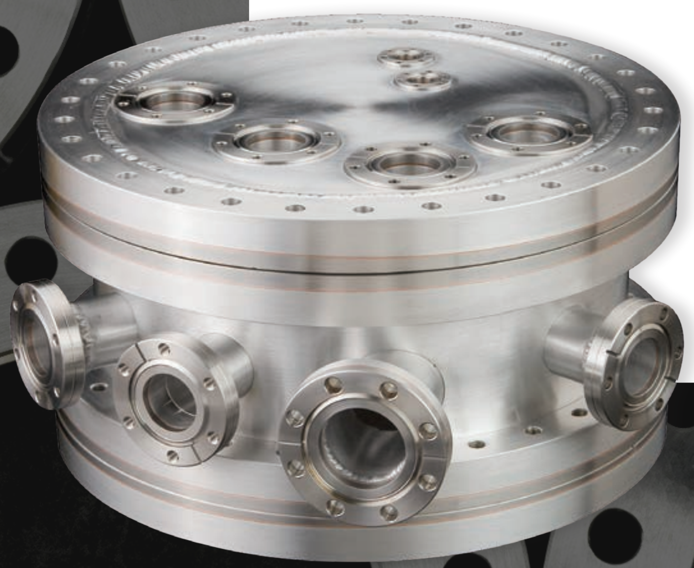
Atlas TECHNOLOGIES

Solving Complex Engineering Challenges

FROM SPACE MISSIONS TO PARTICLE COLLIDERS TO SEMICONDUCTOR FABRICATION

BONDED DISSIMILAR METALS

As science and industry become increasingly complex, engineers are continually looking for metals that solve their design dilemmas. Bonded dissimilar metals offer vastly improved performance while minimizing the design trade-offs of single metals.



ALUMINUM & TITANIUM VACUUM SOLUTIONS

For applications requiring non-magnetic, contamination-free vacuum environments, aluminum and titanium chambers offer benefits especially important for ultra-high vacuum (UHV), extra-high vacuum (XHV), and ultra-high purity (UHP) applications.

Useful Properties of Common Bonded Dissimilar Metals

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Al ALUMINUM

- High strength to weight
- High thermal conductivity
- Highly manufacturable
- Non-magnetic
- Corrosion resistant
- Excellent vacuum properties
- Low nuclear activation

Cu COPPER

- High thermal conductivity
- High electrical conductivity
- High thermal mass
- Corrosion resistant
- Strong
- Non-magnetic
- Antibacterial

Nb NIOBIUM

- Highly heat resilient
- Corrosion resistant
- Strong
- Superconductor at cryo temperatures

SS STAINLESS

- Strong
- Durable
- Corrosion resistant
- Temperature resilient
- Hygienic
- Easily weldable

Ti TITANIUM

- Excellent strength to weight
- Highly corrosion resistant
- Extreme temperature resilient
- Poor thermal conductor
- Non-magnetic

1 Al, Ti Vacuum Chambers
UHV, Semiconductor, Quantum, Aerospace, Cryogenics, Research

2 Cu + SS Transitions
Cryogenics, Energy, Semiconductor

3 Al + SS Flanges
UHV, Semiconductor, Quantum, Research

4 Al + SS Transitions
Aerospace, Energy, Research

5 Ti + SS Fittings and Flanges
Aerospace, Energy, UHV, Semiconductor, Quantum

6 Nb + SS Transitions
Aerospace, Energy, Optics, Cryogenics, Medical

7 Ti + Al Fittings and Flanges
Aerospace, Energy, UHV, Semiconductor, Quantum

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Why Bimetal?

4 KEY BENEFITS

1

SOLID-STATE BONDS ARE RELIABLE AND LONG-LASTING

Solid state bonds – those created through explosion, diffusion, or roll bonding – provide a molecular bond that withstands extreme temperatures, corrosive environments and wrenching forces. These hermetically bonded metals can additionally be machined and welded to adjacent metals. This creates robust connections suitable for the demands of semiconductor fabs, chemical processing, cryogenics, aerospace, and particle physics labs where even infinitesimal porosity or leakage is intolerable.

2

CONTRASTING PROPERTIES IN ONE MACHINED COMPONENT

Metallurgically bonded metals can be designed and manufactured to exploit varied properties all in one component with no additional bonding methods or assembly. That means capturing the positive traits and/or reducing the negative impacts of each metal. For example, highly conductive materials bonded to poor thermal conductors control heat transfer, while a lightweight metal bonded to another stronger metal withstands wind forces.

