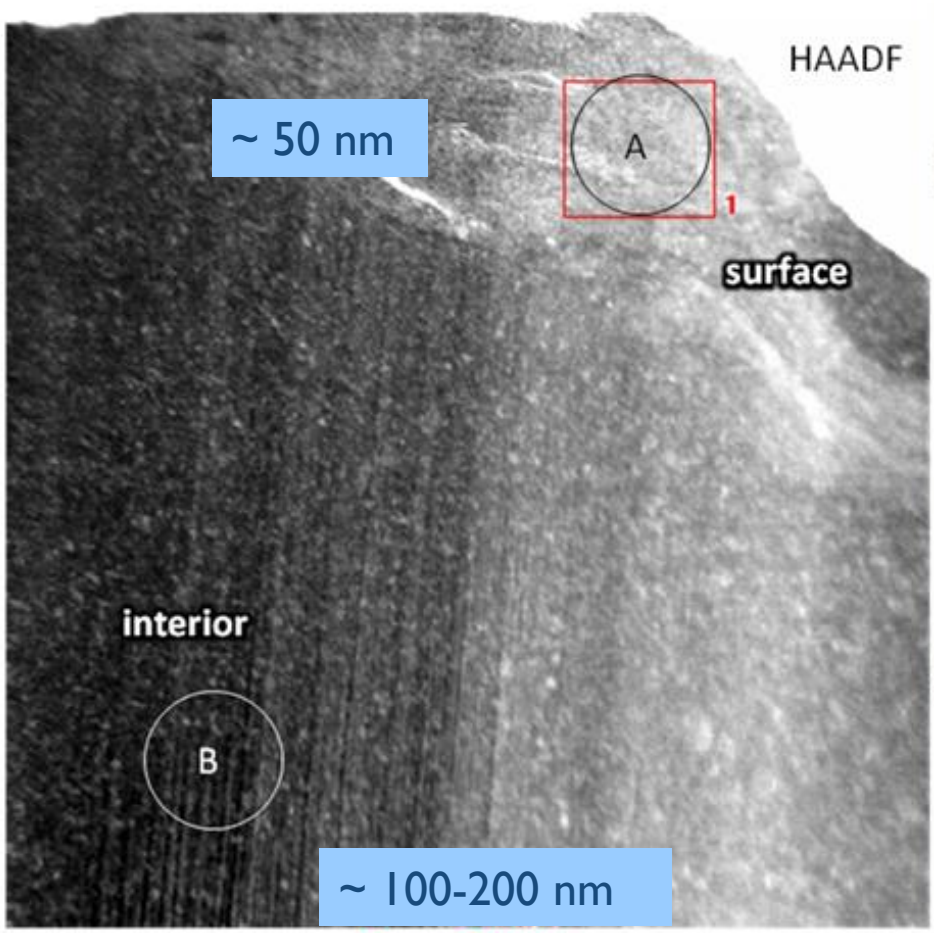
Elem	Wt %	At %
Mg	100.00	100.00

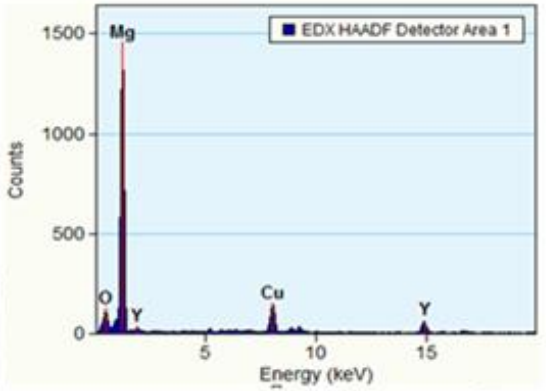
Elem	Wt %	At %
Mg	87.71	96.86
Y	7.32	2.21
Nd	4.98	0.93
Total	100.00	100.00

