



Magnesium Elektron

SERVICE & INNOVATION IN MAGNESIUM

Development & Cold Spray of High Strength Magnesium Alloy Powders

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*CSAT Meeting
Oct 30-31, 2012*



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

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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



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AGENDA

Introduction To Magnesium Elektron Powders

Objectives for Cold Spraying Mg Alloy Powders

Preliminary Results of Cold Spray Trials

Summary and Conclusions

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Magnesium Elektron Operations

MAGNESIUM ELEKTRON

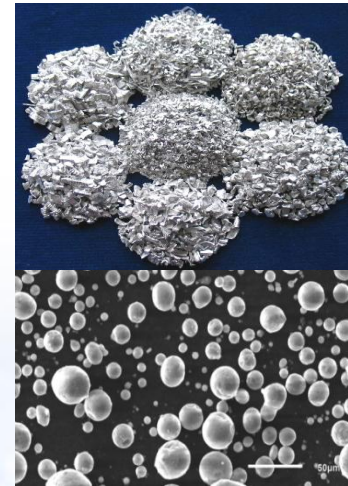
**Magnesium
Casting
Alloys**



**Magnesium
Wrought
Products**



**Magnesium
Powders**



**Magnesium
Recycling**



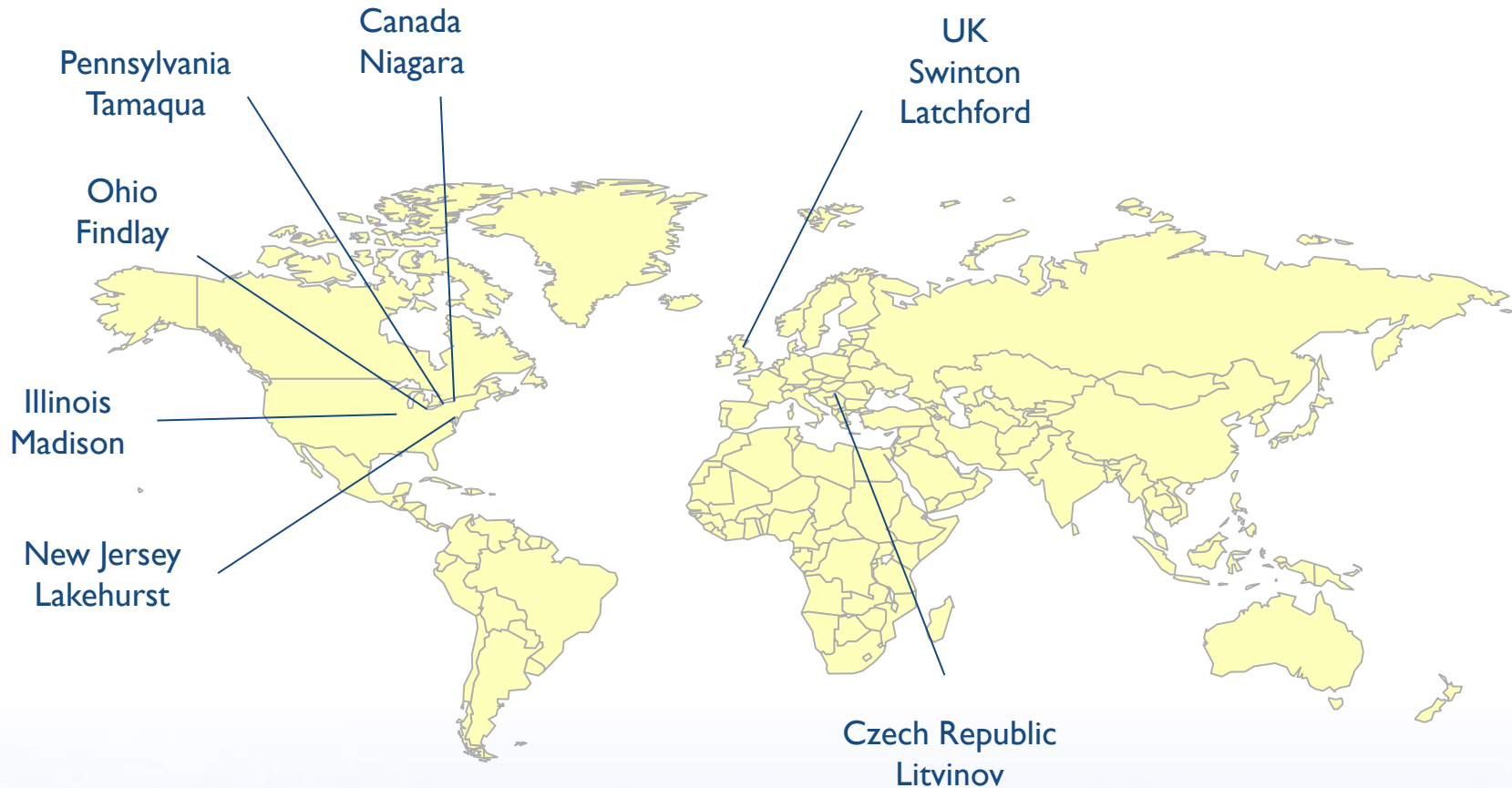
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Magnesium Elektron

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Magnesium Elektron Facilities

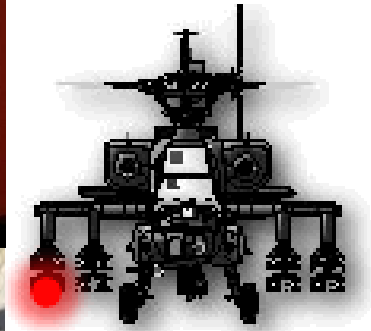


Magnesium Elektron High Performance Mg Casting Alloys

Boeing AH64 Apache



Elektron 21



Lockheed Martin F-22, F-35



Elektron
WE43



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Magnesium Elektron

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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



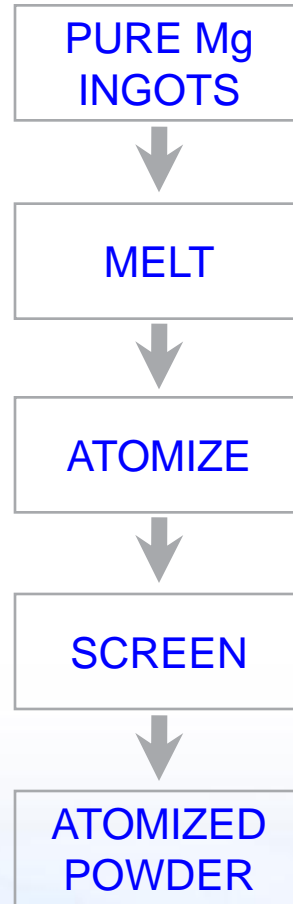
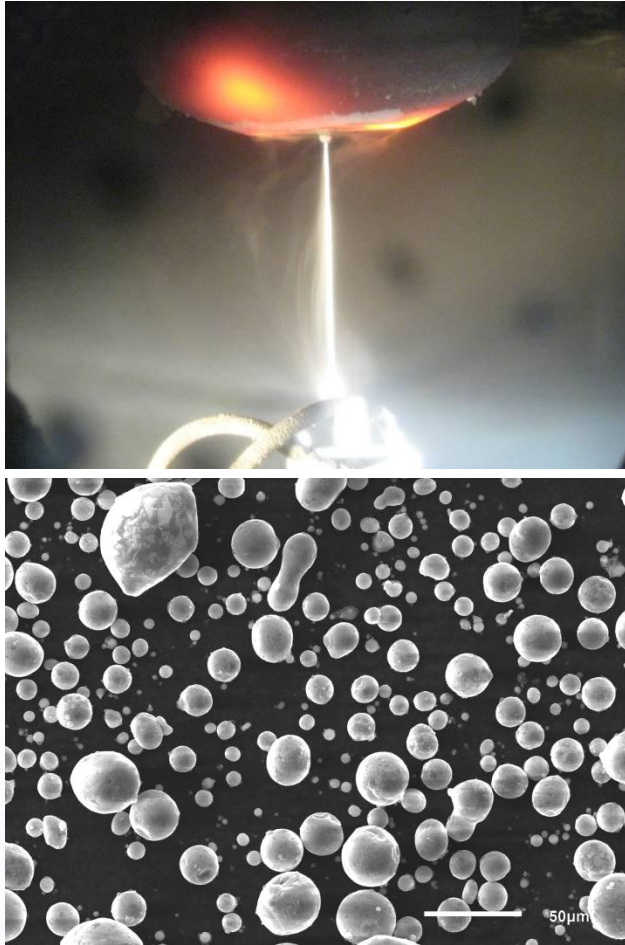
**SPECIALTY
PYROTECHNICS**

