CARPENTER TECHNOLOGY

Advanced Materials Solutions for Semiconductor Production

World-class specialty metals for demanding applications

Booth #L1205

Tom Pease

Senior Metallurgist

Tom Pease is a Senior Regional Metallurgist at Carpenter Technology Corporation based in Philadelphia, Pennsylvania. He received his B.S. in Materials Science and Engineering from Pennsylvania State University with a focus on metals. Tom is the subject matter expert at Carpenter Technology for the semiconductor industry. In his role as a Regional Metallurgist, he currently serves the east coast territory of the U.S. and Canada, supporting key customers and business development opportunities across all markets.

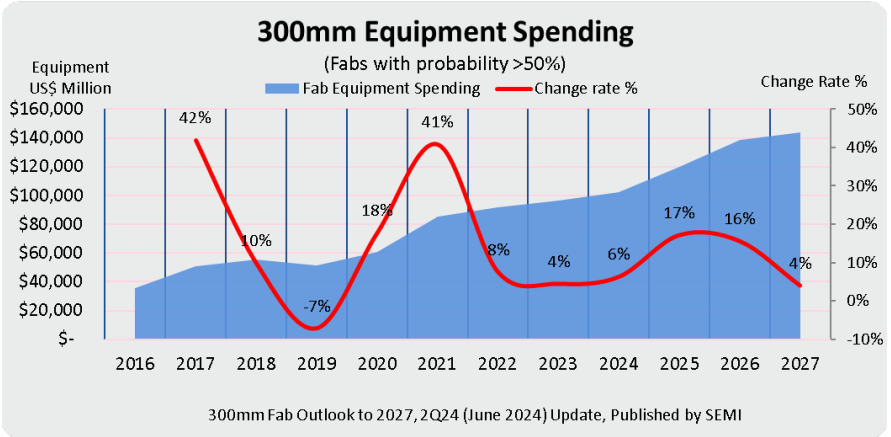
Your partner in keeping up with Moore

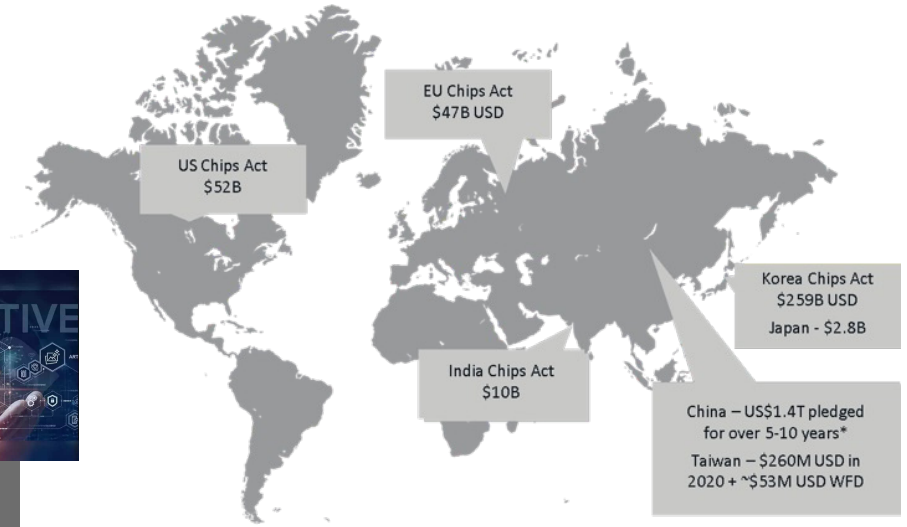
Compounding market growth

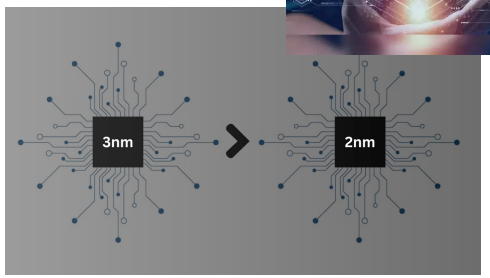
- Strong growth in the segment with equipment spending projecting 13.7% CAGR
- General increase in semiconductor demand across all industries (Generative AI, IoT, Electrification, etc.) driving need for FABs
- Strong global incentives are driving regionalization for national security
- $366B USD of investments in FABs 2022–2027