Elem	Wt %	At %
Mg	55.72	86.52
Y	11.60	4.93
Nd	32.68	8.55
Total	100.00	100.00

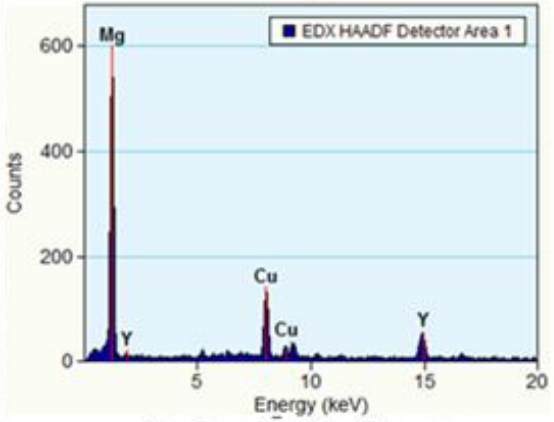
Ground WE43

HAADF TEM: Ground WE43 -100/+230



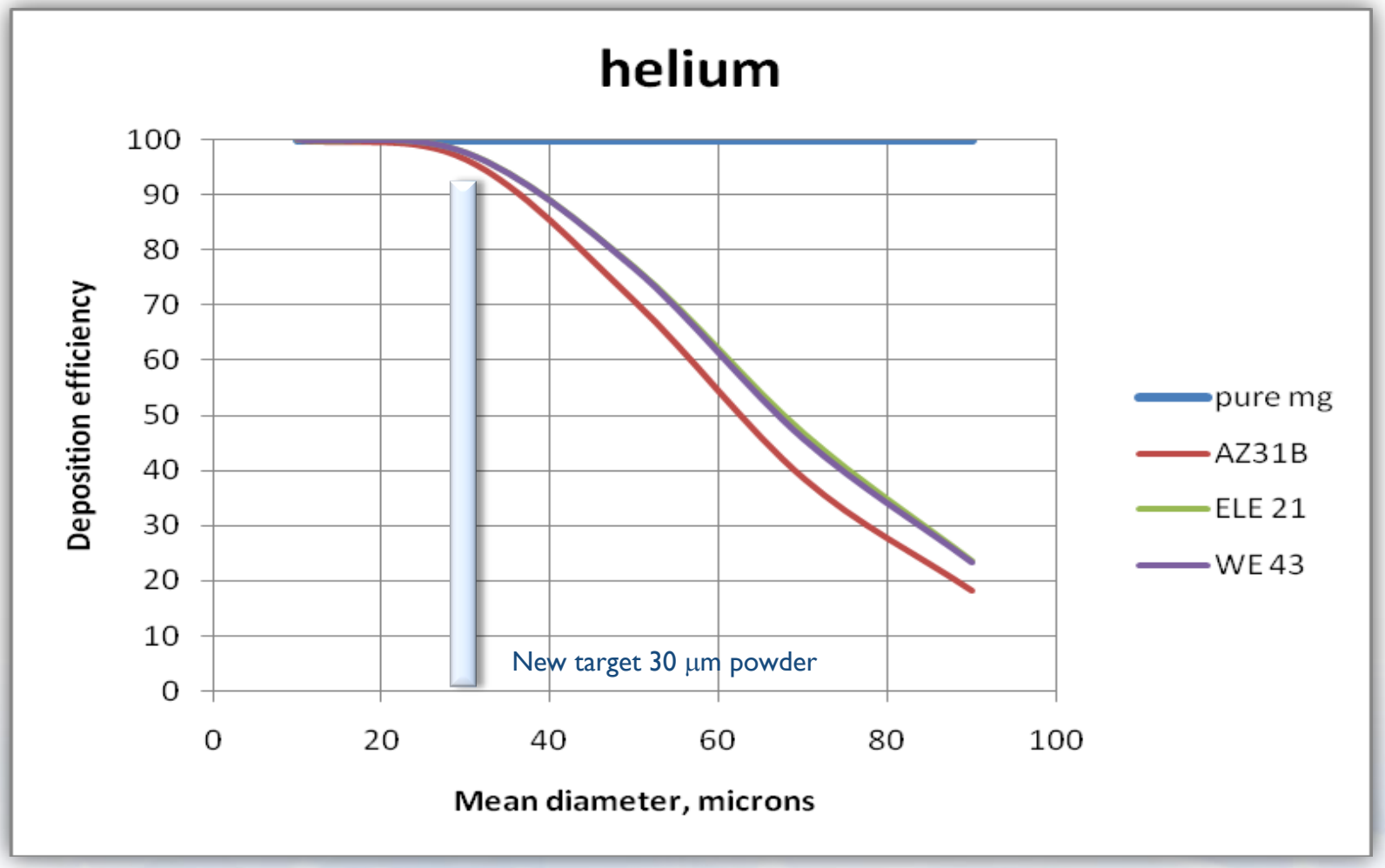


Region A: Presence of Oxygen



Region B: No Oxygen

Process Model for Magnesium Powders



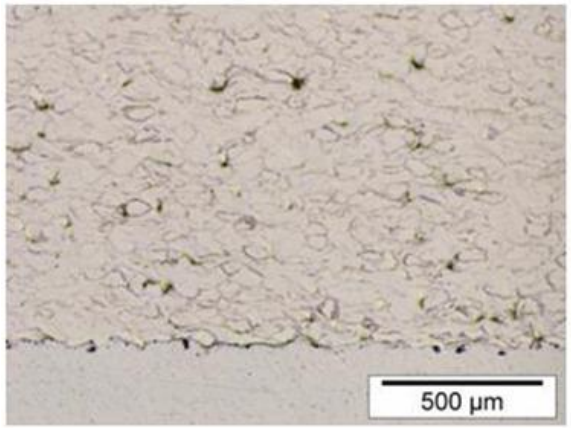
AGENDA

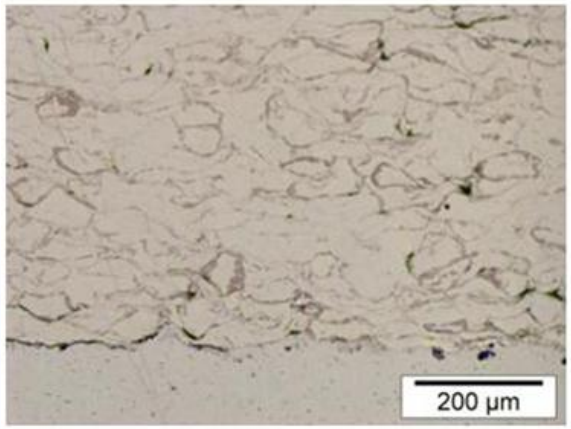
- Introduction To Magnesium Elektron Powders
- Objectives for Cold Spraying Mg Alloy Powders
- Preliminary Results of Spray Trials
- Summary and Conclusions

Summary

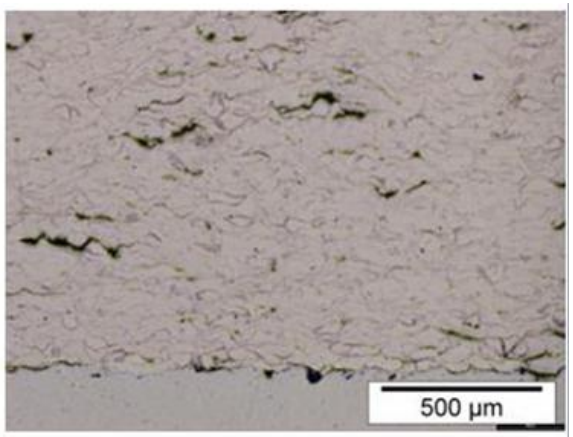
Early Results Using Coarse Ground Mg Alloy Powders