Ground Magnesium Metal & Alloy Powders



- 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



- 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

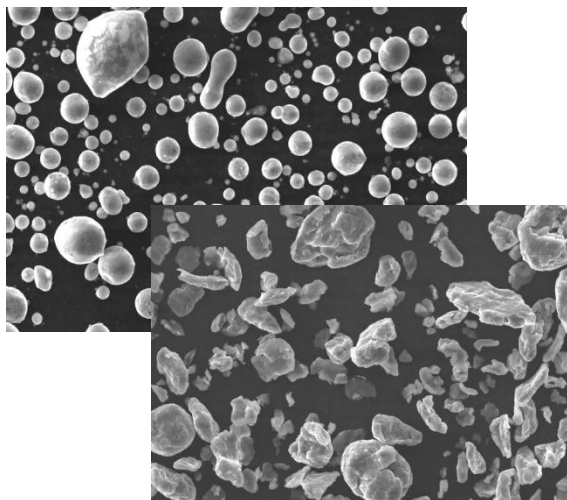


- New pilot atomizer
 - For alloy powder development
 - Scalable system
 - 50 to 125 lbs. Batch
- Funded by U.S. Army and Magnesium Elektron
- Examples of alloy powders being developed
 - AZ91, AZ31, ZE41 & ZE43
 - Elektron 21
 - Elektron 43 & WE43
 - Other High Performance & Custom Alloys

Jul 27, 2010



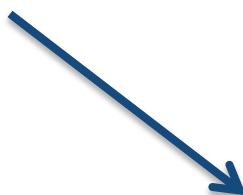
Potential Applications



Lightweight P/M
Components



Cold Spray & Additive
Manufacturing Applications



Energetics

AGENDA

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Summary

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Projectile Cases Produced
by Cold Spray



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



Objectives

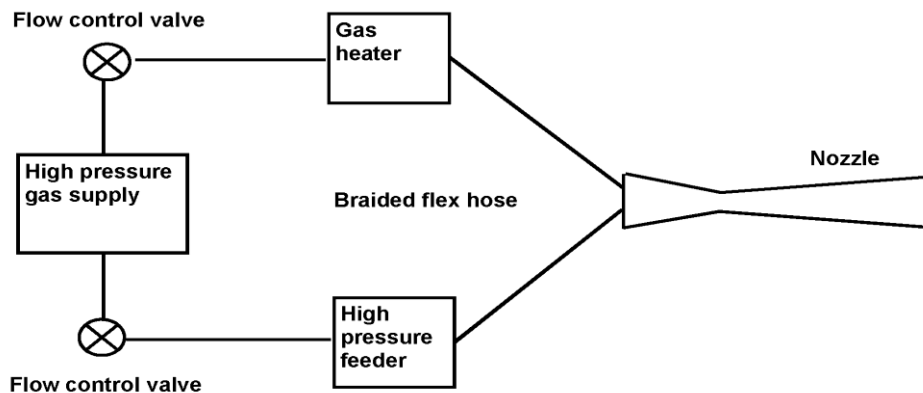
- Investigate Ground Mg-Alloy and Atomized Mg-Alloy Powders for Cold Spray
- Process Modeling
- Powder Characterization
- Preliminary Spray Trials
- Results in terms of porosity, deposition efficiency (DE) & hardness
- Process optimization results
 - AZ31B ground and WE43 atomized at different temperatures/pressures



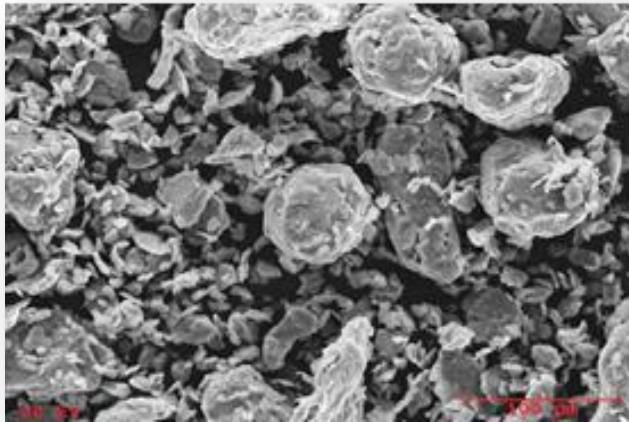
CGT Kinetics 4000 High Pressure Cold Spray System



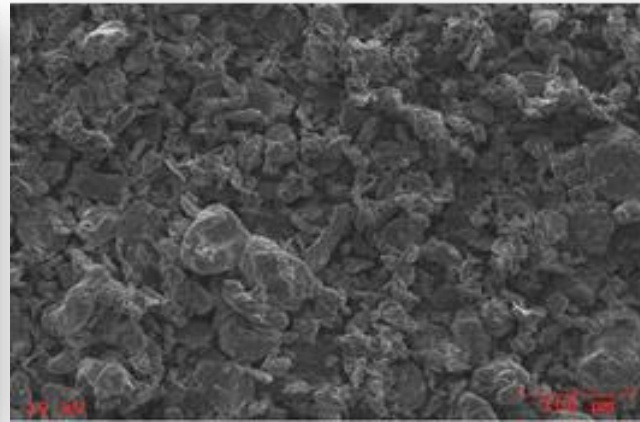
Operating Parameter	Value
Gas Pressure	250 – 580 psi
Gas Temperature	30 - 800 °C
Gas Flow	50 - 200 SCFM
Powder Flow	10 – 50 gram/minute
Particle Exit Velocity	500 - 2000 meter/second



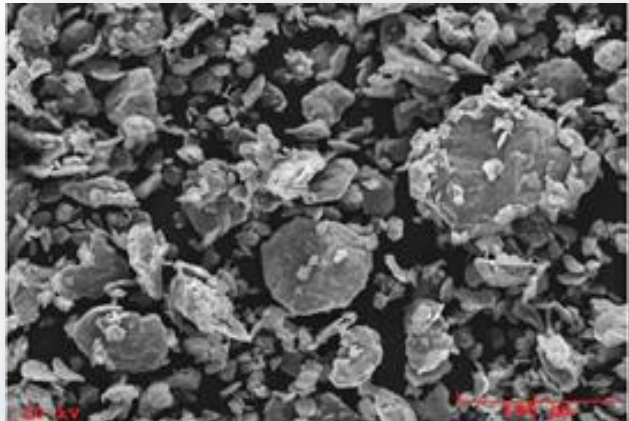
Morphology of Ground Magnesium Alloy Powders