With more demanding technical performance

- Increasingly demanding needs for material performance as we advance technology to finer nanometers and increased chip complexity
- Introduction of new gases and higher temperatures for advanced FAB builds







Carpenter Technology: Leader in specialty materials and solutions

135+ years
of innovation in specialty alloys

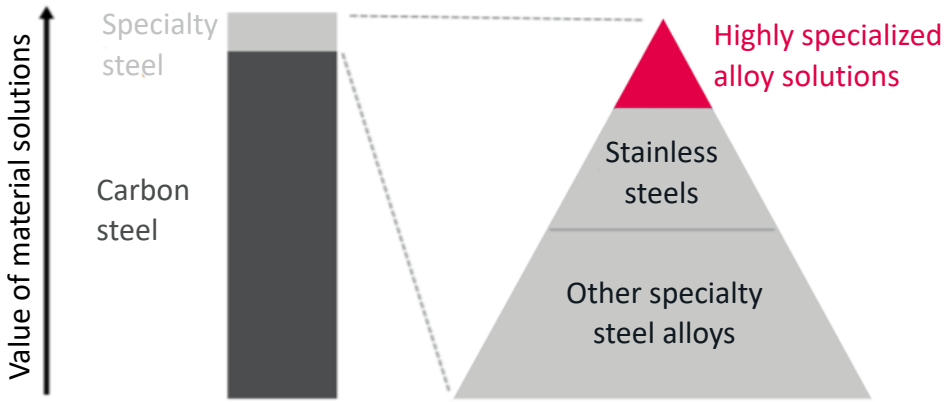
~$2B sales

Global presence
Sales, distribution, manufacturing

Product forms

1. Ingot / Billet
2. Strip
3. Wire
4. Bar
5. Powder
6. Components

Global steel production (volume)



A trusted partner for your engineered solutions for 135 years

Carpenter Technology metallurgical R&D capabilities

Rich history of developing benchmark alloys for critical applications

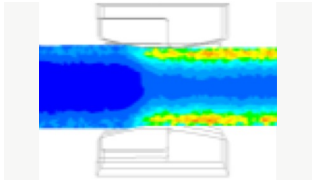
- Integral part in creation of SEMI-F20 specification

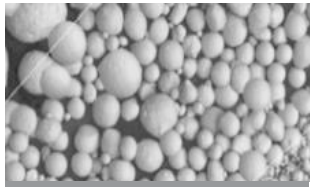
World-class capabilities and supporting infrastructure

- 350-lb VIM atomizer
- 30- and 400-lb lab VIM furnace
- Lab-scale ESR and VAR furnace
- 500-ton lab press, hot mill, cold mill, and wire drawing