3

STRONGER, HEAT AND CORROSION RESISTANT TRANSITIONS

Bonded metals prevent corrosion in seams between dissimilar metals. A welded or glued transition at a critical connection may allow salt water, sewage, or caustic liquids into the seam, facilitating deterioration. Similarly, a bonded metal transition in jet or rocket engine fuel lines can manage heat more effectively than standard welds between dissimilar metals. These bonded joints are also stronger.

4

REDUCED COSTS

By transitioning to a lower cost metal where allowable, overall project costs can be lowered. Other cost savings can be achieved through improved manufacturability. Metals that are difficult to weld or machine can be bonded to metals that are easily manufacturable to reduce costs.

Making the Case for Bonded Bimetal

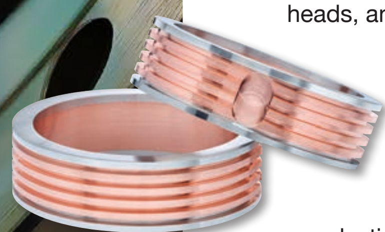
NIOBIUM AND STAINLESS TAKE THE HEAT

In a recent project for Benchmark Space Systems, Atlas Technologies manufactured niobium/stainless transition rings to connect stainless-steel rocket thruster heads to niobium alloy nozzles. These bimetallic transition rings sit at a critical junction in the system, managing the 2000-degree temperature differential within a span of less than ½ inch.

The niobium is necessary to handle the temperature extremes but is expensive. Although there would be no technical drawback to using it in the entire fuel delivery system, it costs considerably less to switch to stainless steel in lower heat sections.

COPPER AND STAINLESS MANAGE CRYOGENIC EXTREMES

Stainless steel is commonly used for evaporation stages in cryogenic equipment. Because it has poor thermal conductivity, it prevents undesired transfer of external heat to the cold stage heads. However, heat also needs to be efficiently removed at these heads, and stainless steel is poorly suited for this.



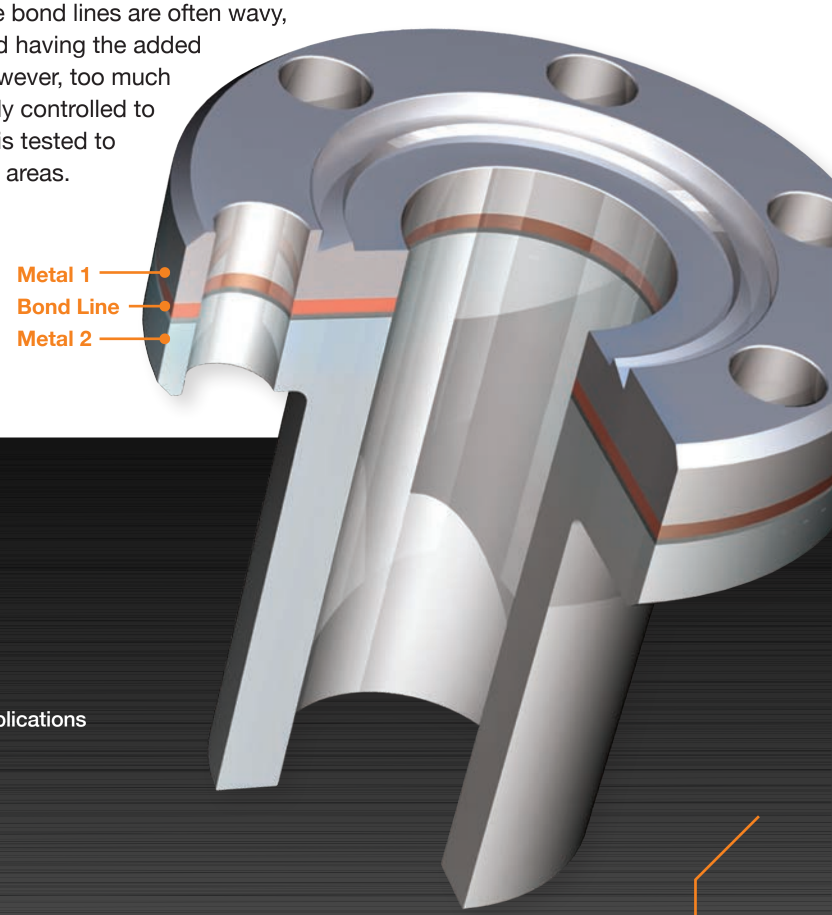
A practical solution to this problem is to bond a different metal with better thermal conductivity, such as copper or aluminum, to the stainless. Both have excellent thermal conductivity, remain ductile at cryogenic temperatures, and meet manufacturability and cost requirements. The combination of high thermal conductivity in one location and poor thermal conductivity in another enables efficient heat management. In a recent cryogenic project, custom Atlas copper stainless water jackets were employed to great success.