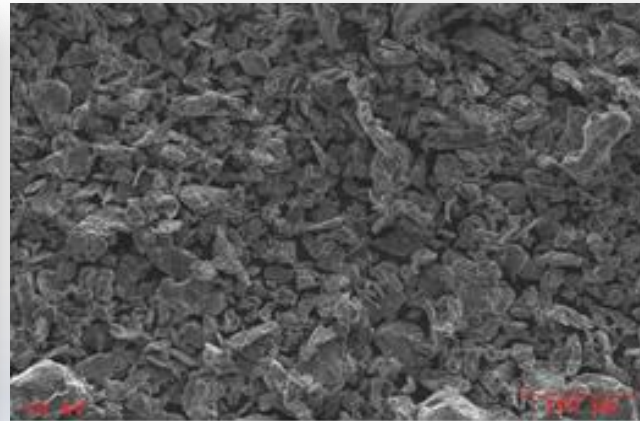
Ground AZ31B -200 mesh



Ground WE43 -230 mesh

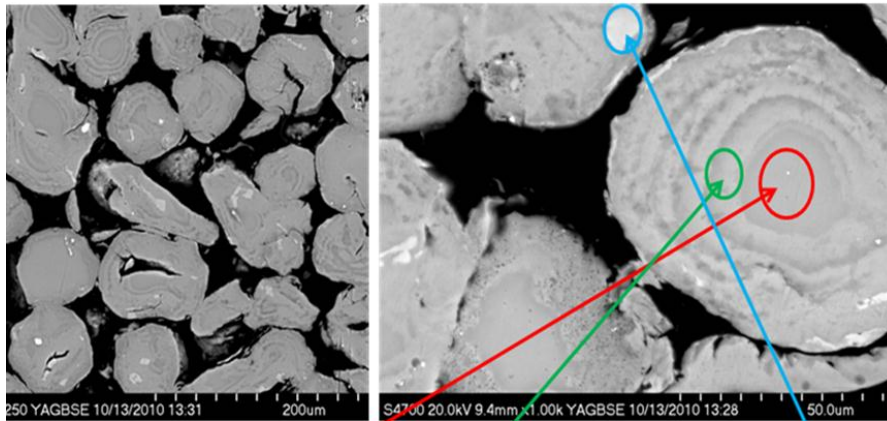


Ground AZ91E -200 mesh



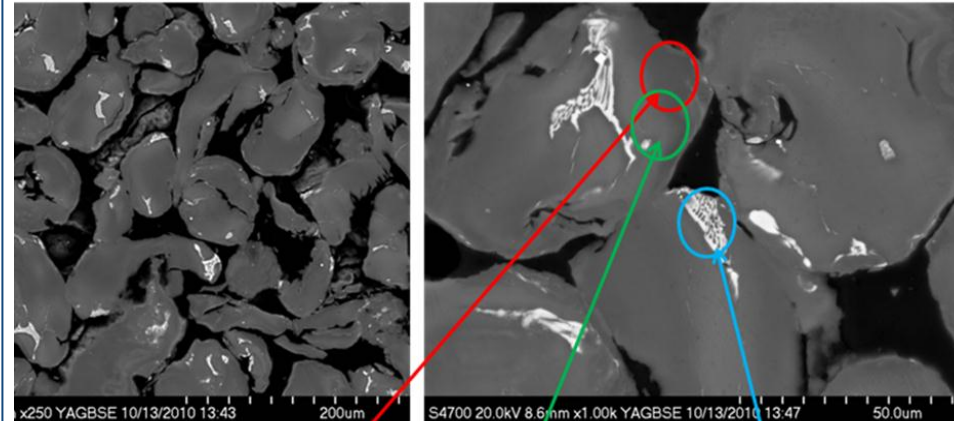
Ground E21 -230 mesh

Cross Section of Ground Magnesium Alloy Powders



Elem	Wt %	At %	Elem	Wt %	At %	Elem	Wt %	At %
Mg	94.77	95.27	Mg	92.70	93.38	Mg	59.45	63.91
Al	5.23	4.73	Al	7.30	6.62	Al	34.96	33.86
Total	100.00	100.00	Total	100.00	100.00	Zn	5.59	2.24
						Total	100.00	100.00

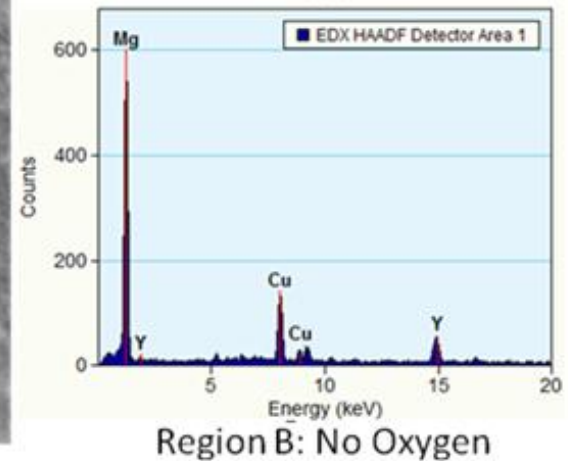
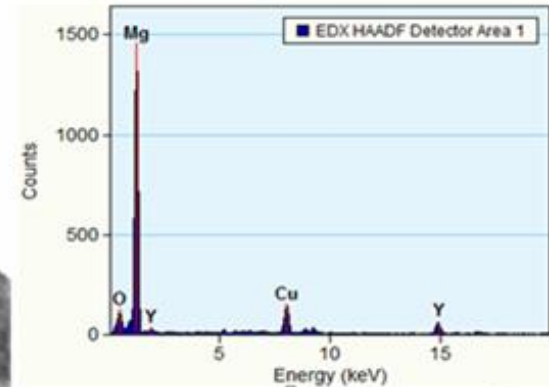
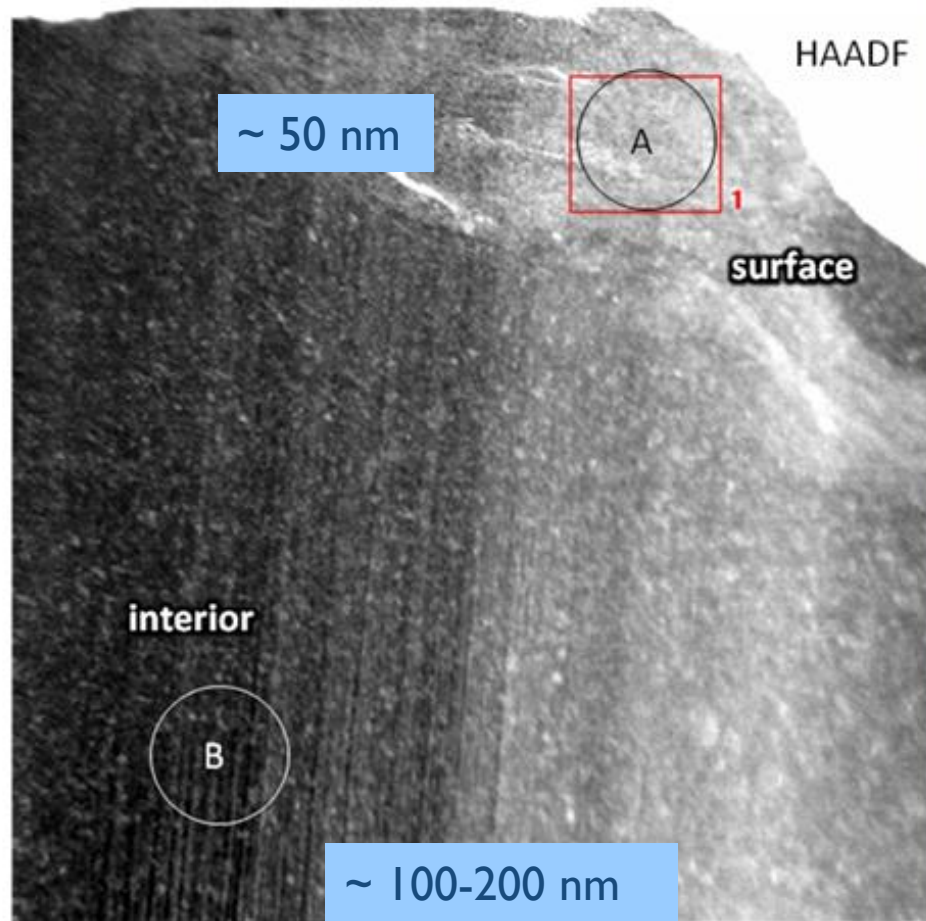
Ground AZ31B



