Suitable Powders for Kinetic Metallization™

17th AeroMat Conference & Exposition

May 15-18, 2006

Ralph M. Tapphorn

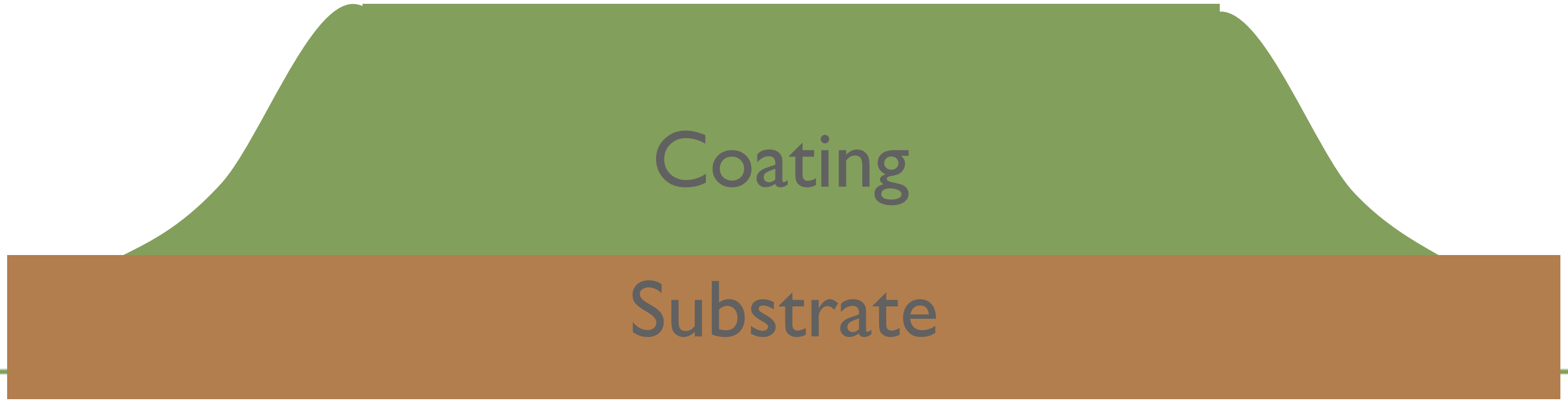
Overview

- Kinetic Metallization™ (KM) Process & Equipment
  - Particle Acceleration: Influence of powder size & density
- Powder Properties Suitable for KM Process
  - Particle shape & chemical properties
  - Particle packing theory
  - Particle size distribution (PSD) - measurements
    - KM NiCrAlY coating quality vs. PSD

What Is Kinetic Metallization™ ?