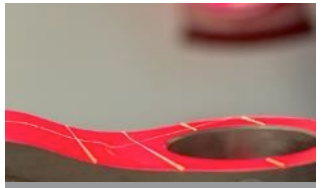
Diverse collaborative network

- National laboratories, industrial research laboratories, universities

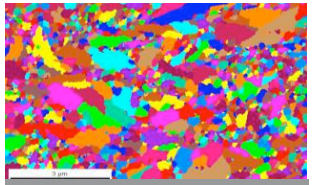

Modeling


Metallic powders


Forming


Process technologies


Alloy development


Materials characterization

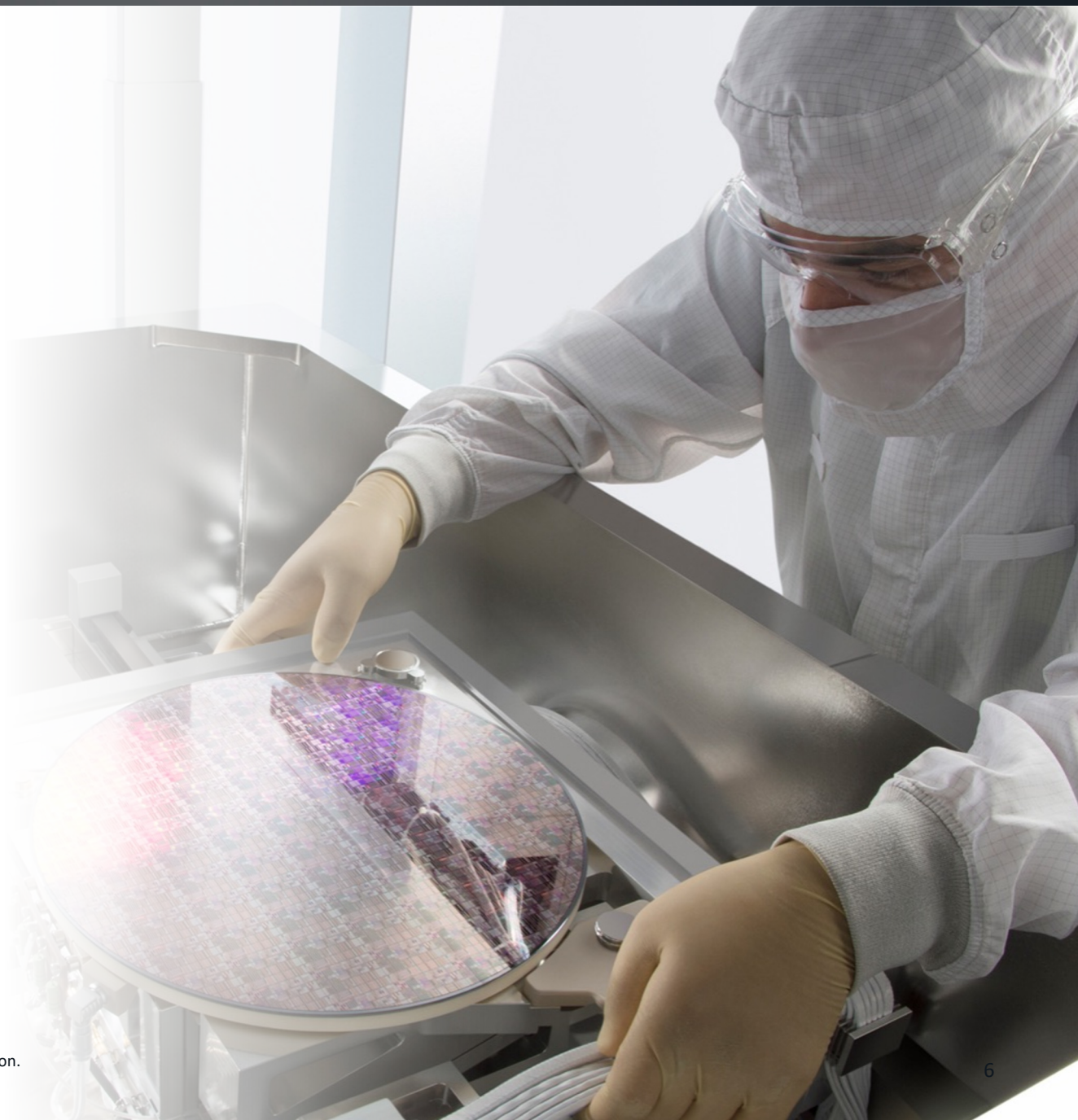

Applied & basic research


Additive manufacturing

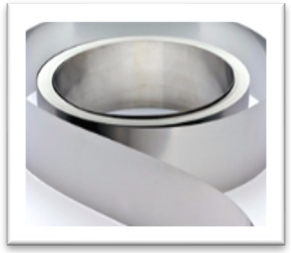

Soft magnetics

Alloy solutions for semiconductor applications

- The leader in high-purity alloys for the semiconductor industry. We deliver solutions that enable component fit for corrosive environments with no tolerance for contamination.
- The largest VIM capacity in the world
- A majority producer of high-purity 316L-SCQ® to support SEMI-F20 standards
- A supplier to many major producers of valves, fittings, and other semiconductor applications in support
- Three standard variants of 316L-SCQ® and multiple custom variants to support unique application needs, including:
  - Corrosion resistance
  - Cleanliness
  - Weldability
  - Machinability
  - Electro-polishability