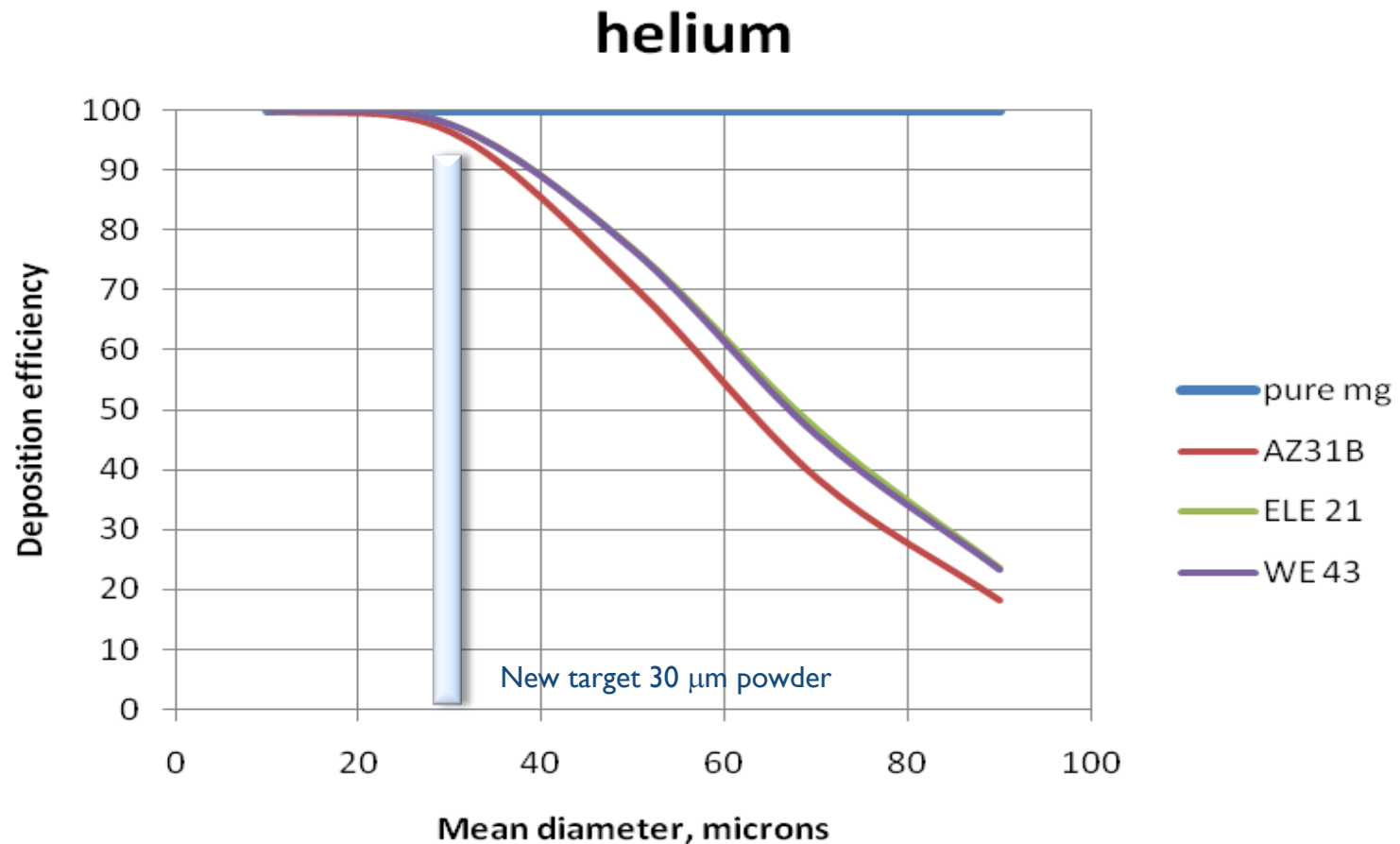
Elem	Wt %	At %	Elem	Wt %	At %	Elem	Wt %	At %
Mg	100.00	100.00	Mg	87.71	96.86	Mg	55.72	86.52
			Y	7.32	2.21	Y	11.60	4.93
			Nd	4.98	0.93	Nd	32.68	8.55
			Total	100.00	100.00	Total	100.00	100.00

Ground WE43

HAADF TEM: Ground WE43 - I00/+230



Process Model for Magnesium Powders



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Introduction To Magnesium Elektron Powders

Objectives for Cold Spraying Mg Alloy Powders

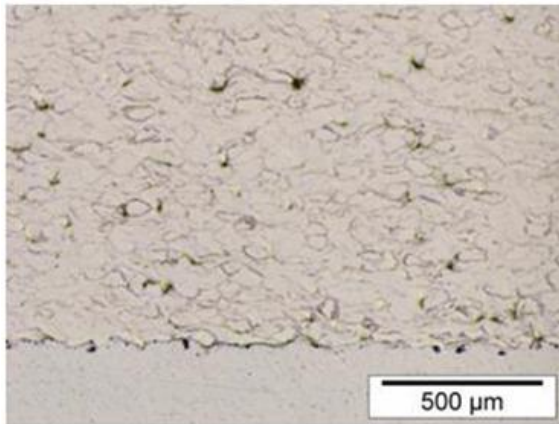
Preliminary Results of Spray Trials

Summary and Conclusions

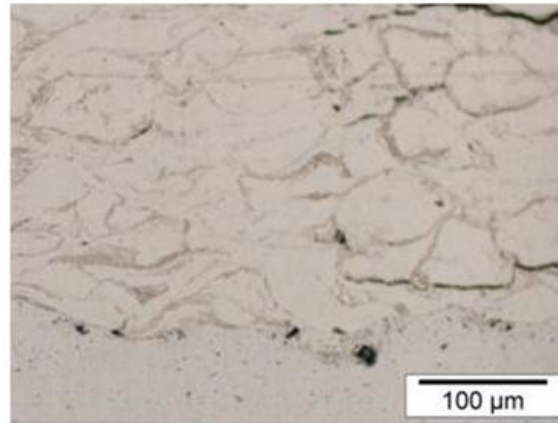
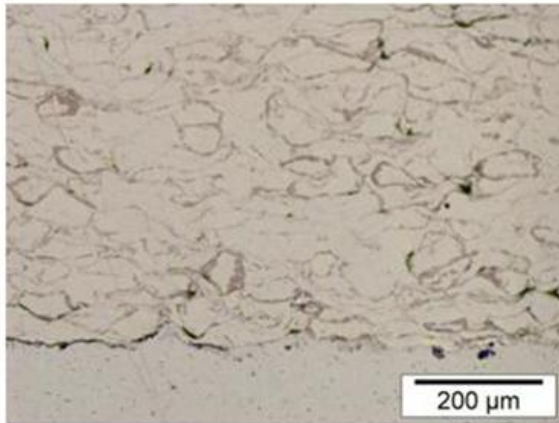
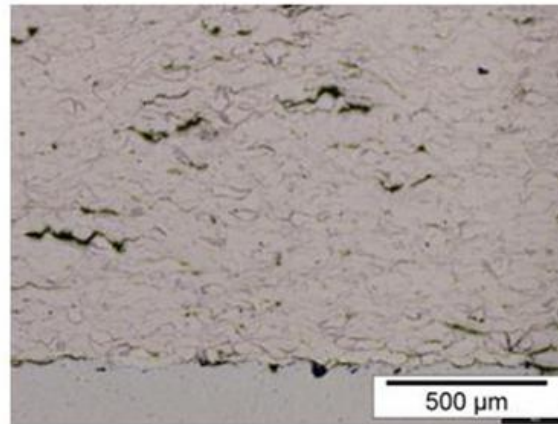
Summary