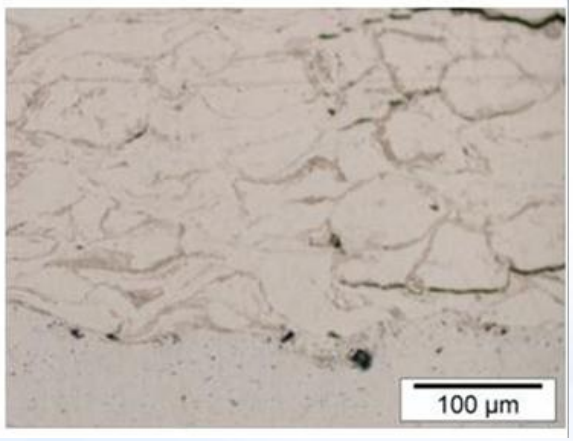
Elektron 21





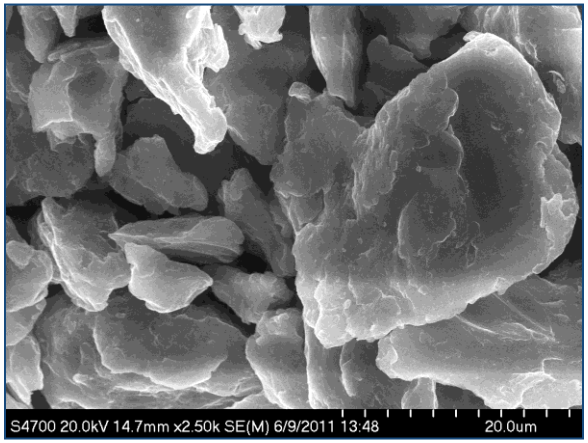
WE43

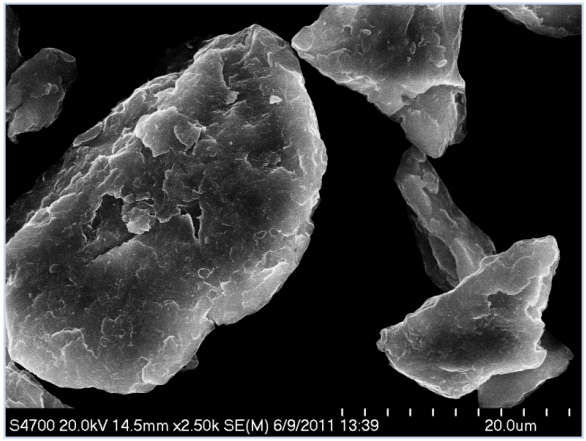


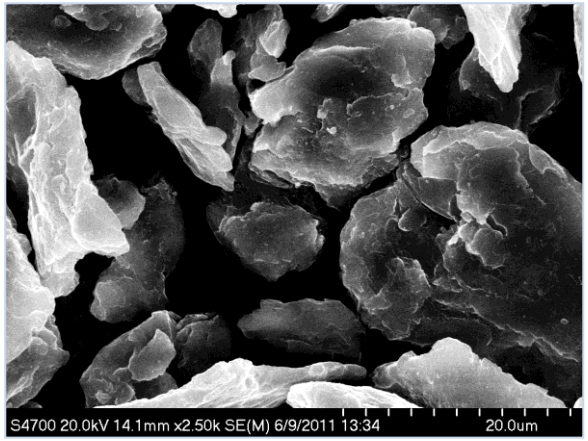


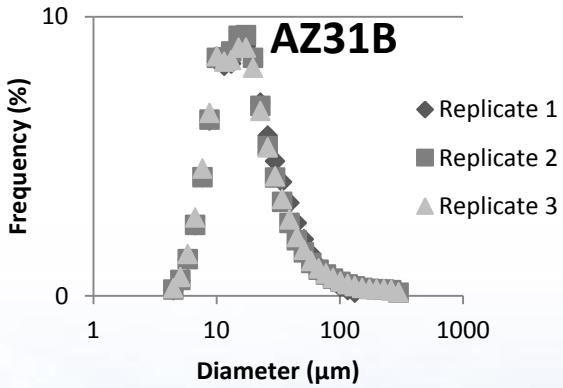
- Porosity
- Undeformed Large Particles
- Low DE

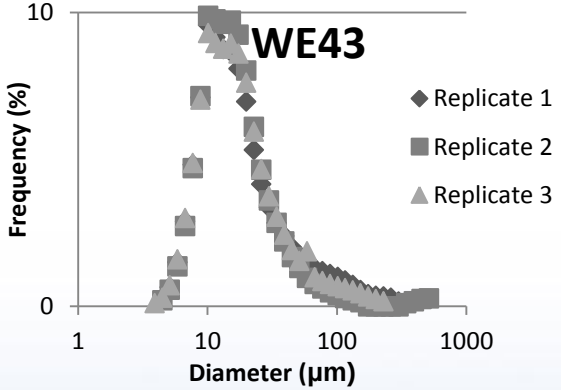
Results Using -400 mesh Ground Mg Alloy Powders