Partnering to excel in critical applications for semiconductor FABs



	FLUID DELIVERY (DEP, ETCH, FAB)	MEASUREMENT SYSTEMS	MOTION SYSTEMS	SHIELDING
Application	• Valves • Fittings • Regulators • Filters	• Sensors, mounts	• Linear actuation • Galling prone applications (nuts, etc.)	• Flux concentrators • Shielding
Alloy	• 316L-SCQ® • Conichrome®/ Elgiloy® (Co-Cr-Ni-Mo) • C-276, 625, C-22	• 316L-SCQ® • 13Cr-8Mo • Invar • Super-Invar 32-5	• Gall-Tough® • Nitronic® family • 440C	• High-Perm 49 • HyMu 80
Key Value Drivers	• Corrosion resistance • Cleanliness • Weldability • Machinability • Electro-polishability	• Uniformity • Thermal stability	• Galling, wear resistance	• Magnetic induction

The largest product breadth for the semiconductor industry

316L-SCQ®

Best-in-class surface finish

- An austenitic stainless tailored to have the best combination of corrosion resistance, electro-polishability, weldability, machinability and cleanliness.
- Sulfur content, which influences inclusion content, machinability, and weldability can be customized in tight ranges less than 0.015%
- For improved internal cleanness and reduced inclusion content, carefully selected melt stock is utilized to restrict the occurrence of typical residual elements and melted by either:
  - Air melting + vacuum arc remelting (AOD + VAR)
  - Vacuum induction melting + vacuum arc remelting (VIM + VAR), depending on the level of micro-cleanness required

24 Cr CHROMIUM

26 Fe IRON

28 Ni NICKEL

C-22

Superior corrosion resistance

- Nickel-moly-chromium-tungsten alloy providing exceptional protection from pitting, crevice corrosion, stress corrosion cracking and oxidizing chemicals.
- Higher corrosion resistance than other alloys in the family, such as C-276, due to its higher Cr content.
- C-22 is ductile and exhibits excellent weldability for ease of fabrication
- Melted by a combination of electric arc melting and electroslag remelting (ESR) for a clean and homogeneous microstructure.

24 Cr CHROMIUM

28 Ni NICKEL

42 Mo MOLYBDENUM

74 W TUNGSTEN

Conichrome®

Superior corrosion resistance

- Non-magnetic, austenitic nickel-cobalt-chromium-molybdenum alloy
- Possesses a unique combination of extremely high strength, ductility, excellent corrosion resistance, and fatigue strength
- Manufactured using premium melting and remelting operations for extremely low inclusion content and improved homogeneity
- Can be cold worked or cold worked + aged to increase ultimate tensile strength to 280+ ksi

24 Cr CHROMIUM

27 Co COBALT

28 Ni NICKEL

42 Mo MOLYBDENUM

Invar

Best-in-class thermal expansion

- Nickel-iron alloy with a rate of thermal expansion approximately one-tenth that of carbon steel up to 400°F
- Available as a free machining version
- Invar is forgeable, weldable, and can be blanked and cold formed with relative ease
- Super Invar 32-5 is also available and is premium melted and designed to provide minimum thermal expansion at room temperature

26 Fe IRON

28 Ni NICKEL

High Permeability 49

Highest saturation flux density of any nickel-iron alloy

- 48% nickel-iron alloy
- Vacuum induction melted (VIM)
- Saturation flux density of about 1600 gauss (1.6 tesla)
- High initial and max permeability with low core loss
- Available in three grades: standard, rotor grade, and transformer grade
- Ideal for applications requiring extremely high permeability at low magnetizing forces to increase efficiency and effectiveness of the equipment