Bonding Processes

A successful metal bond can be challenging to achieve. For example, explosion bonding requires careful control of multiple parameters including type of explosives, plate position, interlayer metals, temperature, contamination, and detonation velocity. Roll bonding relies on precise pressure, temperature and oxide control. Quality and expertise are critical.

In explosion bonding, when the plates impact one another, a plasma forms in the first few atomic layers and propagates across the sheets, removing contaminants and forming an electron bond. When seen closeup, the bond lines are often wavy, a reflection of the different material properties, and having the added benefit of increasing the surface contact area. However, too much wave can be detrimental and must also be carefully controlled to avoid unwanted voids or inclusions. Weld quality is tested to ensure tensile strength and expose any unbonded areas.

Bonded metals are ideal as transitions between two metals that cannot be traditionally welded and to limit usage of expensive metals to specific critical areas.



A FEW USEFUL DISSIMILAR METAL PROPERTY COMBINATIONS

- Metals capable of maintaining mechanical strength at extremely high or cryogenically low temperatures
- Metals with high thermal conductivity versus others with insulative properties
- Metals with excellent strength-to-weight ratios compared to those with greater strength but added weight
- Metals undamaged by chemical or environmental exposures versus those that quickly corrode in the same applications

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Bimetal Possibilities Expanded

CONTRASTING PROPERTIES

Take advantage of multiple metal properties in a single machined component

THERMAL CONDUCTIVITY	Bond highly conductive materials to poor thermal conductors to manipulate heat transfer.
THERMAL DISCONTINUITY	Sandwich a poor thermal conductor like Inconel or Hastelloy within another metal to limit the transmission of heat.
THERMAL EXPANSION	Design bonded metals to intentionally change shape with temperature differences.
THERMAL RESILIENCE	Sustain multi-thousand-degree temperature differentials with one resilient metal transitioned to another as heat is diffused.
VIBRATION ATTENUATION	Manage harmonics with contrasting high and low Youngs modulus metals to attenuate vibration.
X-RAY TRANSPARENCY	Utilize the X-ray transparency of aluminum combined with opaque materials like steels for x-ray optics.

CRITICAL TRANSITIONS

Hermetically bridge dissimilar metals for contiguously welded fabrication

LIQUID AND GAS TRANSITIONS	Prevent corrosion and/or thermal damage in seams between dissimilar metals. These hermetic joints are also stronger than typical joints.
ELECTRIC TRANSITIONS	Bonded aluminum-copper joints provide 100% contact with no oxide or corrosion build-up at the interface between the dissimilar metals for buss bar and thermal bridge applications.
THERMAL TRANSITIONS	For areas of extreme heat, one metal capable of withstanding the temperatures where needed and then transition to lower cost materials
CORROSION-FREE TRANSITIONS	Bonded metals prevent corrosion and/or thermal damage in seams between dissimilar metals.

Bimetal Possibilities Expanded

REDUCED COSTS

Use expensive materials only where they are needed

EFFICIENT USE OF HIGH-PERFORMANCE METALS	Transition to lower cost metals where allowable, to lower the overall cost.
LOW-COST CORROSION RESISTANCE	Bond a corrosion resistant metal to another to prevent deterioration.
IMPROVED MANUFACTURABILITY	Bond metals that are easily manufacturable to metals that are more difficult to weld or machine.
ECONOMICAL MANUFACTURING ALTERNATIVES	Support other economical manufacturing methods – such as extrusion, casting, or forming – by transitioning from metals that don't lend themselves to these processes to those that can.
LOW-COST ELECTRICAL CONDUCTIVITY	Bond aluminum to copper to reduce cost and weight for electrical buss bars.