Kinetic Metallization Basics

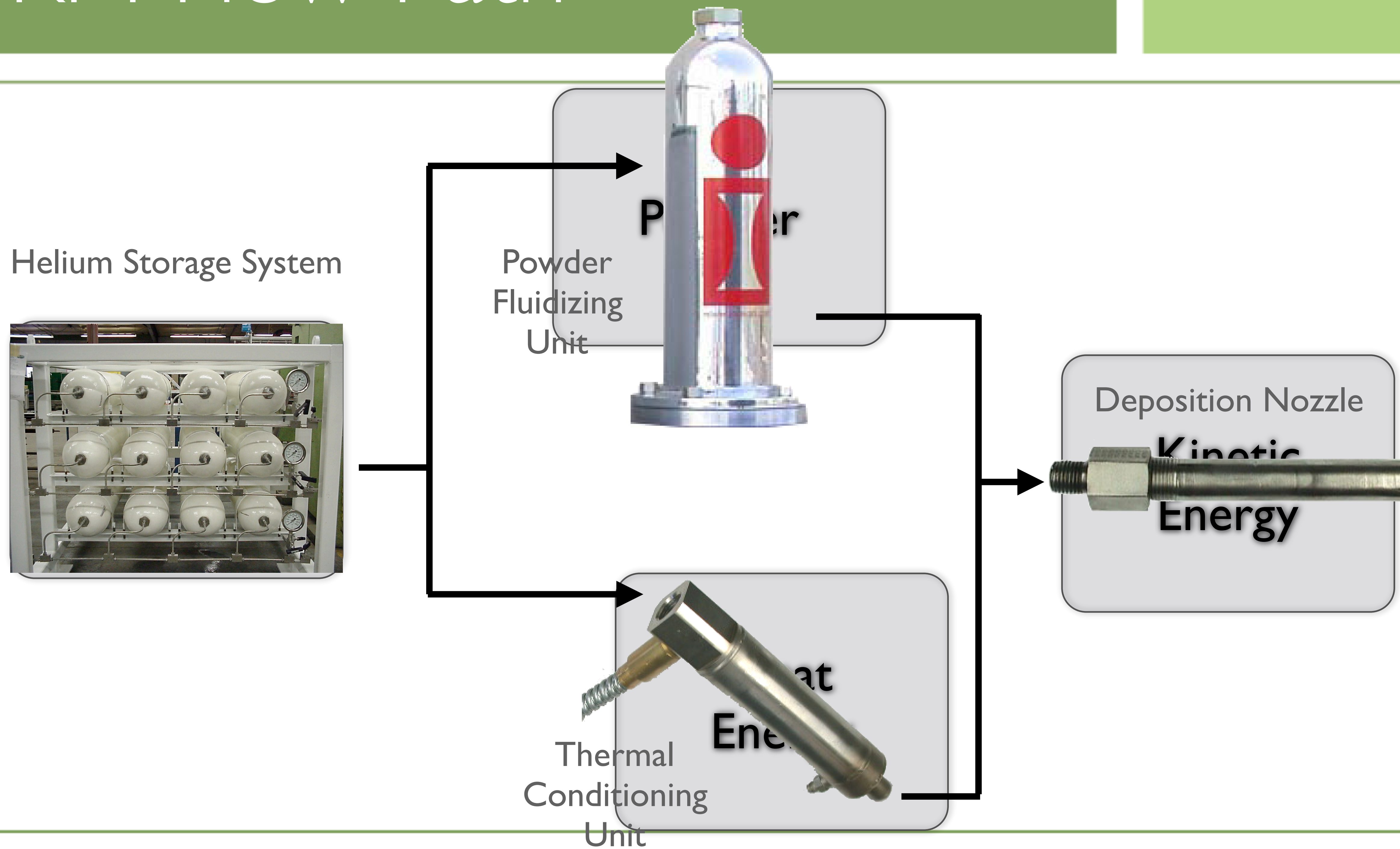
- Impact Consolidation Process
  - Feed-stock: fine powder,
  - Accelerant: inert light gas
- Solid-state Consolidation
  - No melting
  - No liquid chemicals
- KM Sonic Nozzle
  - Friction compensated
  - Low pressure (50 psig)
  - Low gas flow (7.5 SCFM)
- Environmentally Innocuous
  - No hazardous substances



Deposition Processes

Gas	Liquid	Solution	Solid
Vapor Deposition	Thermal Spray	Electrochemical	Impact Consolidation
IVD	HVOF	Plating	KM
CVD	A/VPS	Anodize	CS
PVD	D-Gun	Chemical Conversion	

KM Flow Path



Helium Storage System
Powder Fluidizing Unit
Deposition Nozzle
Energy
Thermal Conditioning Unit

KM-CDS 2.1 Equipment

INOVATI

Particle Acceleration Influence of Powder Size & Density

Particle Acceleration

- Drag Force = ma = $C_D \cdot q \cdot S$
  - C_D = drag coeff., S = surface area
  - Dynamic Pressure, q = 1/2•gas density•V_r^2
    - Relative Velocity, $V_r = V_g - V_p$
- Solve Particle Velocity V_p vs Nozzle Length (x)
  - $a = dVp/dx = 3/4 \cdot C_D \cdot \rho_g/(\rho \cdot D_p) \cdot (V_g - V_p)^2/V_p$
  - ρ_g = gas density
  - $\rho \cdot D_p$ is particle density & diameter