26 Fe IRON

28 Ni NICKEL

Bar **Wire** **Strip** **Flat Bar** **Special Shape Bar**

In a full range of sizes and shapes

SHAPE	CONDITION	SIZE RANGE
Round bar	Annealed	0.1875 in. min OD (4.76 mm) 3.25 in. max OD (82.55 mm)
Round bar	Strain-hardened	0.1875 in. min OD (4.76 mm) 2.5 in. max OD (63.5 mm)
Flat or square bar	Annealed	0.5 x 0.5 in. (12.7 mm) 3 x 3 in. (76.2 mm)
Flat or square bar	Strain-hardened	0.25 x 0.25 in. (6.35 mm) 2.5 x 2.5 in. (63.5 mm)
Special aspect ratio flat bar	Strain-hardened	2: 1 width-to-thickness ratio items 3.5 x 1.75 in. (88.9 mm x 44.45 mm)
Billet	Hot finished or annealed	3.25 in. min (82.55 mm) 4.125 in. max (104.78 mm)
Strip	Cold rolled or annealed	.004 in. thick x 14 in. wide precision strip

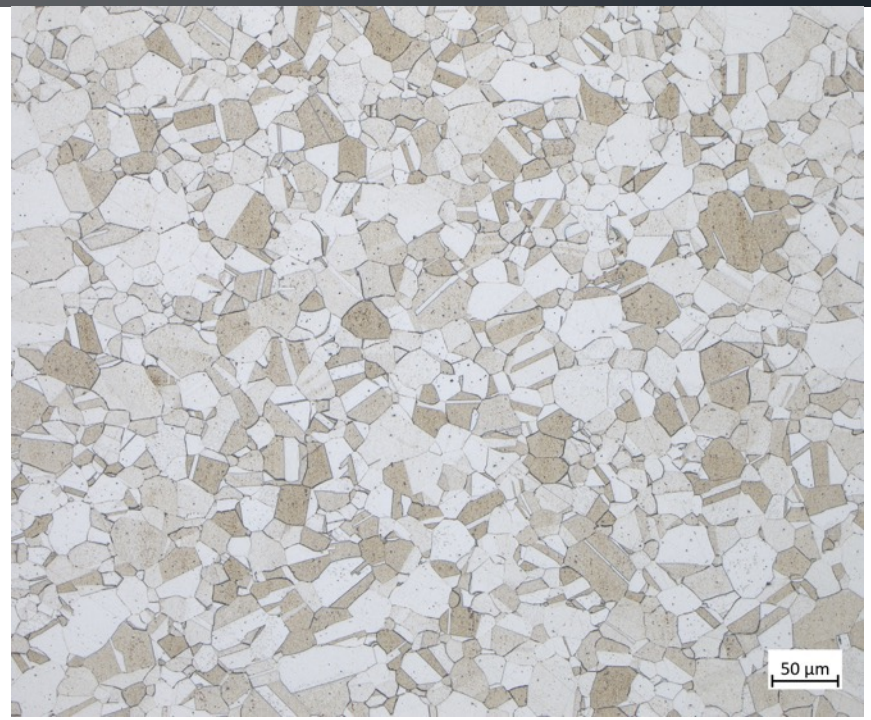
Standard products and sizes are listed above. Please do not hesitate to discuss custom product opportunities.

Advanced chips love clean steel

Why material cleanliness matters

Material cleanliness enhances **final yield**

- Material in fluid and gas systems within the semiconductor fabrication process can adversely affect final yield through contamination and corrosion.
- Higher material purity can reduce contamination in the chip manufacturing process, increasing yield.
- Improved material purity will also reduce the potential of corrosion of manufacturing equipment components, even in extreme operating environments. This minimizes operation downtime stemming from needs to replace corroded system components.
- Reduced corrosion risk boosts operation safety by diminishing the likelihood of system leaks.