Early Results Using Coarse Ground Mg Alloy Powders

Elektron 21

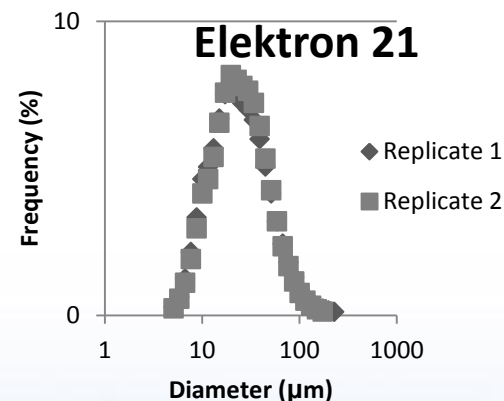
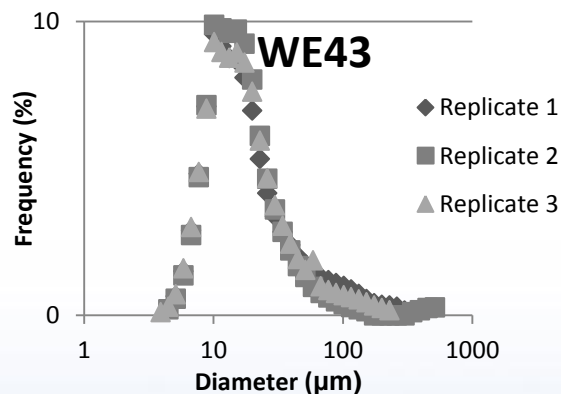
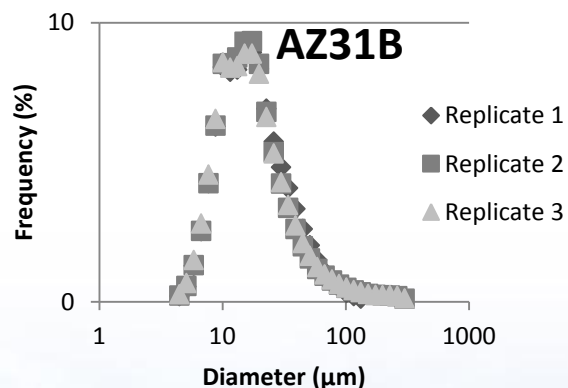
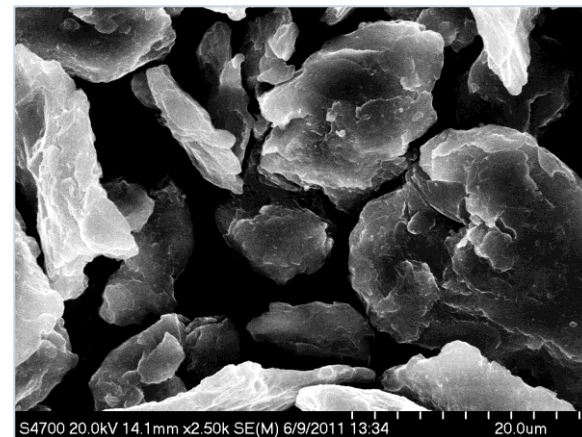
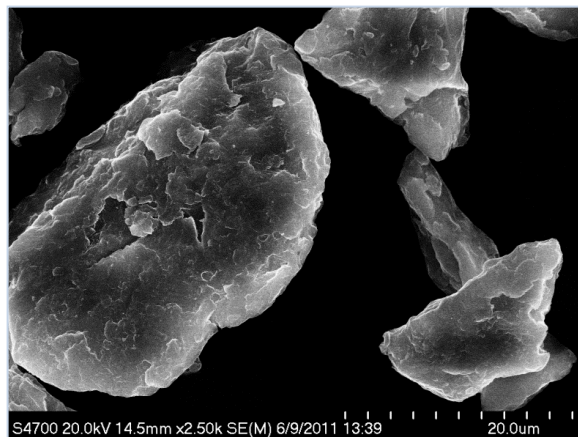
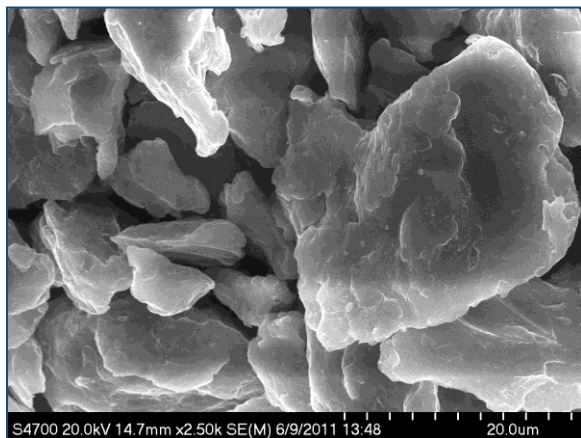


WE43



- Porosity
- Undeformed Large Particles
- Low DE

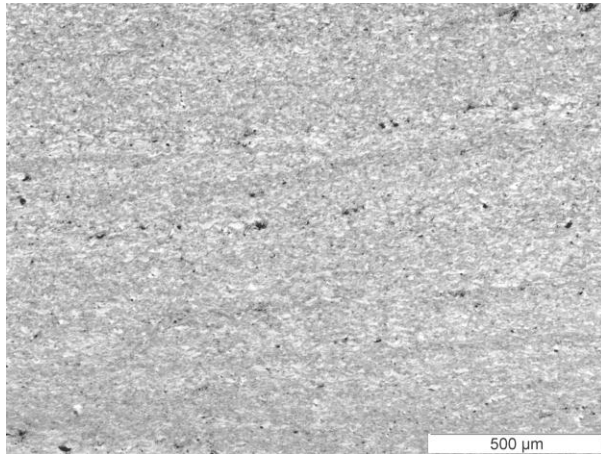
Results Using -400 mesh Ground Mg Alloy Powders



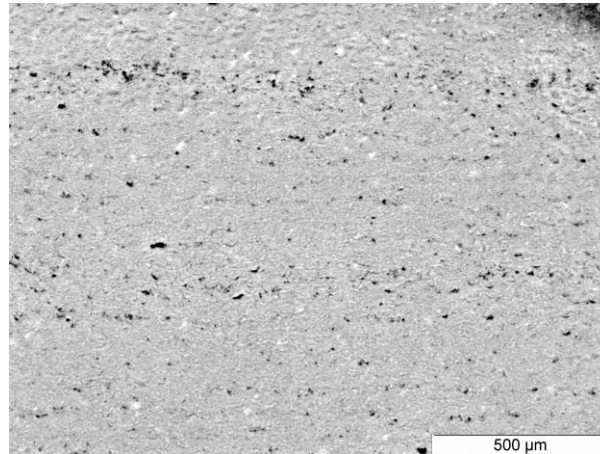
Horiba LA-910	AZ31B	WE43	E21
Mean (μm)	21.3	22.7	28.3