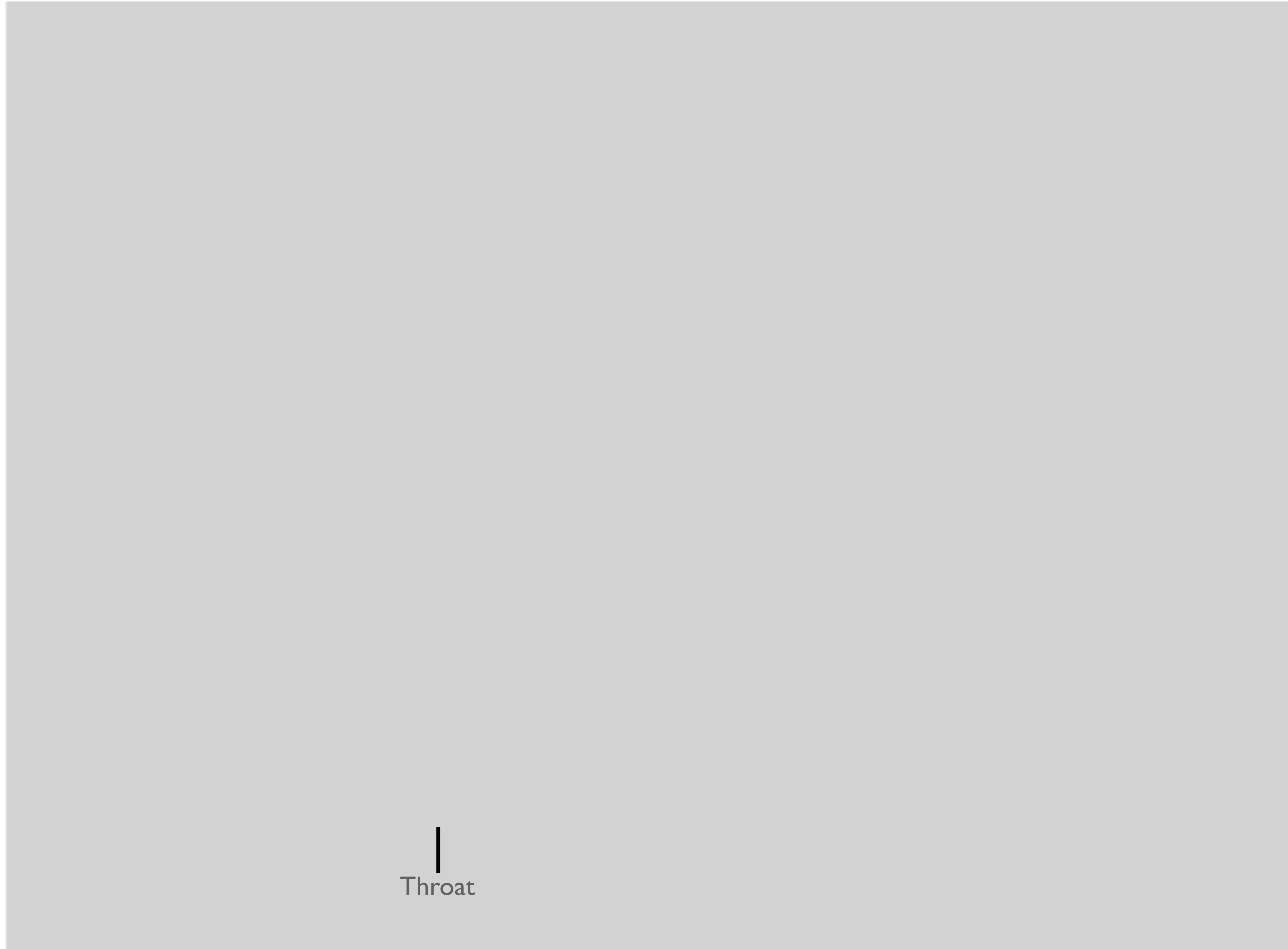
Critical Velocity

- Elastic-to-plastic collision threshold
  - Typically 400 - 600 m/s
    - **Increases** with increased bulk modulus
    - **Decreases** with increased particle temperature
- Selection Criteria: Powders Suitable for KM
    - Particle velocities > critical velocity threshold

Sphere ➠ Ellipsoid

Throat

KM - Al Powder



KM - Ni Powder

Throat

KM - WC/Co

Powder Properties Suitable for KM

KM Particle Shapes

- Atomized Powders (Al, Cu, Ti, NiCrAlY)
  - Spherical
- Carbonyl Decomposition (Ni, Fe, Co)
  - Spherical
- Hydride-Dehydride (Ti, Zr, Nb, Ta)
  - Irregular
- Attrition Milling (WC-Co, Nano-Structured Al)
  - Flake
  - Irregular

Powder Chemistry

- Metallic Powder Purity
  - CP Powders - specifies purity of metallic contaminations
  - Alloys - specifies alloy chemistry
- Non-Metallic Purity
  - Oxide and nitride content
  - Other surface contaminates (sulfides, etc.)
- Organic Purity
  - Specifies organic material (e.g., lubricant)
  - Relevant to attrition milled powders

Particle Structure

Particle Structure

NiCrAlY Particle 20-micrometers

Micro's Courtesy NASA GRC

Powder Packing Theory vs. Experiment

Powder Distribution Requirements

- Ancient History Teaches Fundamentals
  - Building of stone walls
  - Poly-disperse packing theory
    - Greeks - Apollonius of Perga

Theoretical Distribution

Measuring Particle Size

LASER
Diffraction
+
Scattering
(MicroTrac)
(Malvern)

Volume Weighted

?