Material cleanliness:

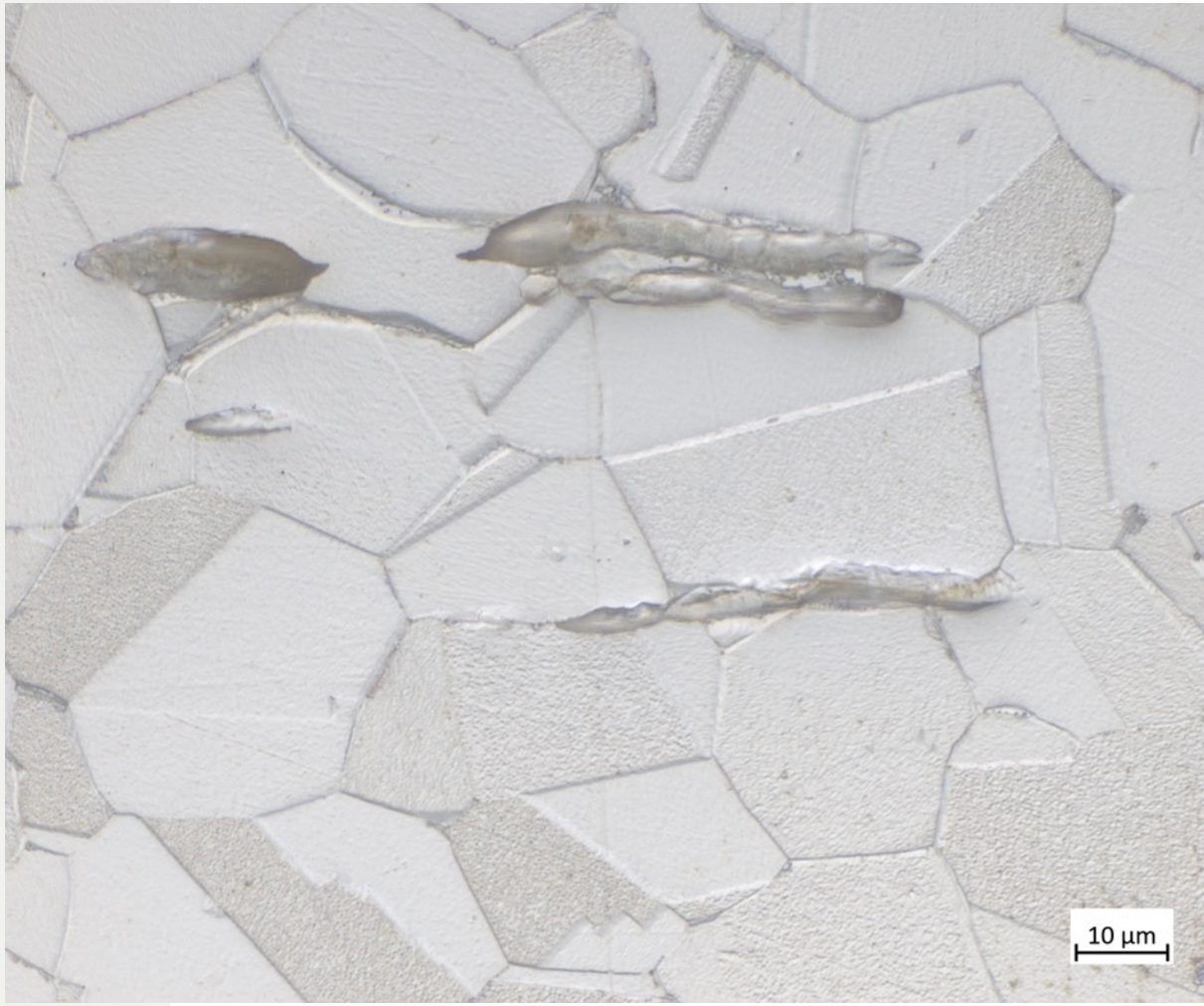
- Improves end-to-end yields
- Reduces/prevents rejects
- Reduces operating costs
- Adheres to quality standards

What is “micro-cleanliness”?

Micro-cleanliness refers to a steel's **inclusion content**

- So, what are “inclusions”?
- Inclusions are non-metallic compounds within the metal.
- Inclusions are classified into four categories (called Type) based on their morphology.*
    - Type A: Sulfide
    - Type B: Alumina
    - Type C: Silicate
    - Type D: Globular Oxide
- Inclusions are rated based on size and frequency.
- The fewer and less severe the inclusions, the higher quality the steel.
- SEMI-F20 gives maximum inclusions ratings for each purity level in accordance with ASTM E 45.