Results Using -400 mesh Ground Mg Alloy Powders

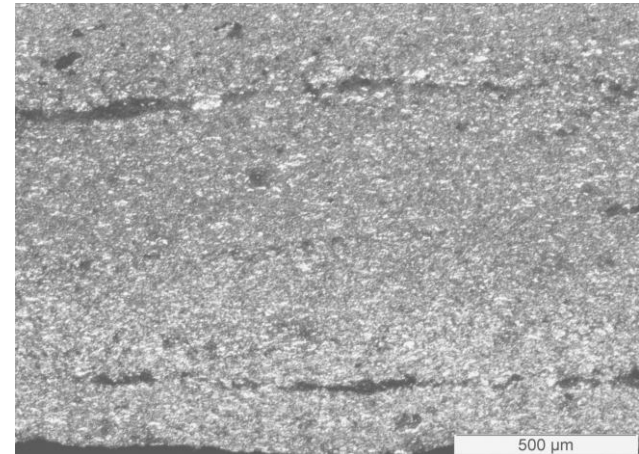
AZ31B : 135 VH (83 VH*)
2.52% porosity



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

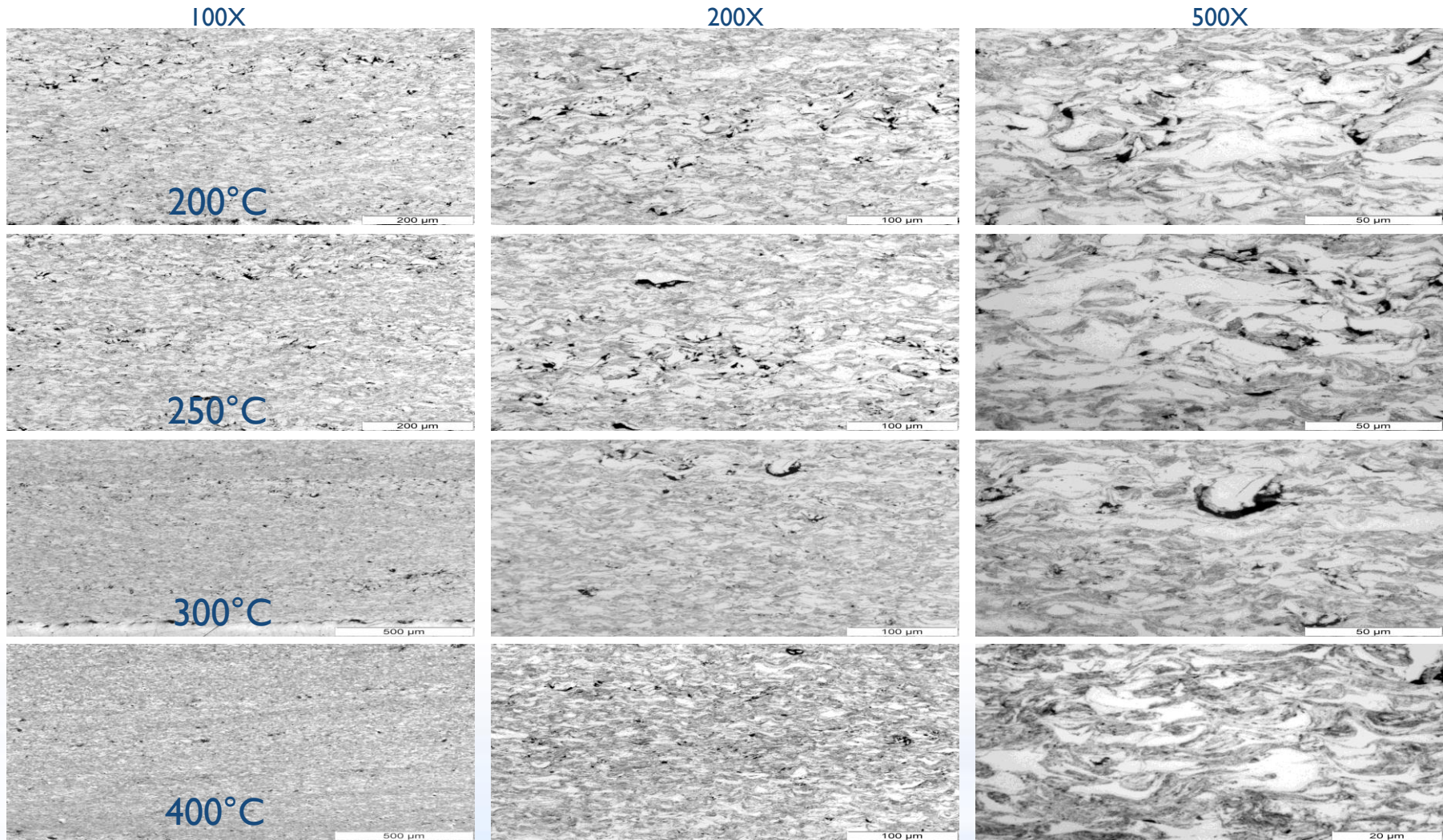


E21 : 105 VH (92 VH*)
11.32 % porosity



Porosity was determined using image analysis

Effect of Gas Temperature : Ground AZ31 B -400 mesh



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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/>

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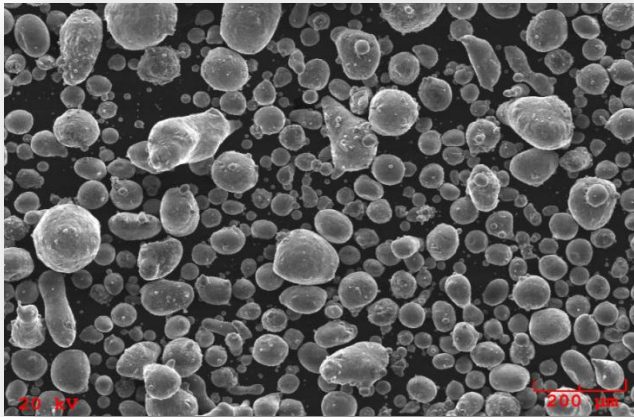
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Observations Using Ground Mg Alloy Powder

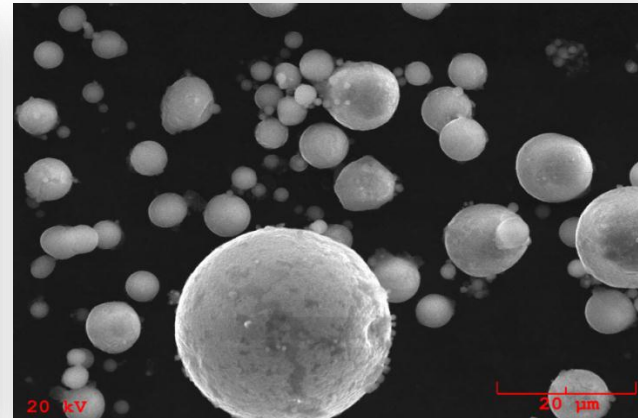
- Finer particles decreased porosity and increased deposition efficiency (<10% to ~40%)
- Hardness measurements indicate high strength over traditional powder products using the same powder
- Atomized powder should yield results more in line with model predictions which will allow for bulk material production and full scale tensile testing



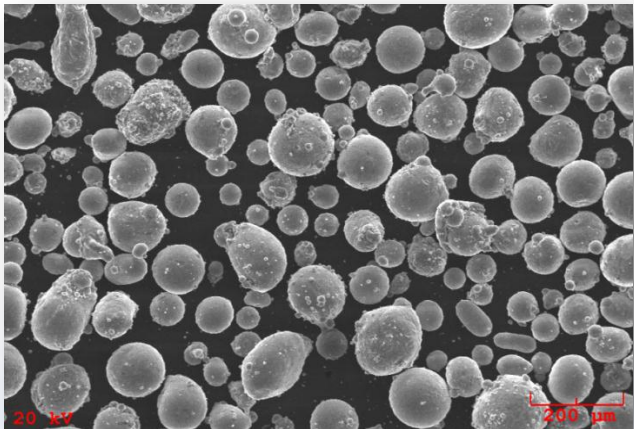
Morphology of Atomized Magnesium Alloy Powders



