# Raymor AP&C: Leading the way with plasma atomised Ti spherical powders for MIM

AP&C, a division of Canada's Raymor Industries Inc., is today the market leader in the production of titanium spherical powders specifically suited for Metal Injection Moulding (MIM). As a result of this success, the company's titanium powders are used in a wide range of commercial and R&D stage applications. Jens Kroeger and Frédéric Marion review the powder production process at Raymor AP&C, highlighting technological innovations and related product developments.

When competing with rival gas atomisation technologies, AP&C has learned that it needs to continually improve on what it does best, namely to deliver powders with consistently high purity and tailored distributions. The unique and patented plasma atomisation process developed and exploited at AP&C allows the production of high purity spherical metal powders. The company's process guarantees the preservation of the high purity of the metal wire used as feedstock. A high quality product, a strong research team and a unique tailored service are some of the reasons why this Canadian company is consistently growing in the competitive market for high-end metal powder production.

Since its foundation, AP&C's primary market has been titanium (CpTi) and titanium alloy (Ti-6Al-4V ELI, Ti-6Al-4V grade 5) powders with a focus on meeting client expectations in terms of purity, flowability, size distribution and delivery time. These powders are now used across many industry sectors, including biomedical and aerospace, to manufacture complex structures with properties such as higher strength, high biocompatibility, high resistance to metal fatigue and desired surface morphologies.

In a rapidly evolving market, and given a broad diversity of powder processing technologies including MIM, rapid prototyping, thermal spray and HIP just to name a few, AP&C is fully aware that precise control of powder properties is necessary to satisfy the particular demands of each application. This is a challenge for the traditionally top-down oriented industry of powder production. However, AP&C has faced

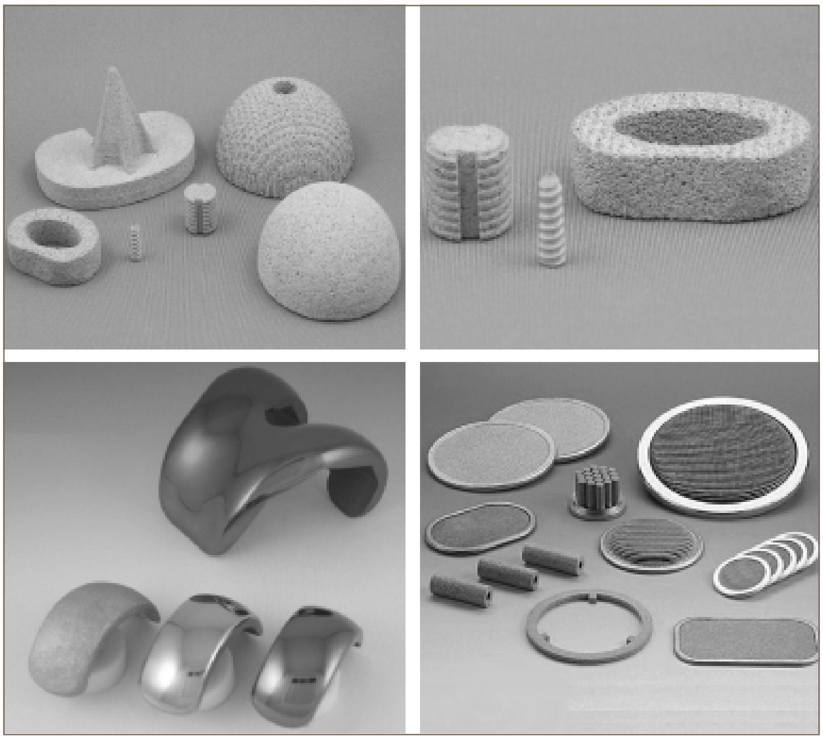

*Fig. 1 Products made from AP&C's titanium or titanium alloy powders. Top left and top right: Titanium orthopedic parts for hip joint replacement made via MIM; Lower left: titanium knee implant parts made via PIM; Lower right: titanium filtering media*

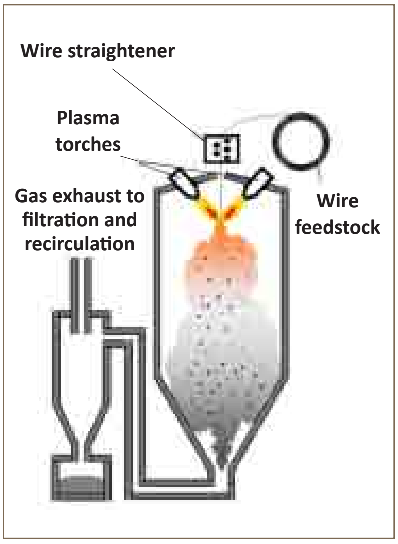


*Fig. 2 Schematic of the plasma atomisation setup*

*Fig. 3 The AP&C plasma atomisation production unit*

*Fig. 4 The plasma torches*

this challenge and achieved remarkable results. From the knowledge acquired to-date, and the company's exclusive technology, it is expanding to offer atomising services for many other materials including nitinol (NiTi), niobium (Nb) and molybdenum (Mo).