SPECIFIC FEATURES

Enhance critical features by adding a superior metal

RUGGEDIZATION	Bond hard metals to softer metals for robust performance.
DISTORTION CONTROL	Engineer materials to minimize distortion, misalignment, or movement caused by thermal expansion during heat cycling.
WEIGHT REDUCTION	Combine heavy, high strength metals with lighter metals to improve strength to weight ratio.
THERMAL EXTREMES	Multi metal transitions effectively maintain strength and ductility at extremely high or cryogenically low temperatures.

Why Aluminum Vacuum?

LESS CONTAMINATION

Aluminum contains about ten million times less hydrogen than stainless steel. It also has little carbon and absorbs far less gas from the atmosphere when a chamber is opened. The result is greatly reduced vessel contamination.

THERMAL CONTROL

Aluminum conducts heat ten times better than stainless steel. Thus, a chamber can be rapidly heated and cooled.
In addition, the process of baking out impurities is faster and more complete.

REDUCED RESIDUAL RADIATION

With a short neutron activated half-life, aluminum offers huge disposal savings and a priceless reduction in potential exposure to personnel.

COMPLETELY NON-MAGNETIC

Aluminum chambers are non-magnetic and offer no measurable disruption to electron and ion optics. Even when exposed to external magnetic fields, aluminum quickly loses magnetization when those influences are removed.

VIBRATION DAMPENING

With significant vibration dampening, aluminum is ideal for precision applications where excess vibration can have disastrous consequences.

IMPROVED BOTTOM LINE

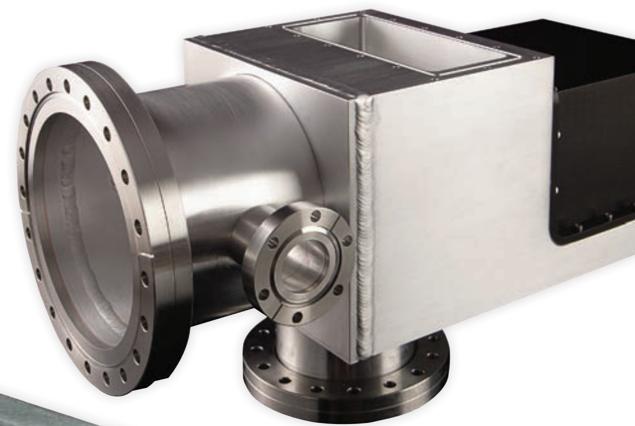
Lighter in weight and less expensive than stainless, aluminum is also easier to manage, less costly to ship and faster to machine.

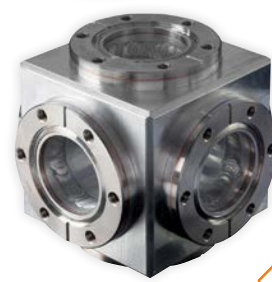
Why Titanium Vacuum?

For extreme high vacuum (XHV), titanium will often be the best choice. Due to material costs and slower machining capabilities, it is typically used only when extreme high vacuum is required or in other demanding applications such as particle physics, cryogenics, aerospace, and medical.