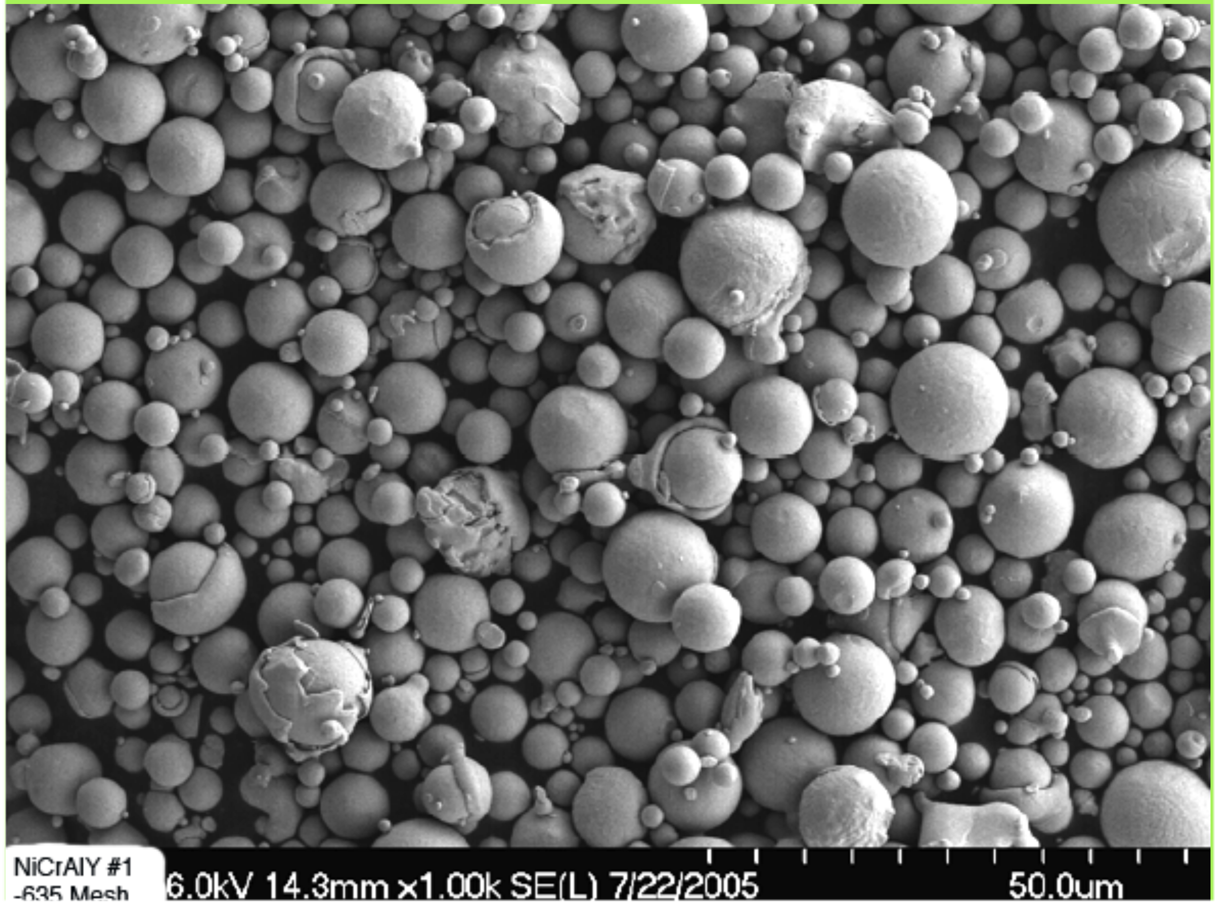
LASER
Diffraction
+
Extinction
Accusizer 780
(Particle Sizing
Systems)