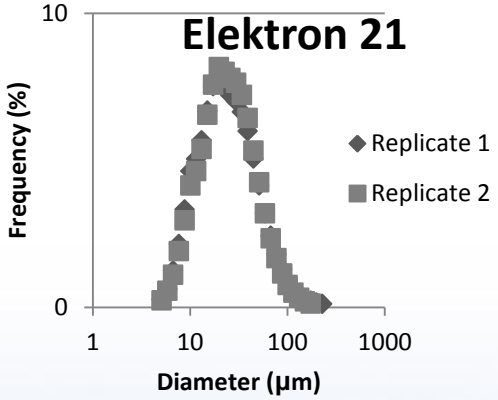








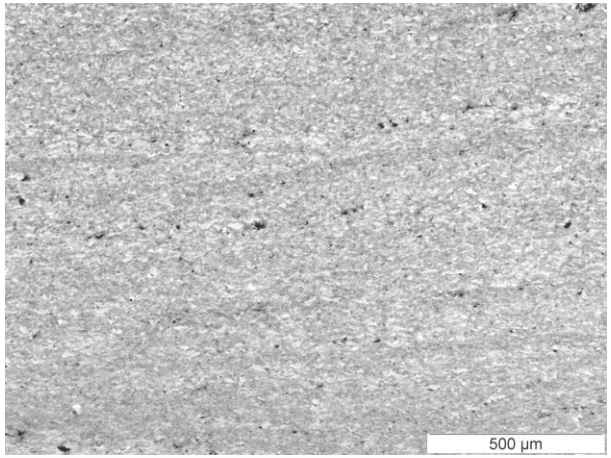




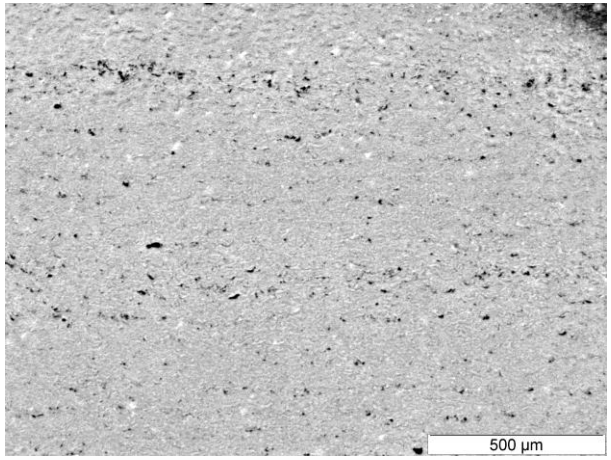
Horiba LA-910	AZ31B	WE43	E21
Mean (µm)	21.3	22.7	28.3

Results Using -400 mesh Ground Mg Alloy Powders

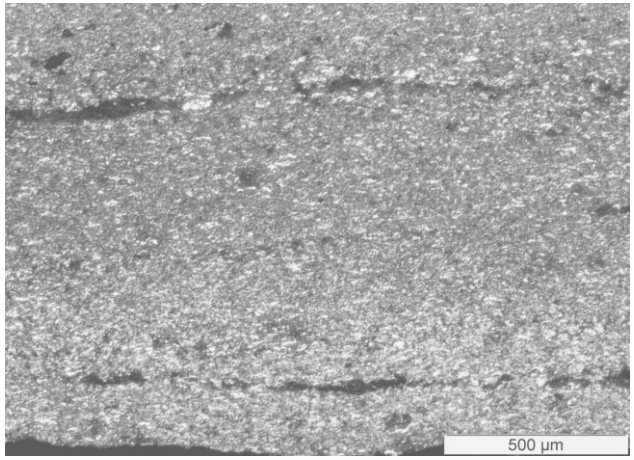
AZ31B : **135** VH (83 VH*)
2.52% porosity