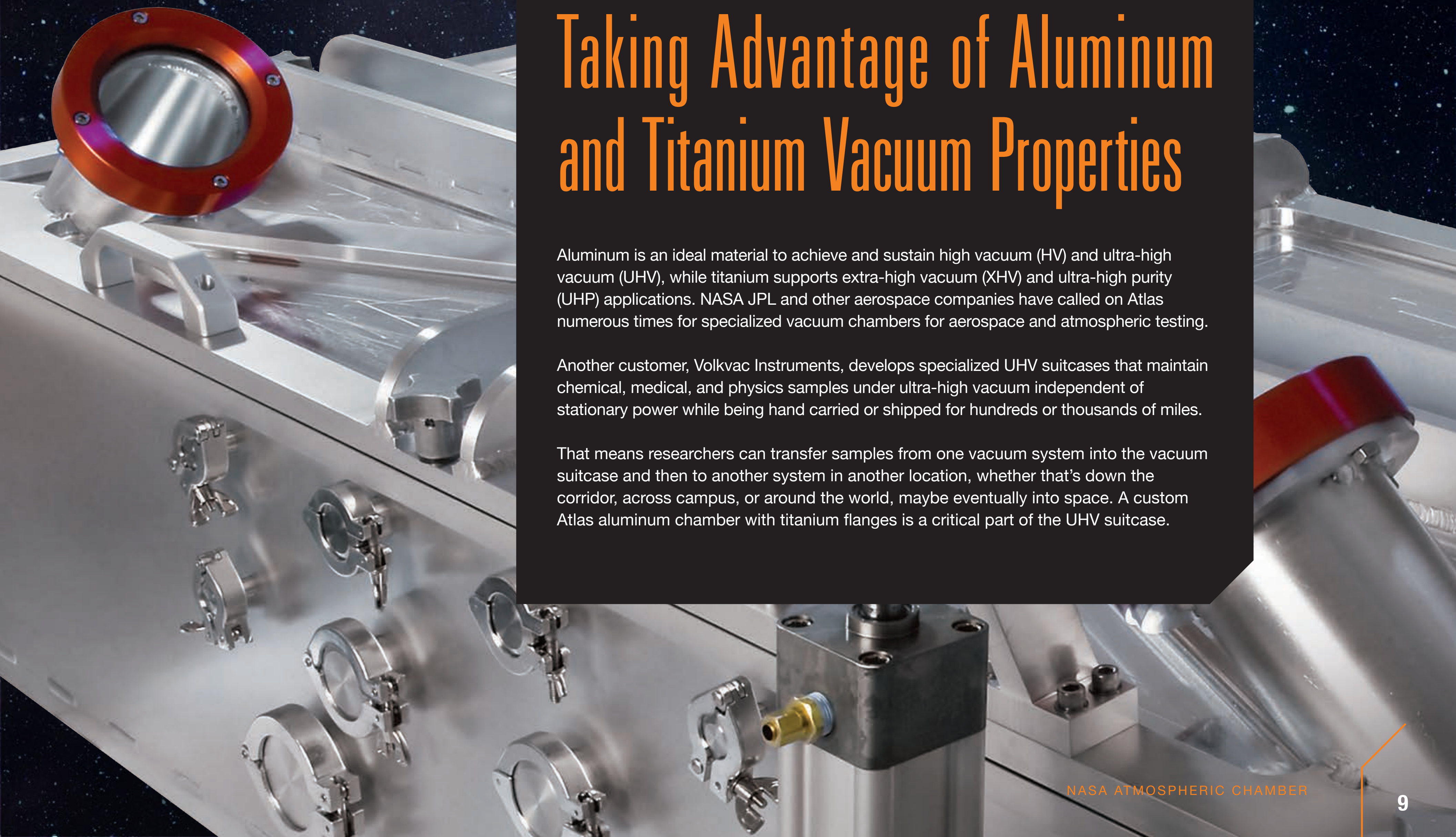
KEY BENEFITS:

- Once activated, behaves as a getter to absorb hydrogen
- Low thermal conductivity and expansion
- No hydrogen for ultra-pure vacuum
- No carbon for greatly reduced contamination
- Non-magnetic
- Corrosion resistant
- 45% lighter than steel





Aluminum and titanium vacuum chambers used in electron beam manipulation, medical research, and nanotechnology



Taking Advantage of Aluminum and Titanium Vacuum Properties

Aluminum is an ideal material to achieve and sustain high vacuum (HV) and ultra-high vacuum (UHV), while titanium supports extra-high vacuum (XHV) and ultra-high purity (UHP) applications. NASA JPL and other aerospace companies have called on Atlas numerous times for specialized vacuum chambers for aerospace and atmospheric testing.

Another customer, Volkvac Instruments, develops specialized UHV suitcases that maintain chemical, medical, and physics samples under ultra-high vacuum independent of stationary power while being hand carried or shipped for hundreds or thousands of miles.

That means researchers can transfer samples from one vacuum system into the vacuum suitcase and then to another system in another location, whether that’s down the corridor, across campus, or around the world, maybe eventually into space. A custom Atlas aluminum chamber with titanium flanges is a critical part of the UHV suitcase.

Bimetal and Vacuum Applications

Bimetal applications often cross lines between aerospace and energy, semiconductor and cryogenics, or quantum technology and all the research that extends from it. Atlas bimetal components and aluminum vacuum chambers work in tandem to support each of them.

AEROSPACE

Atlas bimetal components are found in lunar landers, rocket thrusters, and satellites. Vacuum chambers are common in research facilities studying space and atmosphere, national defense, gravity, new energy, and materials innovations.

Blue Origin, SpaceX, NASA and various national labs working in aerospace and defense come to us for help designing and manufacturing complex products that need to perform relentlessly in the most demanding environments.