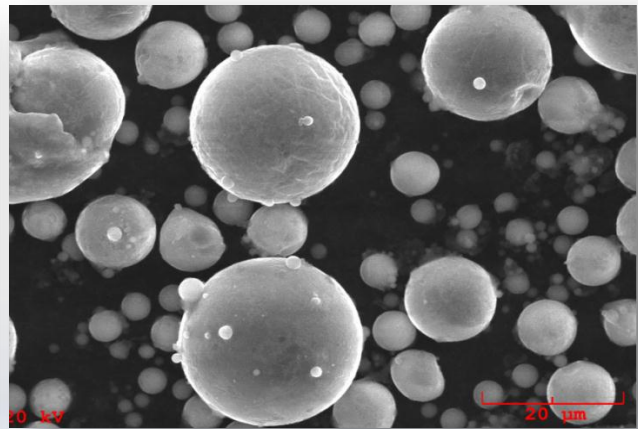
Atomized AZ91E 100/325



Atomized AZ91E -325

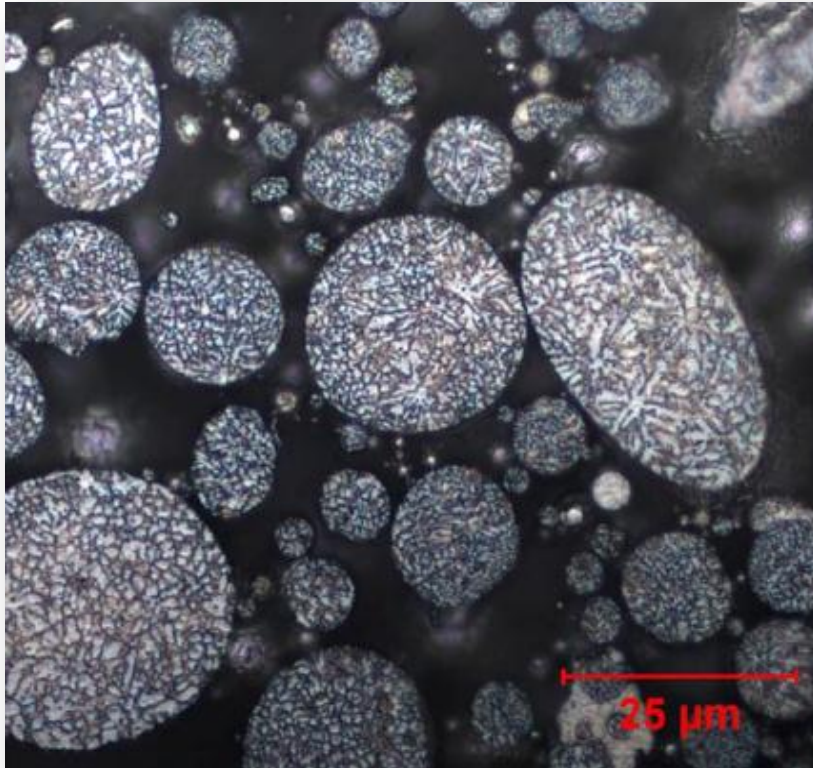


Atomized WE43 100/325



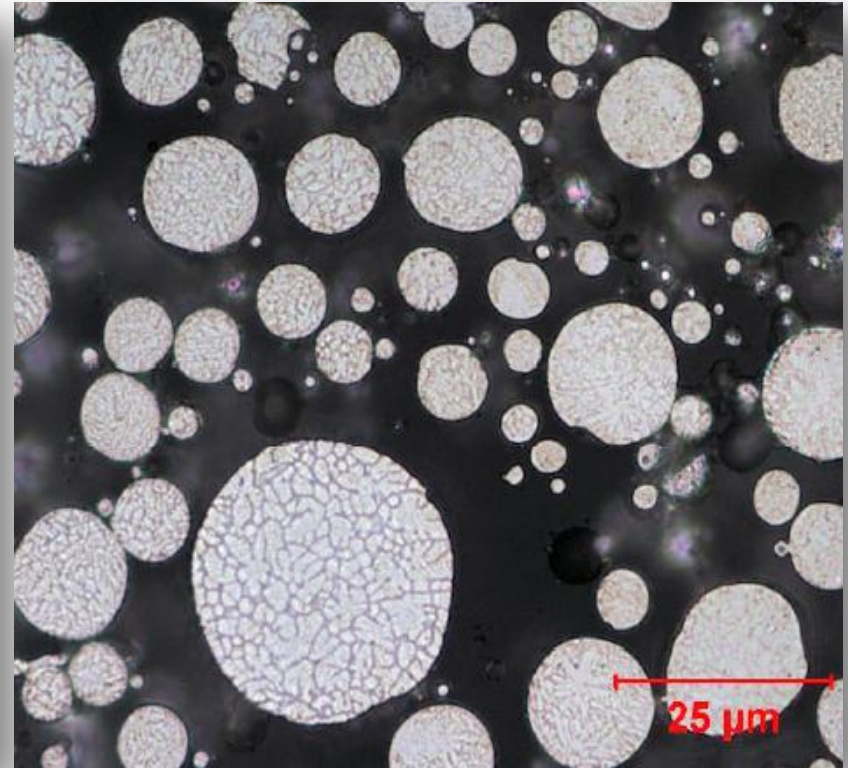
Atomized WE43 -325

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



AZ91E

Dendrite Arm Spacing (n=30) : $0.88\mu\text{m}$
Powder Hardness (n=10) : 100 HV_{10}



WE43

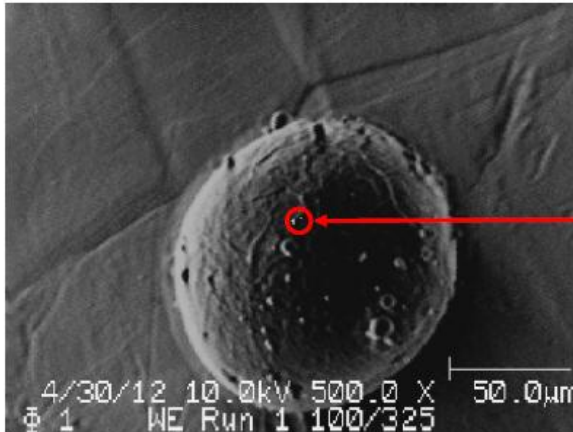
Dendrite Arm Spacing (n=30) : $0.80\mu\text{m}$
Powder Hardness (n=10) : 95 HV_{10}

Gas Atomized Powder Characteristics

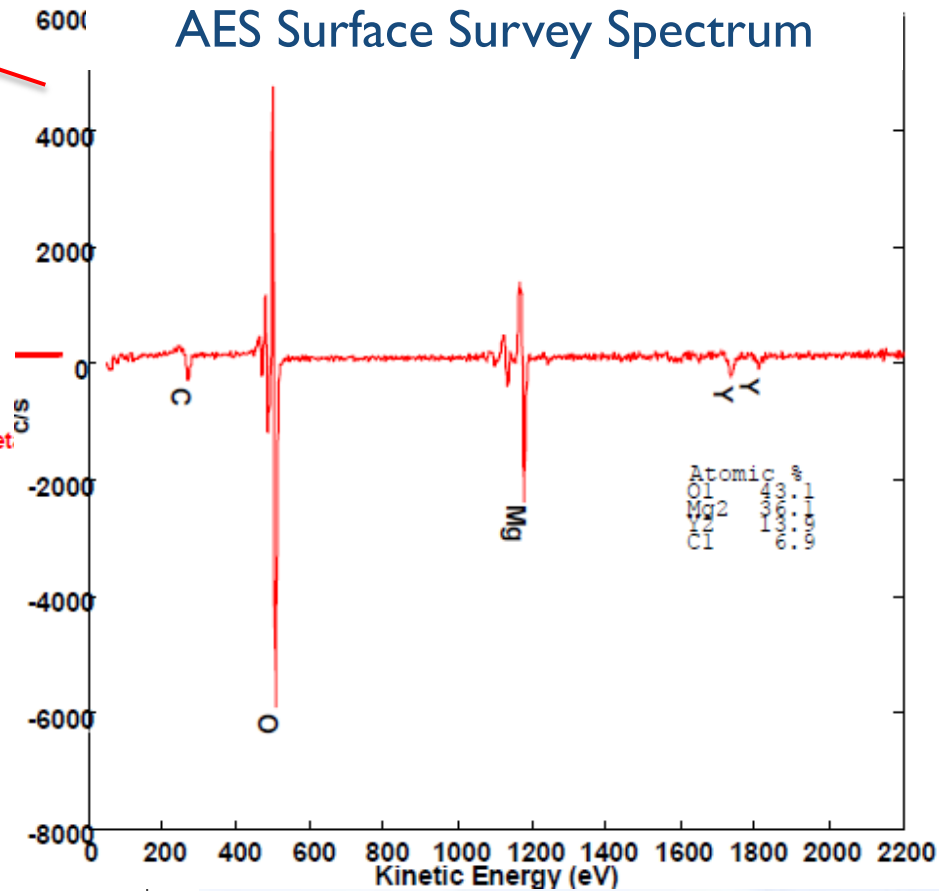
POWDER DESIGNATION	Density, g/cm ³		MICROTRAC SIZE, mm		
	Apparent	Tap	D ₁₀	D ₅₀	D ₉₀
AZ91E Atomized -325	0.75	0.93	6.6	21.1	41.0
WE43 Atomized -325	0.78	0.94	7.1	20.8	40.1



