CARPENTER ADDITIVE®

CASE STUDY

Plasma Spheroidization for Improved Metal Powder Flow and Packing Properties

To achieve optimum flow characteristics and high packing density, an ideal Additive Manufacturing (AM) metal powder should be highly spherical in shape with no satellites. As spherical particles have minimum surface area to volume ratio this brings an added advantage in principle, of reduced surface contamination e.g. oxygen pick up. Increased particle sphericity can improve powder feeding, resulting in smoother layers, improved packing density, increased heat conduction in the powder bed and an enhanced melting profile.

Generating a component by AM, also known as metal 3D Printing, relies on building the final design through a series of many thousands of layers. Whilst different metal powders can be selected according to the required performance of the final part, reproducible behavior of the powder throughout the process is key to a successful build.

Plasma Spheroidization

In principle, any metallic powder can be plasma treated to improve the flow and packing properties of low sphericity, irregular, sponge-like, agglomerated and angular metallic powders produced by other methods e.g. water atomization, chemical and mechanical processes, and standard gas-atomization.

This case study presents the results of Carpenter Additive's plasma spheroidization process on morphology, flow, and packing properties of three different metallic powders - pure Tungsten (W), Ti6Al4V, and pure Tantalum (Ta).

Results

Several trials have been performed for each powder feedstock to determine the optimum processing parameters. The powder samples were fully characterized after each plasma treatment trial and compared with those of the starting feedstock.

The results demonstrate that when spheroidization parameters are optimized for the particular feedstock, particle morphology, powder flow and packing properties are significantly improved.

Plasma Spheroidization for Improved Metal Powder Flow and Packing Properties

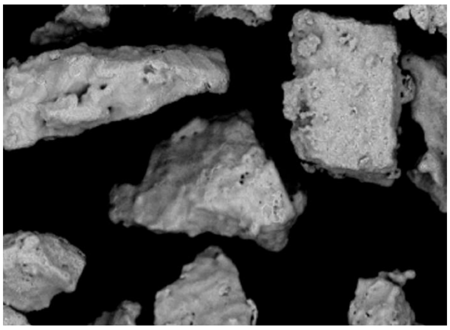
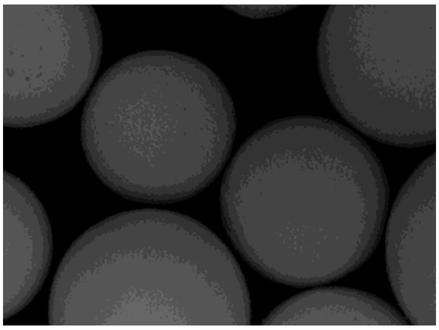
	Before Plasma Treatment	After Plasma Treatment
Product	Ti-64 feedstock (HDH and mechanically crushed)	Ti-64 spherical
Particle Size, µm	45-105 µm	45-105 µm
Hall Flow rate, sec/50g	47.31	22.3
App. Density, g/ee	N/A	2.6
Tap Density, g/ee	2.2	3.0
Shape Analysis	Circularity: D10: 0.556, D50: 0.774, D90: 0.937 Elongation: D10: 0.083, D50: 0.260, D90: 0.428	Circularity: D10: 0.81, D50: 0.989, D90: 0.995 Elongation: D10: 0.008, D50: 0.044, D90: 0.366
Morphology SEM - x1000 mag		

Figure 1. Comparison of Ti64 before spheroidization (L) and post-spheroidization (R)

Figure 1 shows one of the most commonly used Ti-based alloys: Ti6Al4V Grade 23. The starting powder, produced by mechanically crushing "embrittled" ingots via a Hydride-DeHydride (HDH) process, is angular and elongated. Considering the particle size the flow rate is low and the tap density is less than 50% of the theoretical bulk density for this material. The SEM image shows that post spheroidization, the particles are almost perfectly spherical i.e. with a circularity close to 1, [Circularity: D10: 0.81, D50: 0.989, D90: 0.995], flow time is improved by a factor of two and tap density is increased to almost 60% of the theoretical bulk density.