WE43 : **74** VH (96 VH*)
5.63 %porosity

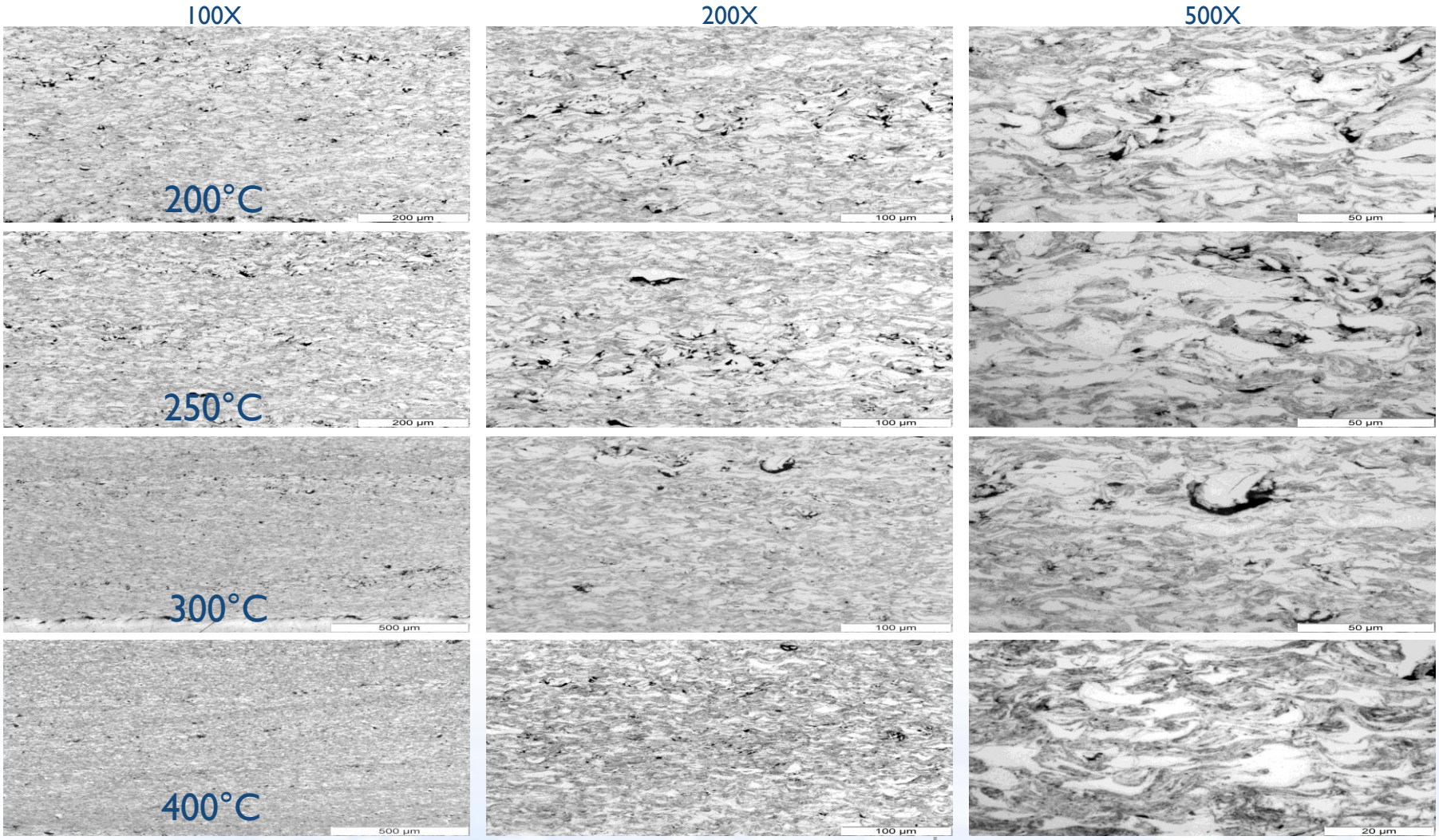


E21 : **105** VH (92 VH*)
11.32 % porosity



Porosity was determined using image analysis

Effect of Gas Temperature : Ground AZ31B -400 mesh



Approved for public release

Results Using Ground AZ31B -325 mesh Powder

Temperature °C	Porosity %	Deposition Efficiency %	Average Hardness VH
200	5.4 (±3.3)	33.7	146 (±13.9)
250	3.7 (±1.4)	37.2	159 (±9.3)
300	2.7 (±1.5)	41.1	161 (±13.5)
400	2.5 (±2.2)	30	135 (±11.2)

Melting range: 566-632°C*
Annealing Temperature: 345°C¤

*Magnesium Elektron AZ31B wrought alloy data sheet
¤ Annealing Temperature from http://www.matweb.com/

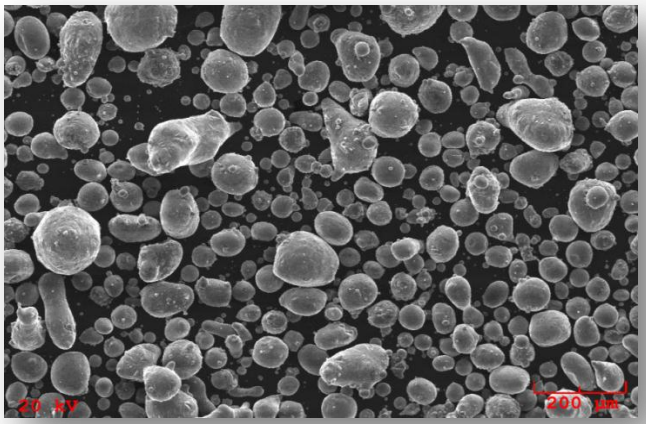
Observations Using Ground Mg Alloy Powder

- Finer particles decreased porosity and increased deposition efficiency (<10% to ~40%)

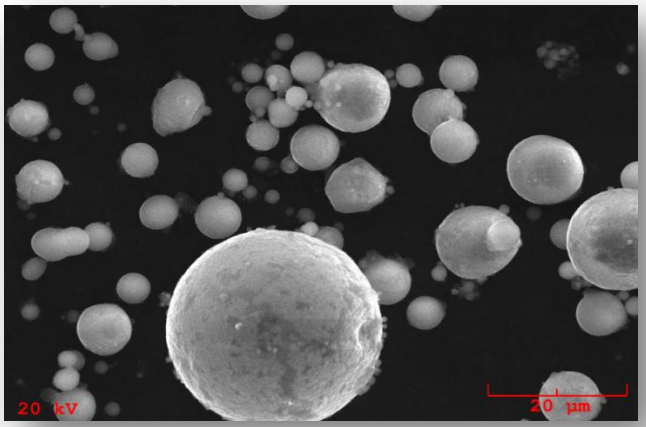
- Hardness measurements indicate high strength over traditional powder products using the same powder

- Atomized powder should yield results more in line with model predictions which will allow for bulk material production and full scale tensile testing

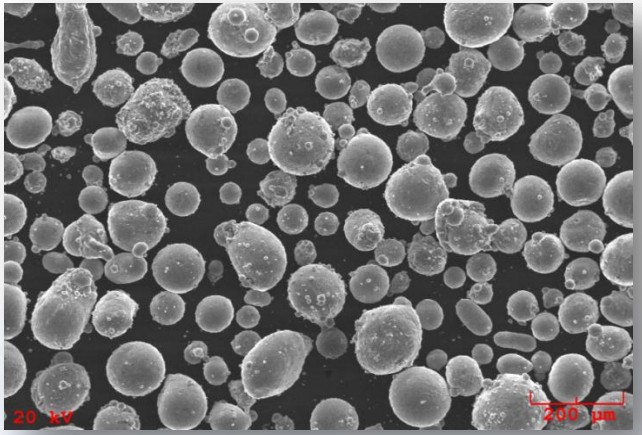
Morphology of Atomized Magnesium Alloy Powders