One customer who straddles aerospace, defense, and cryogenics fields, offers cold atom sensors for measuring gravity. This technology has proven useful in navigation and threat location as well as mapping materials found in the earth's crust. Atlas bimetal fittings withstand the temperatures necessary to achieve success. Another aerospace customer focused on rocket thrusters and engines uses our aluminum stainless demountable ATCR fittings in their test chambers.

Atlas solutions are found in:

- Atmospheric and space simulation chambers
- Gravitometers
- Commercial and government satellites
- Moon landers
- Rocket thrusters

OEM

From tiny startups to vast organizations, our many OEM customers work across all industries.

- Semiconductor fabs
- New energy forms
- Analytical life sciences
- Quantum sciences
- Cryogenics
- Chemical manufacturing
- CVD
- Aerospace

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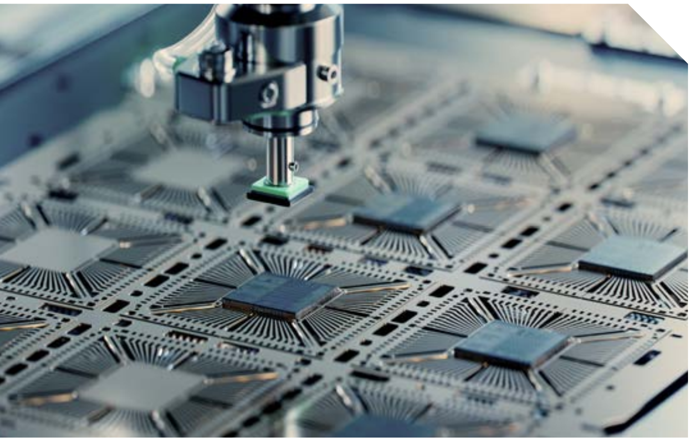


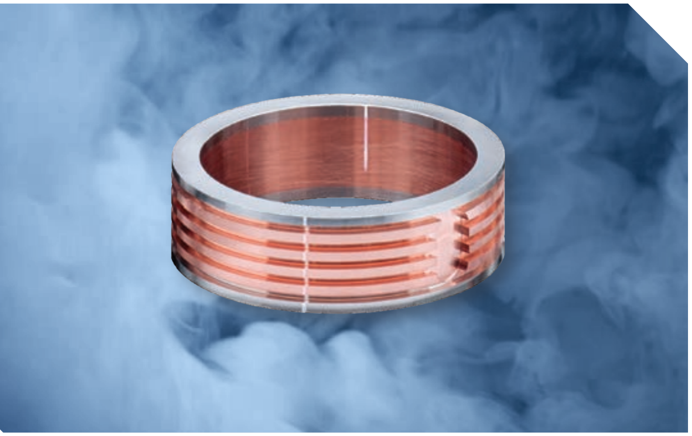
SEMICONDUCTOR

Nearly all processes in semiconductor manufacturing require the low-pressure, contamination-free environment found inside a vacuum chamber. Aluminum and titanium vacuum chambers with bimetal fittings and flanges offer benefits especially important for ultra-high vacuum (UHV), extra-high vacuum (XHV), and ultra-high purity (UHP) applications.

One of our current customers uses our aluminum chambers and bimetal components in their extreme ultraviolet lithography setups to nanofabricate semiconductor chips. Another relies on our robust bimetal solutions to manufacture specialized crystal wafers, while a third works in cooled infrared materials and large format circuit design.

Our semiconductor customers use Atlas solutions for:

- Etching and lithography
- Ion implantation
- CVD and PVD processes



CRYOGENICS

For a recent project, Atlas manufactured a fitting with copper sandwiched between stainless to help manage heat transfer and allow our cryocooler customer to continue their quest for ever colder temperatures and capacities.

Another customer who straddles aerospace, defense, and cryogenics fields offers cold atom sensors for measuring gravity. Atlas bimetal fittings withstand the temperatures necessary to achieve success. Our all-titanium CF flanges and face seal fittings suit applications requiring rugged durability, low weight and fully non-magnetic qualities. Numerous cryogenics customers rely on Atlas vacuum chambers as well.