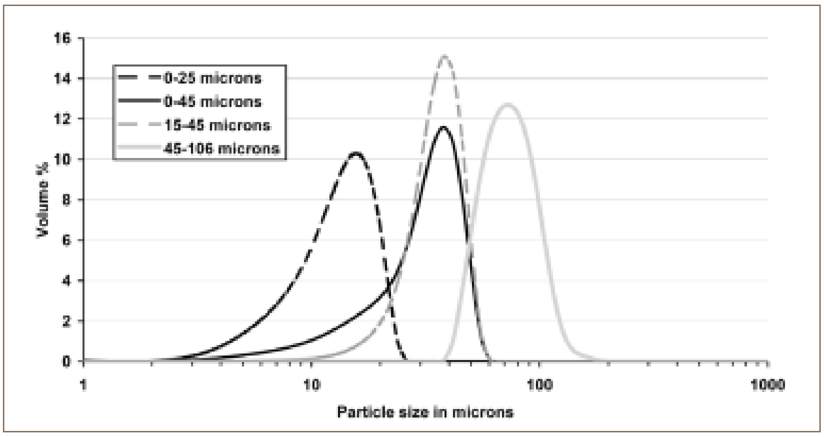


*Fig. 5 Laser diffraction measurements of the particle size distribution of Ti-6Al-4V ELI powders produced via plasma atomisation*

## AP&C's unique plasma atomisation process

The patented plasma atomisation production units (US patent #5707419) operated at Raymor's Boisbriand plant in Québec, Canada, have been evolving ever since their initial conception. From an early experimental setup, they have today developed into large capacity production units that consistently deliver high purity spherical metal powders. The system has all the state-of-the-art controls and gas recycling apparatus necessary to ensure product stability and competitive pricing.

As shown in Fig. 2, the first unique aspect of the company's plasma atomisation process is the use of a wire feedstock. Using a wire has many advantages over the typical gas atomisation process, with the most significant being that the metal feedstock, and more importantly the melt, does not come into contact with cold solid surfaces. This ensures a higher purity product and, at the same time, eliminates the costs related to the cooling of the crucible that is typically used.

For low melting point metals and lower purity products, this is less of an issue, but for high purity and high melting point metals, as is the specialty at AP&C, this gives an edge over competing technologies.

The first production step is to straighten the feed wire to ensure its optimal positioning at the apex of three plasma jets. The speed of the wire also needs to be monitored in order to control and adjust the resulting particle size distribution. Three DC plasma torches, each delivering about 65 kW of power, are placed in a specific geometry so that the plasma jets converge on the metal wire (Fig. 4). The supersonic nozzles installed at the exit of the torches ensure a maximum gas velocity to successfully atomise the metal wire.

By using argon plasma as the atomising medium and heat source, a lower gas flow rate can be used, since the heated gas has a higher velocity and thus a stronger atomisation force is applied. Additionally, using a hot atomising gas instead of a cold one prevents the particles rapidly freezing together into irregular shapes. The plasma enables the melt to be highly superheated and the resulting cooling ensures complete spheroidisation. It is for this reason AP&C's metal powders have some of the highest levels of sphericity on the market.

A low concentration of suspended atomised particles is maintained in each of the company's production units. This is necessary to prevent the presence of satellites. Satellites have the effect of reducing powder flowability, so extra care is taken in their prevention.

Powder collection is done via a typical cyclonic device and the powder is carefully passivated to ensure safe manipulation in open air by the company's staff and its clients. Furthermore, passivation allows a better control of the added oxygen.

Another advantage of plasma atomisation technology is that almost any metal can be atomised. This means that AP&C can offer customised atomisation services. This even applies if customers require a particular alloy in small quantities down to 100 kg. Customers can also provide the metal wire feedstock, relying on AP&C to undertake the atomisation service.