Population Weighted

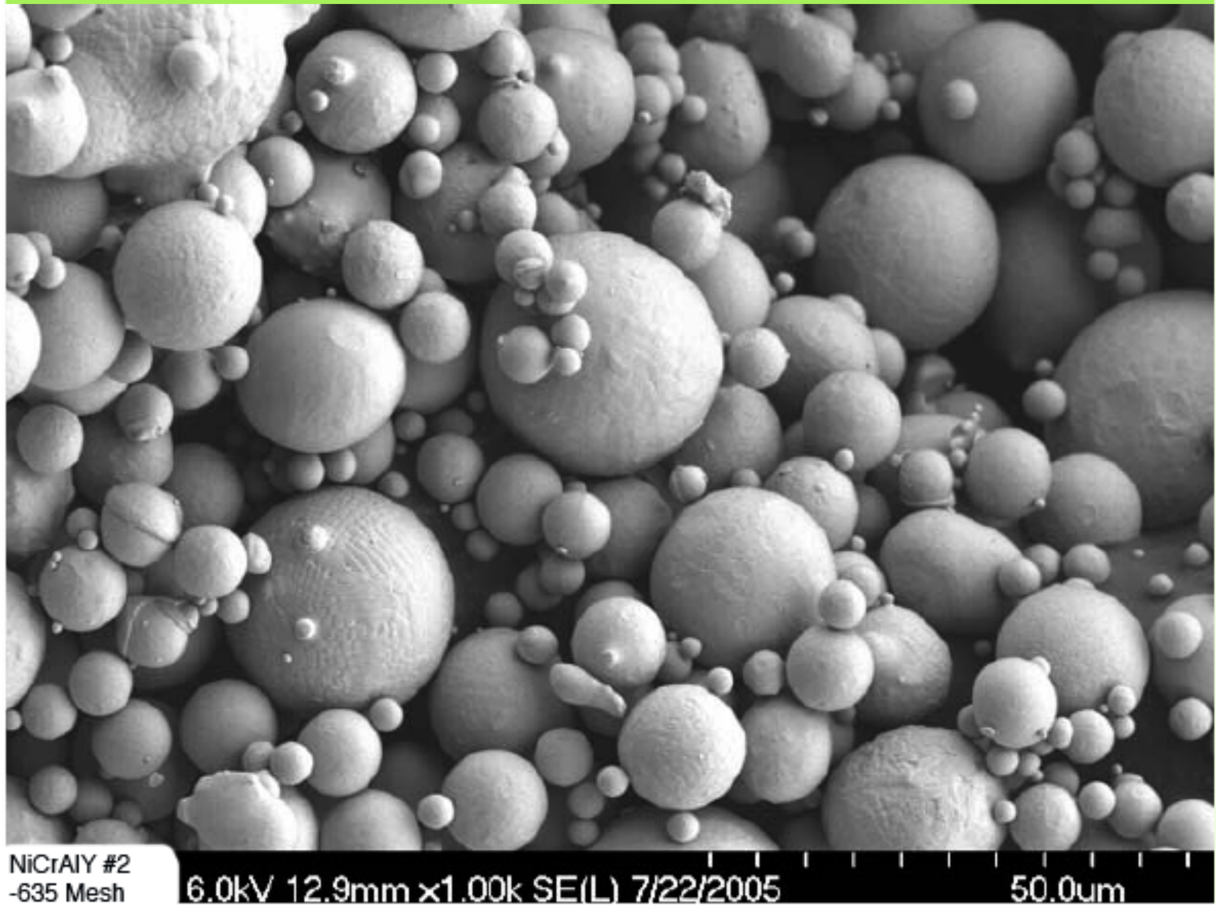
?

NiCrAlY Powder Comparison

NiCrAlY Sample #1 (-635 mesh)



NiCrAlY Sample #2 (-635 mesh)

