Plasma Spheroidized (PS) Titanium Powders.

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Agenda

• Introduction to Reading Alloys.
• Spherical Titanium Powders.
• Hydride-Dehydride (HDH) Process.
• HDH Powder Morphology.
• Spherical HDH Powder Process.
• Plasma Spheroidized Powder Morphology.
• Summary.
Introduction to Reading Alloys

Reading Alloys Manufacturing Site

Technology Center

Powder manufacturing
Introduction to Reading Alloys

• Since 1953, Reading Alloys has been a producer of aerospace grade master alloys for the titanium and super alloy industries. Principally Al-V, Al-Mo-Ti and Ni-Nb MA.

• Since 2001, Reading Alloys has been a producer of Hydride-Dehydride (HDH) Ti and Ti-6Al-4V powders.

• In 2012 Ametek Reading Alloys launched a new powder metallurgy - Plasma Spheroidized (PS) powder.
Spherical Titanium Powders

• Spherical Ti powder manufacturing processes are Plasma Rotation Electrode Process, Gas / Plasma Atomization.

• PREP, GA and PA powders are characterized by their spherical morphology, high purity and high cost, and are well suited for powder HIPping, MIM and Additive (3D) Manufacturing.

• HDH powders are characterized by their blocky and angular morphology, lower cost and are ideally suited for Press/Sinter, CIP/Sinter, Roll Compaction and Plasma Spraying.
Spherical Titanium Powders

Plasma Rotation Electrode Process (PREP) Ti-6-4 Powder

-80 mesh

-80 mesh
Spherical Titanium Powders

Gas Atomized (GA) Ti-6-4 Powder

-140+325 mesh

-140+325 mesh
Spherical Titanium Powders

Plasma Atomized (PA) Ti-6-4 Powder

-325 mesh

-325 mesh
Hydride-Dehydride Process

• Titanium has a very high affinity for interstitial elements such as oxygen, nitrogen, hydrogen and carbon.

• When heated in a hydrogen atmosphere, a stable brittle titanium hydride (δ phase) is produced.

\[
\text{Ti (s) + H}_2\text{(g)} \leftrightarrow \text{TiH}_2\text{(s)} \text{ (Reversible Reaction)}
\]

• Titanium hydride can be readily crushed, milled and screened into a titanium hydride powder.
Hydride-Dehydride Process

HDH Furnace

Inert Screening

Crushing

Powder De-oxidation
HDH Powder Morphology

HDH Hunter and Kroll Sponge Powder

-60+100 mesh

-100+200 mesh
HDH Powder Morphology

HDH CP Ti and Ti-6-4 Powder

-60+100 mesh

-70+200 mesh
Plasma Spheroidized Powders

• The HDH Ti powder is fed into an induction coupled plasma field which melts and spheroidizes the HDH Ti powder.

• The resulting Plasma Spheroidized (PS) powder morphology is very similar to the PREP powder, free from agglomerates and satellites which eliminate argon gas entrapment.

• The PS powder has significantly increased apparent density and powder flow compared to the HDH Ti powder feed stock.
Plasma Spheroidized Powders

Plasma Spheroizdation Process Flow.

Process Flow Diagram

- Raw Materials ➔ Hydride ➔ Mill/Screen ➔
- De-Hydride ➔ De-oxidize ➔ Plasma Process
- Re-screening ➔ Inspection ➔ Final Test
- Pack ➔ Ship.
Plasma Spheroidized Powders

Coarse Plasma Spheroidized (PS) Ti-6-4 Powder

-45+60 mesh

-45+60 mesh
Plasma Spheroidized Powders

Standard Plasma Spheroidized (PS) Ti-6-4 Powder

-200+325 mesh

-200+325 mesh
Plasma Spheroidized Powders

Fine Plasma Spheroidized (PS) Ti-6-4 Powder

-325+500 mesh

-325+500 mesh
# Plasma Spheroidized Powders

## Comparison Table by Manufacturing Process

<table>
<thead>
<tr>
<th></th>
<th>Ti Powder</th>
<th>PSD (mesh)</th>
<th>Roundness</th>
<th>Sterilities</th>
<th>Agglomerates</th>
<th>Powder Flow</th>
<th>Tap Density</th>
<th>Entrapped Argon</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREP Powder</td>
<td>-40+325</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Poor</td>
</tr>
<tr>
<td>GA Powder</td>
<td>-80+635</td>
<td>Good</td>
<td>Moderate</td>
<td>Poor</td>
<td>Moderate</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>PA Powder</td>
<td>-140+635</td>
<td>Good</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>HDH Powder</td>
<td>-35+500</td>
<td>Poor</td>
<td>Good</td>
<td>Poor</td>
<td>Poor</td>
<td>Moderate</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Very Good</td>
</tr>
<tr>
<td>PS Powder</td>
<td>-35+500</td>
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</tbody>
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Powder Comparisons: Very Good, Good, Moderate and Poor
Summary

• The PS process is a high volume batch process.
• The PSD range of the PS powder is predetermined at the HDH process stage improving powder yield / utilization.
• Plasma Spheroidized (PS) powder process can produce the full range of powder PSD from coarse to fine.
• PS titanium powders are ideally suited for PM applications such as HIPping, Additive (3D) Manufacturing and MIM.