*Note that the chemical names associated with the four types were derived from historical data collected on inclusions found in these morphologies. For example, a Type C inclusion may not always be a Silicate.



Where do inclusions come from, and how do we control them?

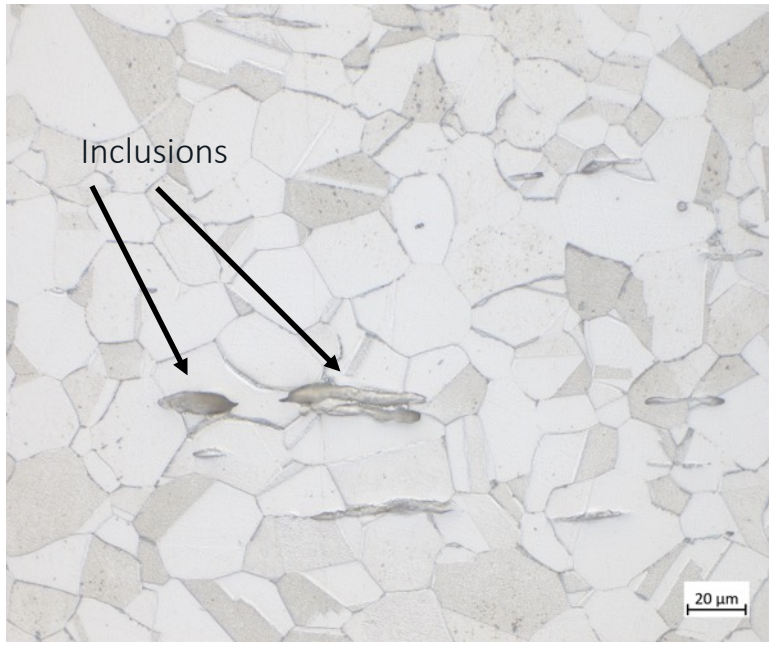
Nonmetallic inclusions are compounds formed during the primary melting process.

- As molten metal solidifies, foreign compounds solidify as inclusions.
- Controlled melt practices and premium melting decreases inclusion content.
- Tight controls over raw material feedstock restricts the amount of sulfur, aluminum, and other elements prone to forming inclusions.
- Vacuum induction melting (VIM) and vacuum arc remelting (VAR) can further reduce inclusion content by limiting oxygen content and pulling out these inclusion formers.
- All Carpenter Technology 316L-SCQ® material is VAR and meets high-purity SEMI-F20 inclusion requirements.

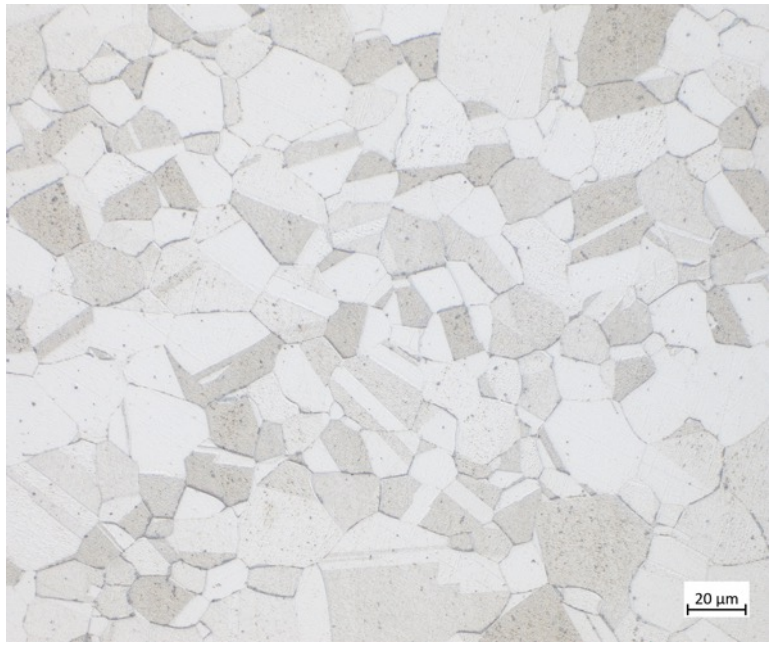
316L-SCQ® portfolio to SEMI-F20 limits for fluid delivery systems