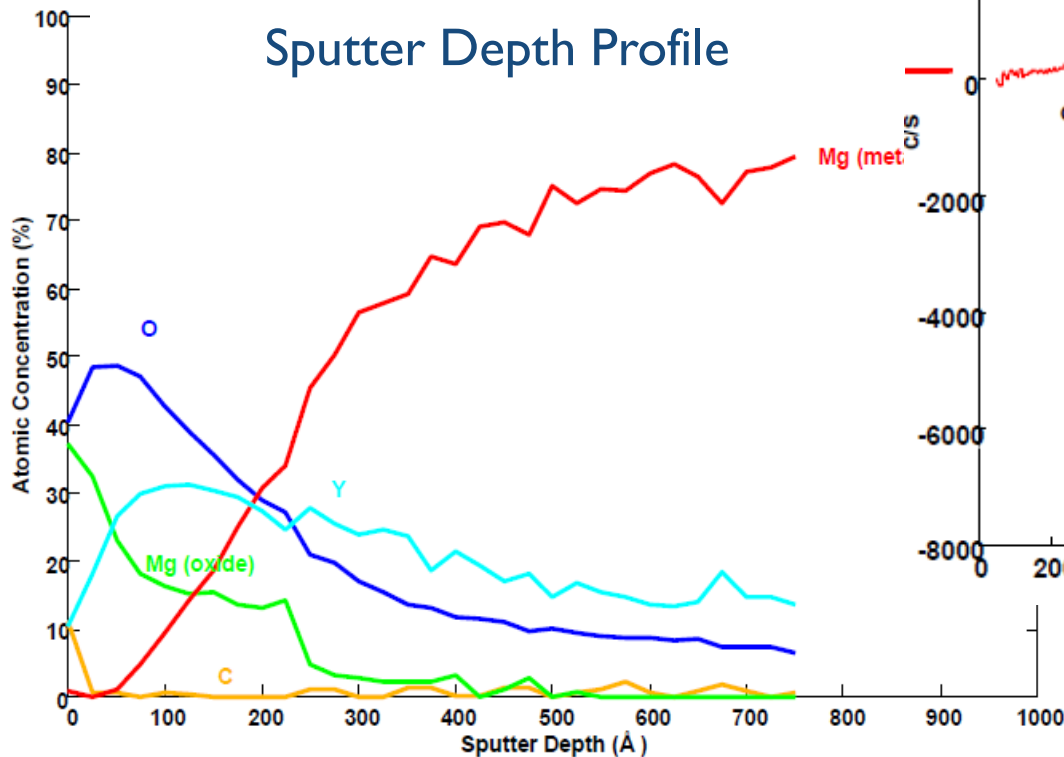
WE43 Auger/XPS Analyses



AES Surface Survey Spectrum



Sputter Depth Profile

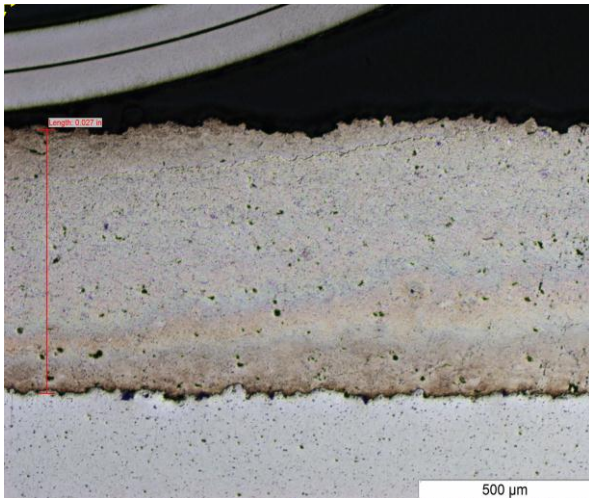


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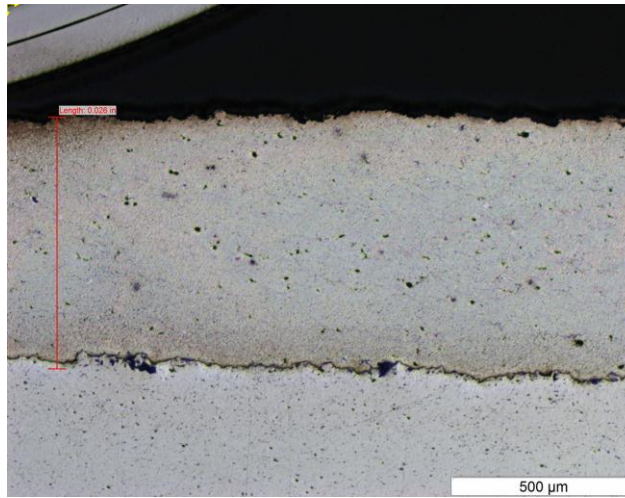
Results Using -325 mesh Atomized WE43

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



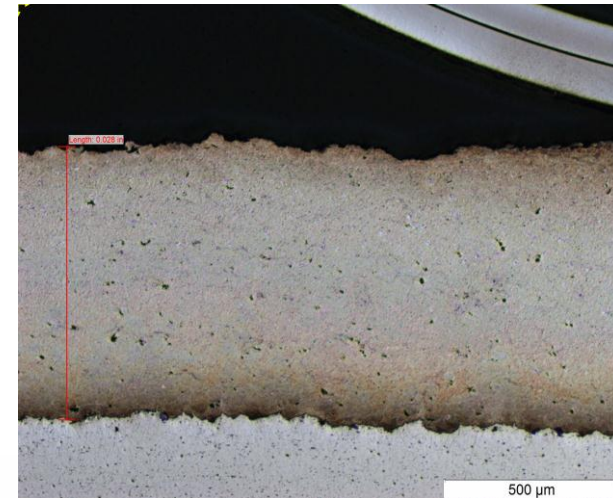
25 bar, 300°C

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



30 bar, 300°C

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

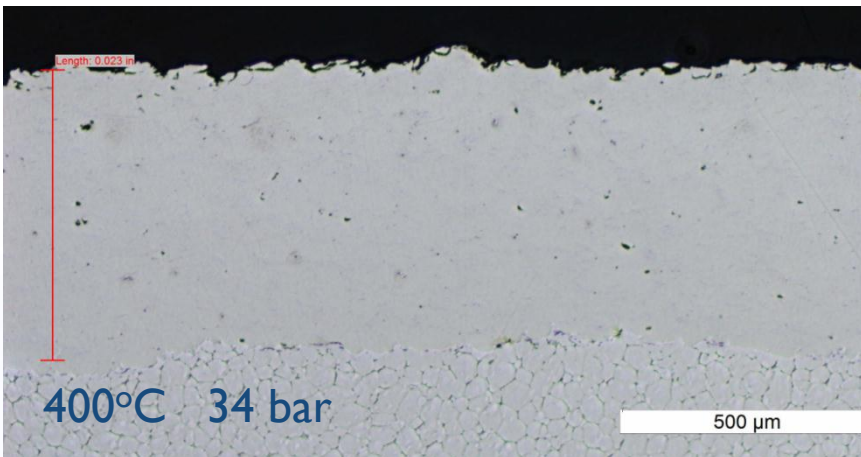
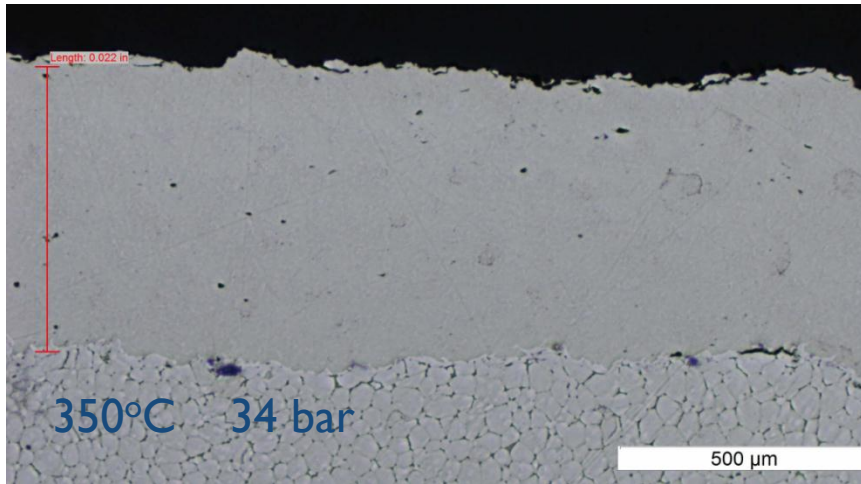


34 bar, 300°C

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



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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





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