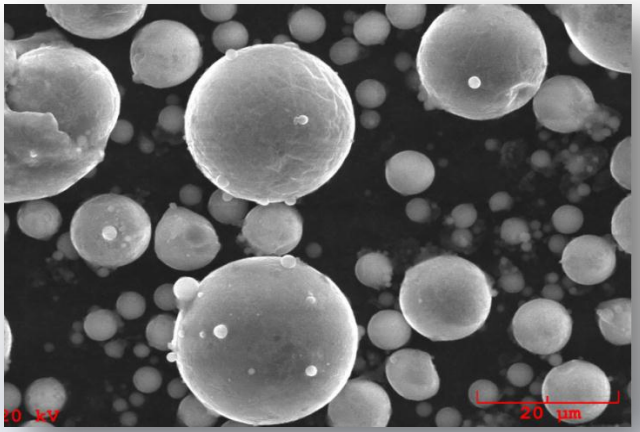
Atomized AZ91E 100/325



Atomized AZ91E -325

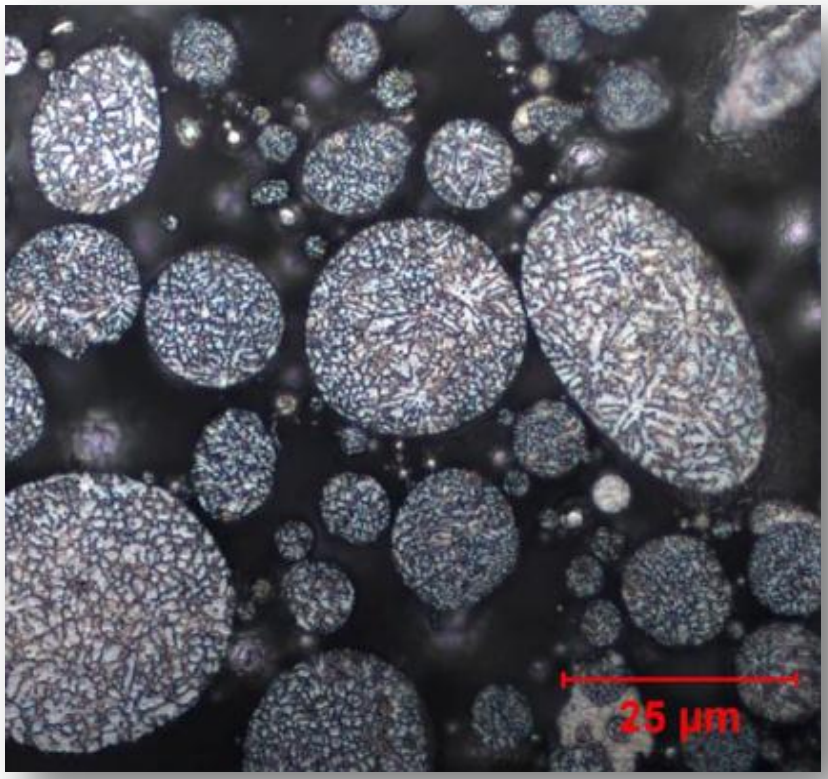


Atomized WE43 100/325



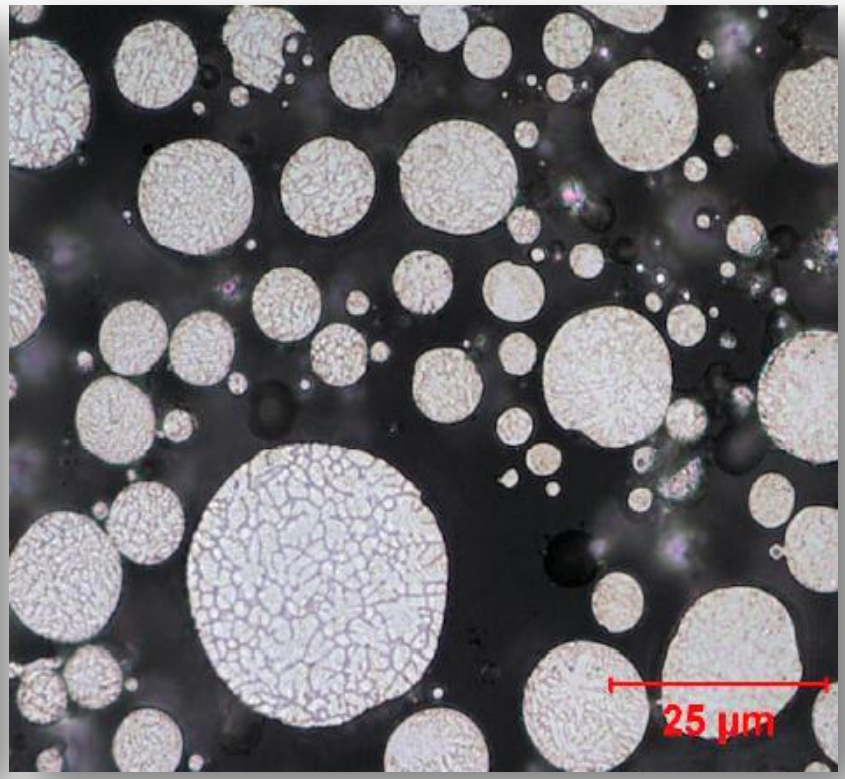
Atomized WE43 -325

Cross-Section of Gas Atomized Powders (<325 mesh)