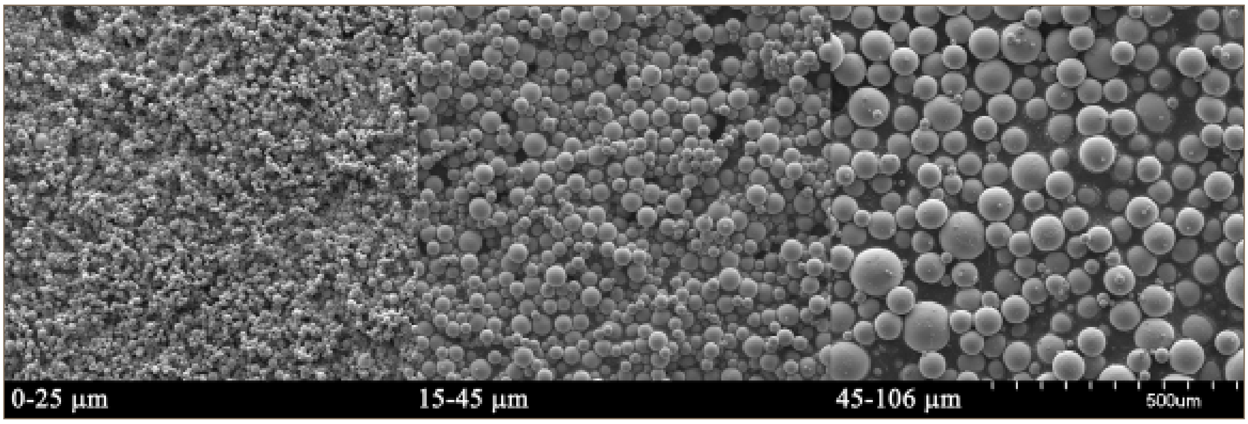


*Fig. 6 SEM's of AP&C's (left) 0-25 μm powder, (centre) 15-45 μm powder and (right) 45-106 μm powder*

## Application focused post-production powder treatment

With the development of new innovative technologies, the use of metal powders to form complex components has expanded from its origins in the automotive sector to sectors with far longer development cycles, such as the biomedical and aerospace sectors. While MIM, HIP and rapid prototyping technologies mature and set higher standards, so must powder manufacturing techniques.

At AP&C, the powder manufacturing process is monitored and controlled from ingot to final delivery. This careful monitoring has allowed AP&C to consistently deliver the highest quality powder while meeting client specific needs in terms of elemental composition, size distribution and flowability.

To achieve this goal, after the passivation stage, the powder is sieved with an ultrasonic resonator according to the client's size distribution needs. Typically the plasma atomisation process delivers powders with sizes up to 300 μm. The most frequent demands are for 0-25 μm, 0-45 μm, 15-45 μm and 45-106 μm. For cut sizes smaller than 25 μm, a gas separation apparatus, based on saltation velocity theory, is used to ensure the effective removal of the smaller particles (<5 μm, <10 μm or <15 μm).

For clients requiring a highly flowable product, removal of humidity and static is also offered to ensure optimal flowability. Those two parameters are known to decrease the flowability of powders.

Fig. 5 shows the particle size distributions of different Ti-6Al-4V ELI powders measured by laser diffraction. The apparent densities of these powders are about the same (typically >2.50g/cm$^3$) but their flowability is very different. The 0-25 μm powder does not flow at all, hence it is targeted towards cold spray or surface finish application. The 0-45 μm powder does not flow under normal conditions of temperature and humidity but in a controlled environment with low humidity and without static it can flow. The 15-45 μm powder has been specially engineered to flow in under 35s in the Hall flowmeter according to ASTM-B213. Finally, the 45-106 μm powder flows in less than 25s in the Hall flowmeter according to ASTM-B213. As demonstrated with the SEM pictures in Fig. 6, the high sphericity of the powder is seen in every size distribution and very few satellites are present.

Over the years, AP&C has gained the trust of many biomedical and aerospace companies with its attention to detail and the consistent high quality of its products. It is by pursuing this philosophy that the company continues to develop new products and improve existing ones.

## Atomising metals with higher melting points

While the titanium and titanium alloy powders produced at AP&C enjoy increasing demand, the frequent requests received for new materials has led the company to perform research and adapt its processes to be able to atomise, into spherical powders, materials with high melting points which cannot easily be obtained by other manufacturing processes. This year, the company's plasma atomisation process successfully atomised niobium (Nb), molybdenum (Mo) and nickel-titanium alloy (nitinol), a superelastic and memory alloy that is extremely difficult to process given its sensitivity to any crystallographic modification.

AP&C's R&D team strives to understand powder behaviour at micron scale. This knowledge is helping the company to constantly improve its technology, adapt to the growing needs of its customers and understand the materials that they are working with.

The company's R&D team is currently completing the development of a new generation of its plasma atomisation production unit, with the pre-production testing phase underway. With this new unit, AP&C will be able to atomise pure metals and alloys with even higher melting points, such as tungsten, in 2012. Due to its high melting point, spherical tungsten powder is rarely found on the market. It is the company's hope that its unique plasma atomisation process will allow its processing in the near future.

In partnership with a sister division, Raymor Nanotech, AP&C is also working on the integration of carbon nanotubes (CNT) and metal powders in order to develop new and enhanced composite materials that can be used as feedstock for existing manufacturing equipment. Enhancing existing products and developing new high-end products to meet evolving customer needs is an integral part of the mission of Raymor AP&C.

## Contact

Bruno Beauchamp
AP&C (Division of Raymor Industries Inc.)
3765 La Verendrye, Boisbriand, Québec J7H 1R8, Canada
Email: bbeauchamp@raymor.com
www.raymor.com