Cryogenics customers use Atlas solutions for:

- Medical and pharmaceutical research
- Quantum technologies
- Chemical manufacturing
- Physics research

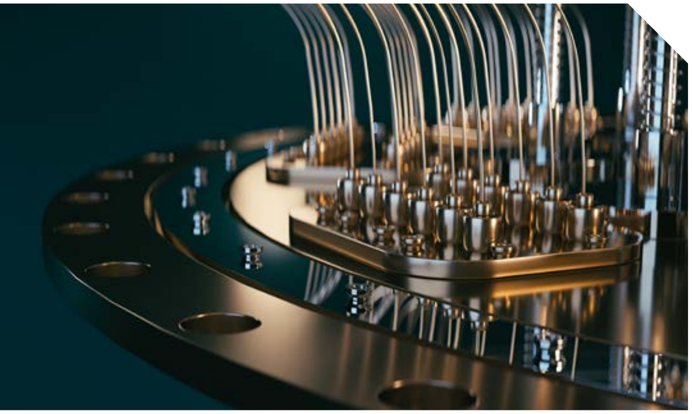
ENERGY

As new fuel types become available, the possibilities for bimetal usage will expand. Meanwhile bonded dissimilar metals are used to manage and withstand the heat, steam, and corrosives common in oil and gas extraction and refinement, as well as in nuclear facilities. Bimetals are also used in the research of emerging options like fusion and biogas, and in lithium battery production.

FUSION Numerous national labs and research facilities have reached out to Atlas for bimetal components and custom vacuum chambers to support their work.

ENERGY RESEARCH Beyond fusion, Atlas aluminum chambers with bimetal connections are used to research new photovoltaics, methane and ammonia energy applications, and energy storage options.

OIL AND GAS Because pipes and critical transitions are often found in difficult to access locations, bimetal fittings make sense.



QUANTUM SCIENCES

Our current quantum technology customers are working on exciting advances in sustainable energy, new medicine, futuristic new chips and more. Because quantum systems require the utmost cleanliness, limited magnetic interference, and low vibration, Atlas aluminum chambers with bimetal flanges offer unique advantages. In addition, our bonded dissimilar metal transitions support the necessary cryogenic applications.

For a recent project, our client asked us to build a large custom aluminum chamber with all bimetal aluminum-stainless flanges to house their latest quantum computer. The black-anodized, welded design is fully leak tested and allows safe access to the computer.

Atlas bimetal fittings and aluminum and titanium chambers are used to facilitate:

- Super conducting thin film circuits
- Laser manipulation
- Ion trapping environments

NATIONAL LABS

What an exciting time to be involved in science. Atlas bimetal solutions and aluminum vacuum chambers are used in every area of research and have been for decades. Below are a few of the labs and projects we've been a part of over the years.

Brookhaven National Laboratory
Los Alamos National Laboratory
Lawrence Livermore National Laboratory
Berkeley Lab
Fermilab
University of Maryland

BROOKHAVEN From disease vector research to ion colliders, climate research to nanoscale materials development

LOS ALAMOS Working on national security and the biotechnology, physics, energy, and advanced sciences to support it

LAWRENCE LIVERMORE One of the earliest to reach break-even energy output in a fusion reactor, LLNL also focuses on global security, climate and energy, and physical and life sciences

LAWRENCE BERKLEY Focused on clean energy and a healthy planet, photovoltaics, bio manufacturing (biodegradable methane-based polymers for instance), and carbon negative materials

FERMILAB Learning how the universe works takes a lot of science, a lot of people, a lot of bimetals, and constant new innovations through particle physics research and accelerators

UNIVERSITY OF MARYLAND Their current research areas are batteries, environmental energy, nanostructures for energy storage, materials innovation, and renewable biomaterials

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DESIGN • DEVELOP • MANUFACTURE • SUPPORT

Our customers count on us to design, develop, manufacture and support a broad range of bimetal and multi-metal assets—everything from tiny fittings used in rocket thrusters to vacuum chambers housing quantum computers.

EXPERTISE IN DISSIMILAR METAL BONDING & ALUMINUM AND TITANIUM VACUUM

With 30 years' solid state metal bonding experience, along with our expertise in machining and welding, we understand the metallurgical challenges of joining dissimilar metals. And we've been designing and manufacturing high performance vacuum chambers just as long. We regularly bond and machine aluminum, titanium, niobium, copper, and stainless steel in our fully integrated facility located in the United States, and we happily help customers with other metals as needed.

Let us help you solve your complex engineering problems.

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