AZ91E

Dendrite Arm Spacing (n=30) : 0.88µm
Powder Hardness (n=10) : 100 HV_{10}



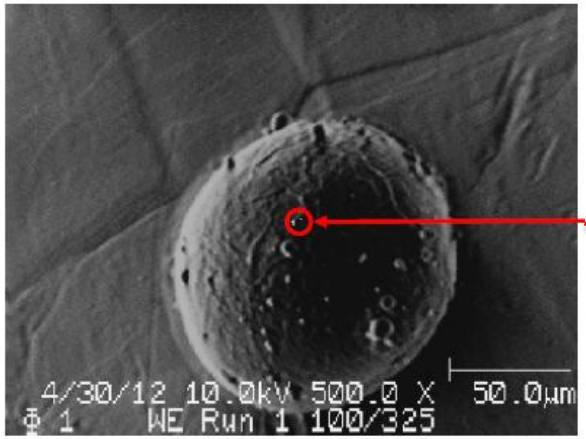
WE43

Dendrite Arm Spacing (n=30) : 0.80µm
Powder Hardness (n=10) : 95 HV_{10}

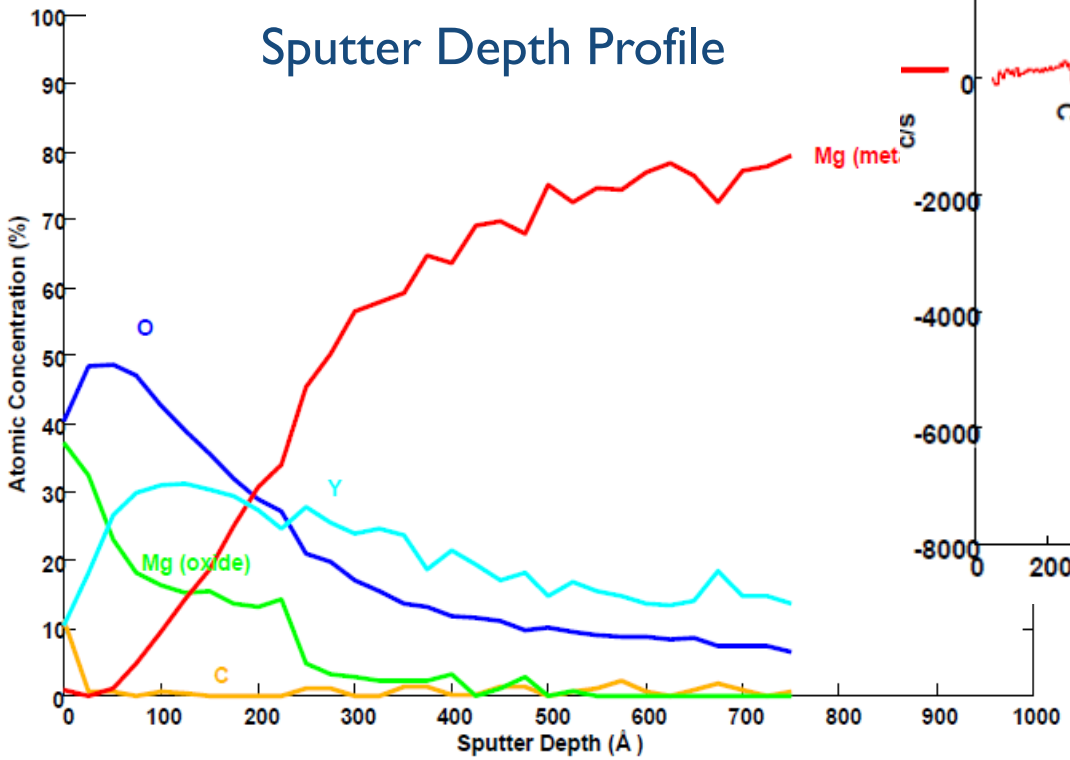
Gas Atomized Powder Characteristics

POWDER DESIGNATION	Density, g/cm³		MICROTRAC SIZE, mm		
	Apparent	Tap	D_{10}	D_{50}	D_{90}
AZ91E Atomized -325	0.75	0.93	6.6	21.1	41.0
WE43 Atomized -325	0.78	0.94	7.1	20.8	40.1