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Plasma Spheroidization for improved metal powder flow and packing properties

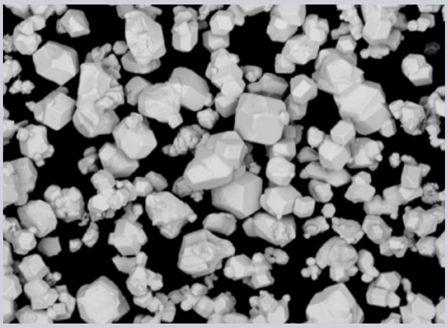
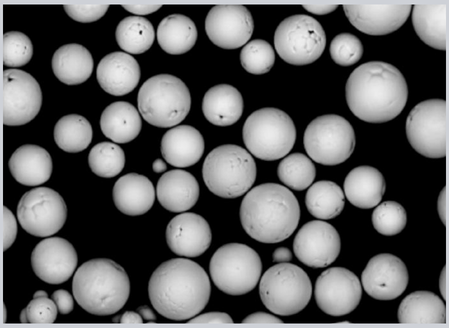
	Before Plasma Treatment	After Plasma Treatment
Product	W feedstock	W spherical
Particle Size, µm	15-45 µm	15-45 µm
Hall Flow rate, sec/50g	7.5	5
Tap Density, g/ee	11.2	14.3
Shape Analysis	Circularity: D10: 0.70, D50: 0.89, D90: 0.95 Elongation: D10: 0.05, D50: 0.17, D90: 0.36	Circularity: D10: 0.80, D50: 0.95, D90: 0.98 Elongation: D10: 0.02, D50: 0.15, D90: 0.33
Morphology SEM - x1000 mag		

Figure 2. Comparison of Tungsten before spheroidization (L) and post-spheroidization (R)

Figure 2 shows the results for the refractory metal Tungsten, which at 3422 °C has the highest melting point of all metals in its pure form. The tungsten feedstock was produced by reducing Tungsten oxides and demonstrates angularity, although both flow and packing density (~58% of the theoretical bulk density) are relatively good. After plasma treatment, the majority of the powder particles are shown to be spherical and both flow and packing (~74% of the theoretical bulk density) are improved.

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Plasma Spheroidization for Improved Metal Powder Flow and Packing Properties

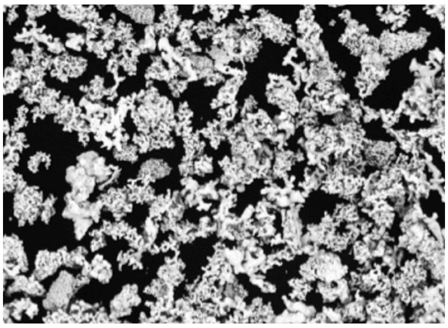
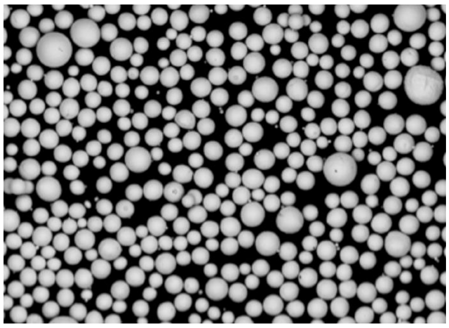
	Before Plasma Treatment	After Plasma Treatment
Product	Ta feedstock (dendritic)	Ta Spherical
Particle Size, µm	15-45 µm	15-45 µm
Hall Flow rate, sec/50g	17.4	5.2
App. Density, g/ee	N/A	N/A
Tap Density, g/ee	8.32	11.16
Shape Analysis	N/A	Circularity: D10: 0.790, D50: 0.989, D90: 0.996 Elongation: D10: 0.007, D50: 0.050, D90: 0.276
Morphology SEM - x275 mag		

Figure 3. Comparison of Tantalum before spheroidization (L) and post-spheroidization (R)

Figure 3 shows the results for refractory metal tantalum, melting point 3017 °C. The tantalum powder was produced by electrolysis of a solid feedstock and has a very irregular, dendritic shape. The flow is slow for the density of material and tap density is less than 50% of the theoretical bulk density. After optimized spheroidization the powder particles become highly spherical and both the flow and packing (~6 7% of the theoretical bulk density) are significantly improved.

Plasma Spheroidisation Conclusion

Morphology and packing density have a significant effect on the quality of the powder layer and melting behavior, depending on deposition system. Plasma Spheroidization at Carpenter Additive has been shown to be an effective method of controlling the shape, flow and packing characteristics to defined specifications across a range of metallic powders to deliver reliable, reproducible performance.

At Carpenter Additive, we have a wealth of expertise in metal AM, and extensive experience of working with leading companies within the aerospace, biomedical, and automotive industries. We utilize this knowledge and the capabilities of plasma technology to provide solutions across a wide range of industries and AM platforms.