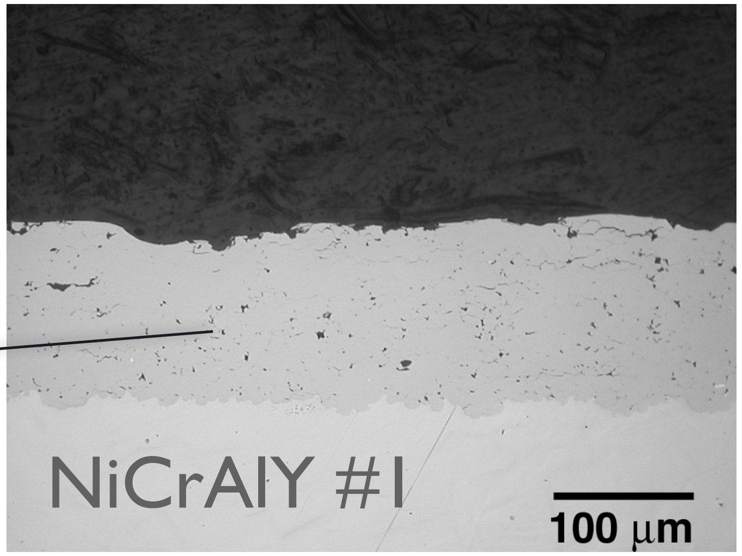


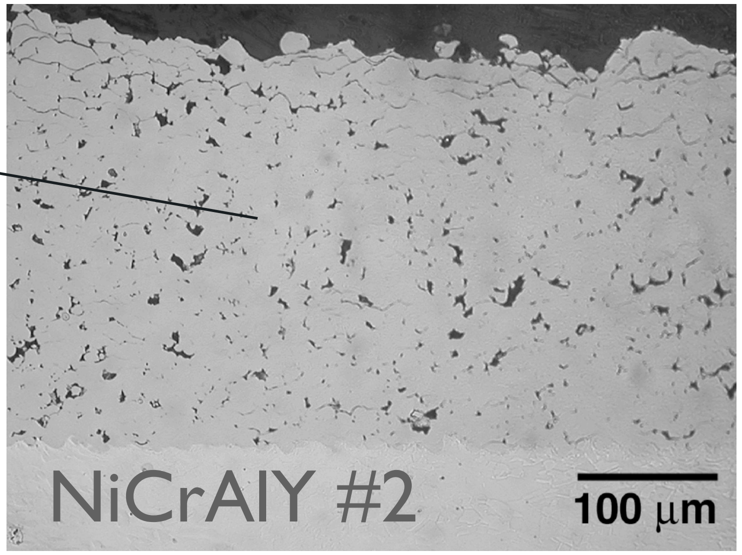
SEM Analysis of PSD

Micrographs courtesy of NASA GRC

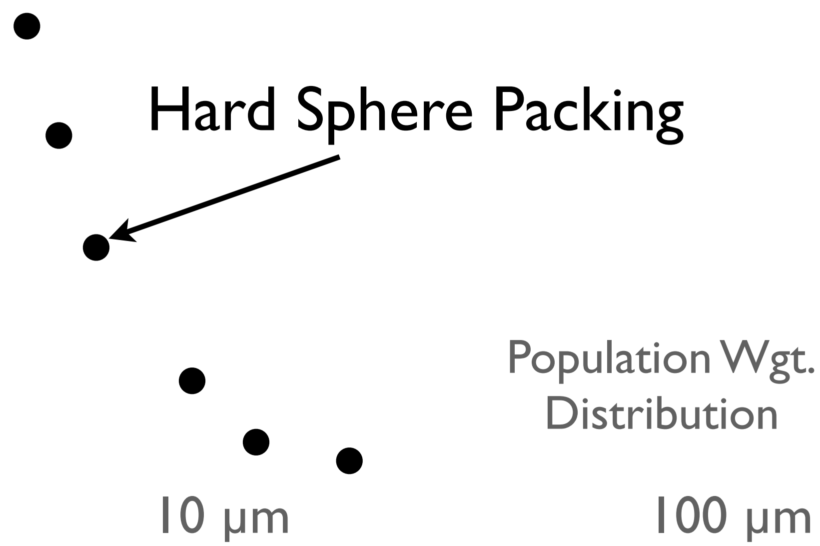