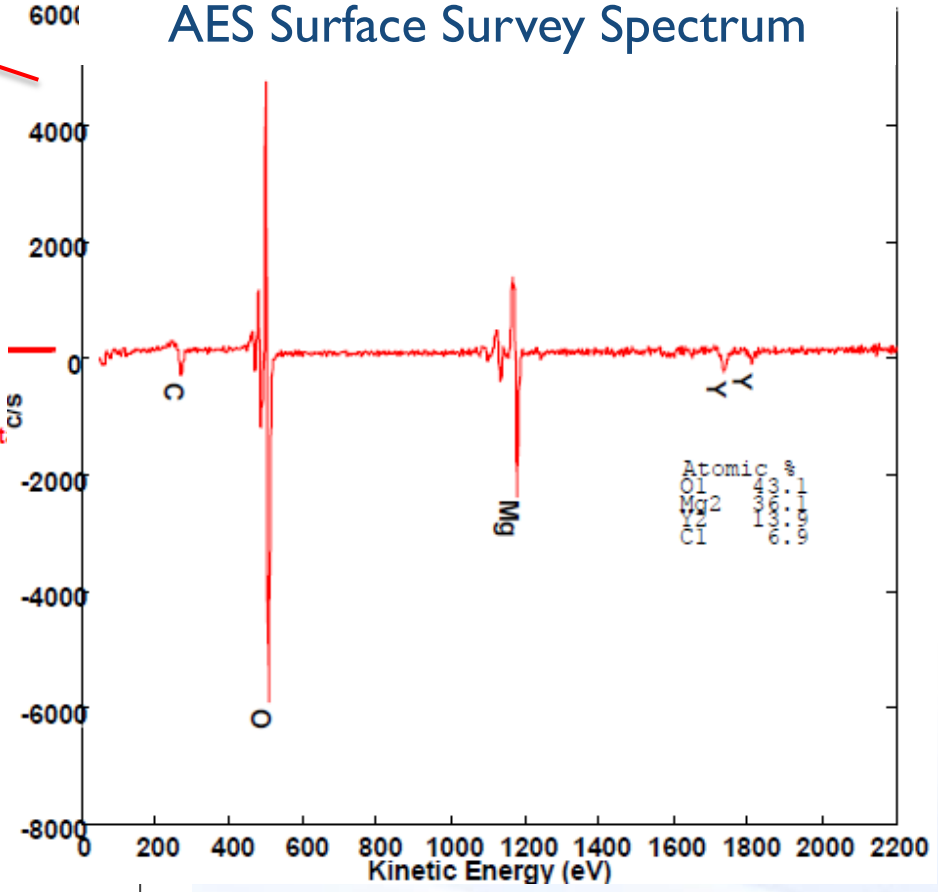
WE43 Auger/XPS Analyses



Sputter Depth Profile



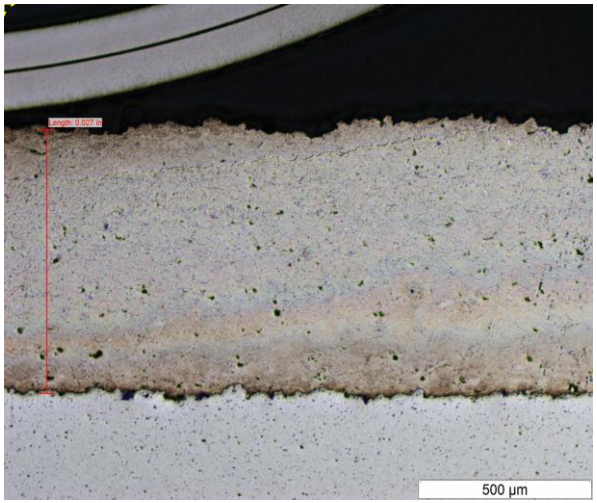
AES Surface Survey Spectrum



Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

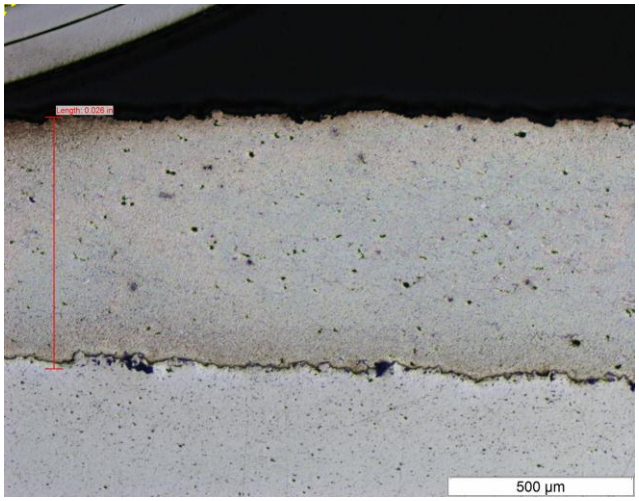
Results Using -325 mesh Atomized WE43

WE43 : **122** VH (96 VH*)
1 % porosity



25 bar, 300°C

WE43 : **148** VH (96 VH*)
1.2% porosity



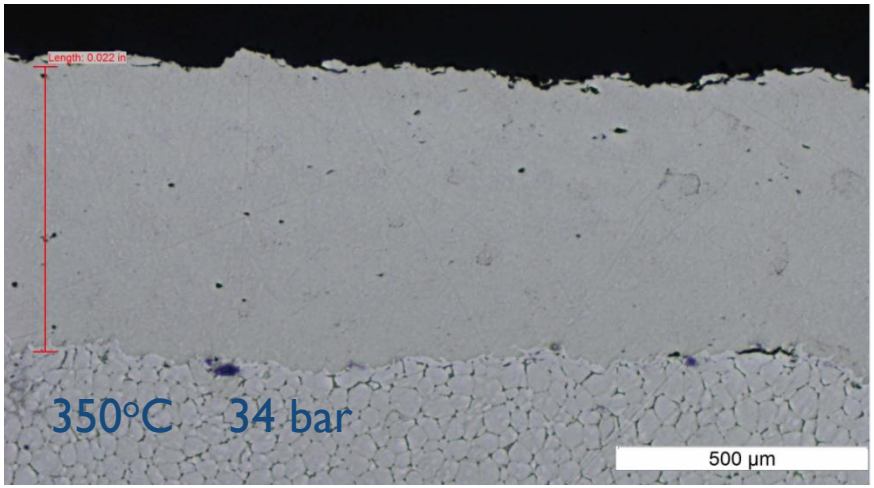
30 bar, 300°C

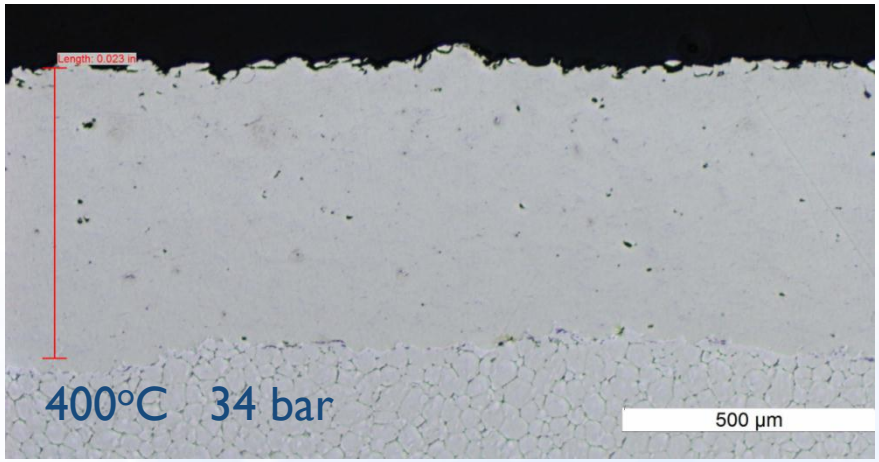
WE43 : **157** VH (96 VH*)
0.6% porosity

34 bar, 300°C

Increasing pressure

Effect of Gas Temperature : Atomized WE43-325 mesh





Results Using Atomized W43-325 mesh Powder

Temperature °C	Porosity %	Deposition Efficiency %	Average Hardness VH
300	0.6	37	157
350	0.23	-	157
400	0.18	-	146

Melting range: 540-640°C*

*Magnesium Elektron WE43 wrought alloy data sheet

AGENDA

- Introduction To Magnesium Elektron Powders
- Objectives for Cold Spraying Mg Alloy Powders
- Preliminary Results of Spray Trials
- Summary and Conclusions

Summary

Summary and Conclusions

- Differences between Ground and Atomized Mg Alloy Powder in Cold Spray Trials

- Improved Density of as-sprayed Atomized WE43 powder coating

- Optimize Deposition Efficiency of Atomized WE43 powder

- Demonstrate Fabrication of WE43 Block for further mechanical performance testing

- Evaluate AZ91E, Elektron21 atomized powders

Magnesium Elektron

SERVICE & INNOVATION IN MAGNESIUM

LUXFER GROUP

ENVIRONMENTAL • HEALTHCARE • PROTECTION • SPECIALITY