INOVATI

PSD Influence on Porosity



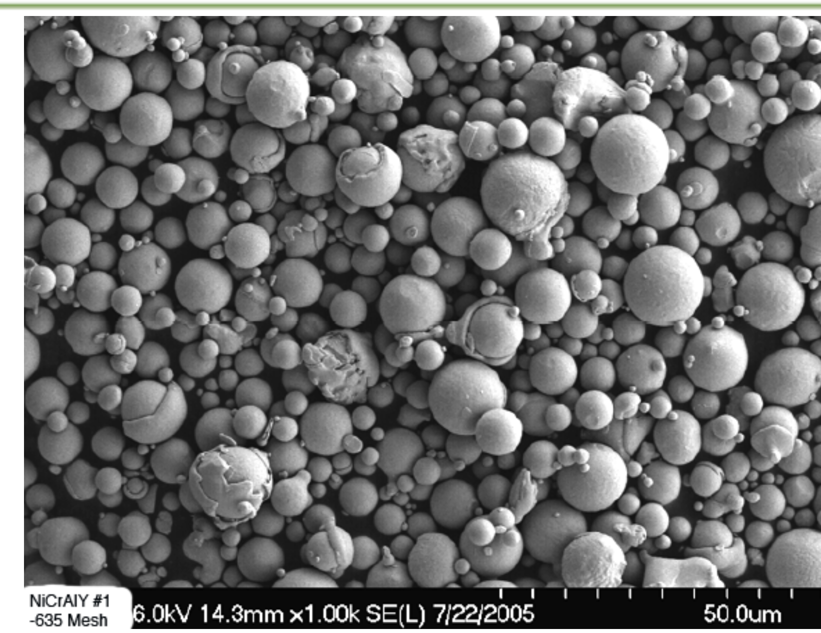


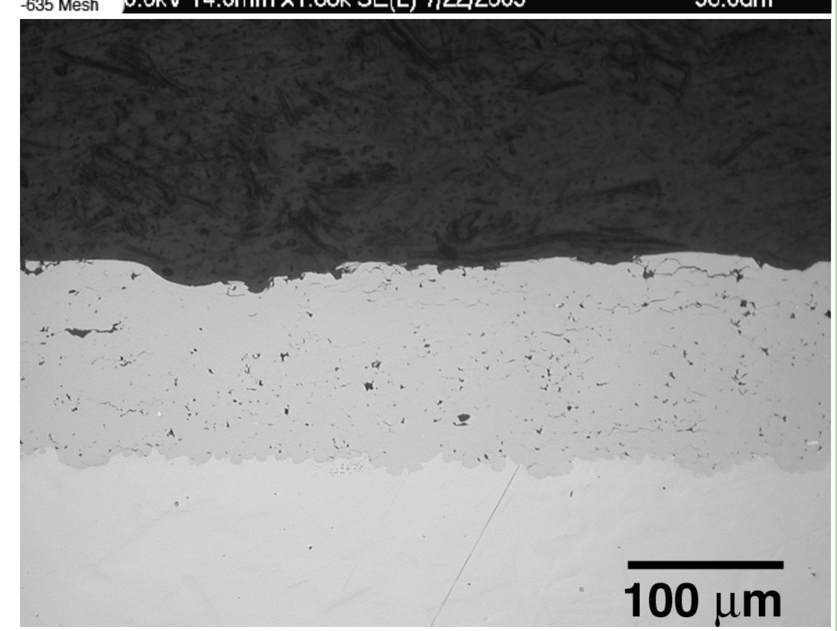
NiCrAlY #1 (-635 Mesh)



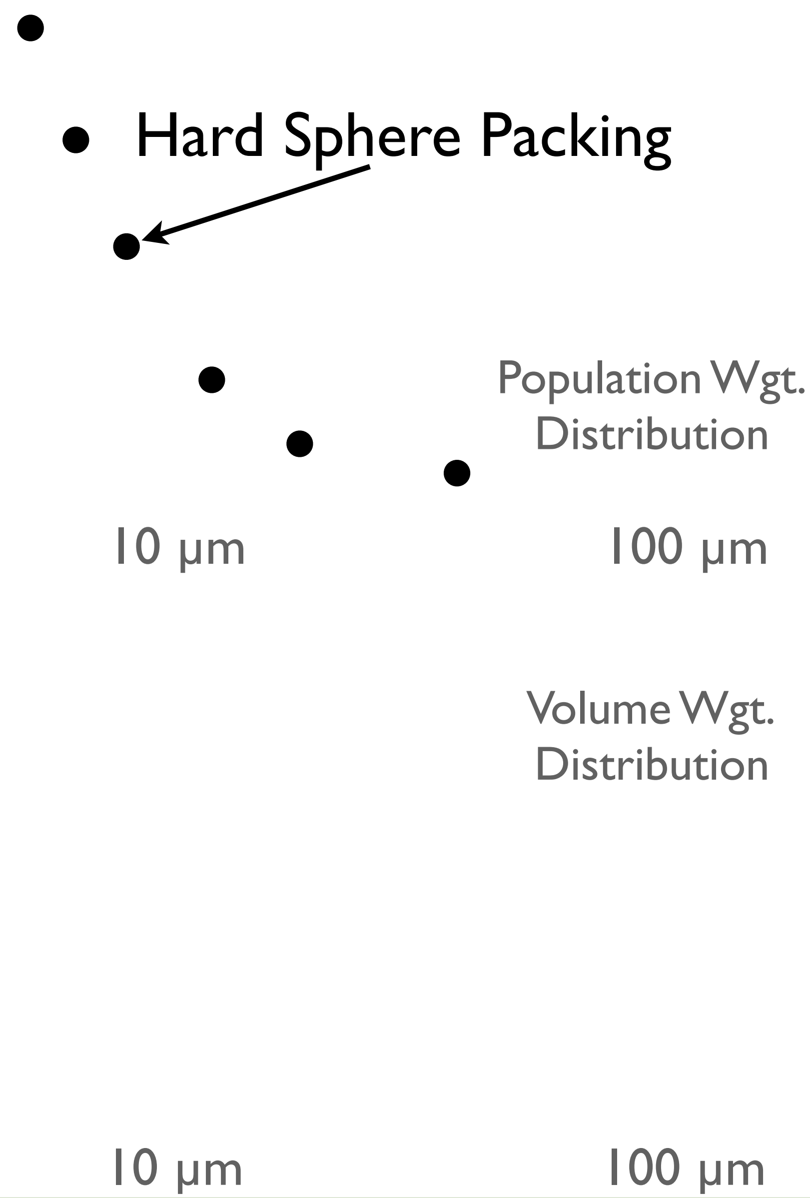
Volume Wgt.
Distribution

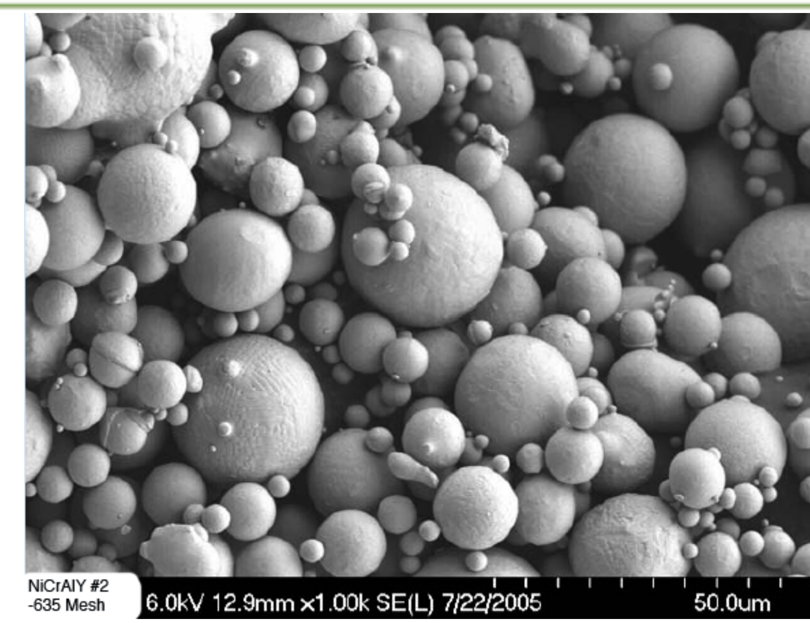
10 µm   100 µm

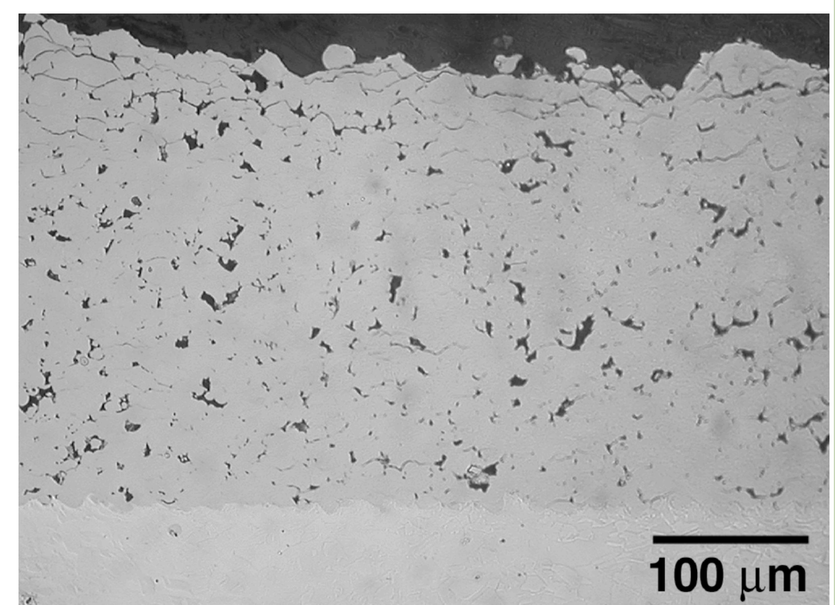




NiCrAlY #2 (-635 Mesh)







Conclusions KM Powder

- Suitable Particle Size
  - Strong function of size distribution for high density packing
  - Improves deposition efficiency (i,e., upper limit cut-off)
  - Dependent on powder density & shape
  - Powder manufacturers are evolving processes to accommodate KM
- KM Coating Properties
  - Influenced by chemical purity of powders
  - Mechanical properties vs. coating quality
    - Thermal conditioning of powder (up to 600 F)
      - Improves D_e & reduces plastic deformation flow stresses