SEMI-F20 LIMITS	GENERAL PURPOSE GRADE (GP)	HIGH-PURITY GRADE (HP)	ULTRA-HIGH-PURITY GRADE (UHP)	316L-SCQ+
• Type A • Type B • Type C • Type D	• Thin 2.5 / Heavy 1.0 • Thin 2.5 / Heavy 1.0 • Thin 2.5 / Heavy 1.0 • Thin 2.5 / Heavy 1.0	• Thin 2.0 / Heavy 1.0 • Thin 2.0 / Heavy 1.0 • Thin 2.0 / Heavy 1.0 • Thin 2.0 / Heavy 1.0	• Thin 1.5 / Heavy 1.0 • Thin 1.0 / Heavy 1.0 • Thin 1.0 / Heavy 1.0 • Thin 1.0 / Heavy 1.0	• **Thin 1.0** / Heavy 1.0 • Thin 1.0 / **Heavy 0.5** • Thin 1.0 / **Heavy 0.5** • Thin 1.0 / Heavy 1.0
Carpenter Technology Melt Type	• ARC/AOD	• ARC/AOD + VAR	• ARC/AOD + VAR • VIM + VAR	• VIM + VAR
Key Benefits	• Cost-effective offering for less critical applications	• Controlled chemistry coupled with vacuum arc remelting (VAR)	• On select chemistries, UHP can be achieved with a single vacuum melt (ARC + VAR)	• Beyond SEMI-F20 UHP limits • For ultimate cleanliness and critical applications
Shapes Offered	• Rounds, flats, hex, and large-diameter bar for seamless tubing			

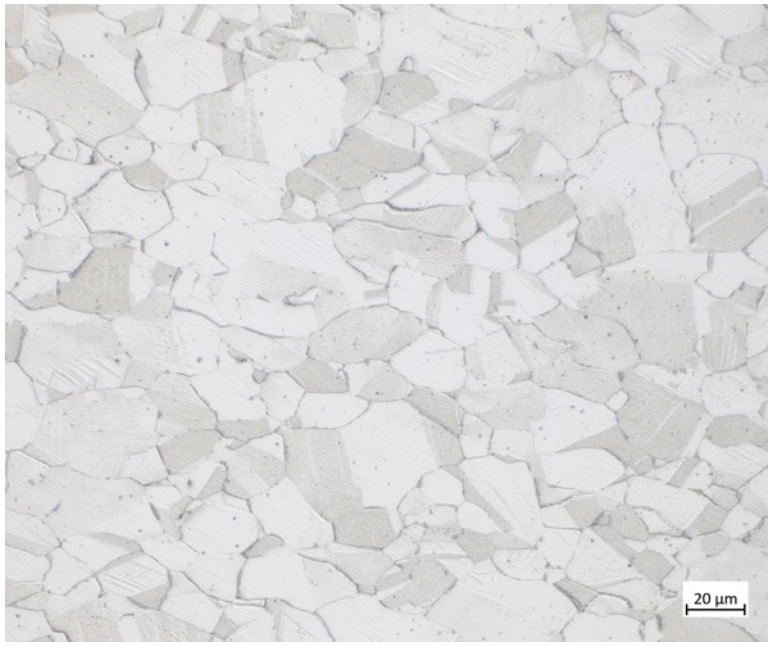
Cleanliness of 316L-SCQ®



Standard 316L Stainless Steel



ARC+VAR 316L-SCQ®



VIM+VAR 316L-SCQ®

- Improved cleanliness for better corrosion resistance and safety.
- Refined and uniform grain structure for enhanced electro-polishability.

Typical corrosion performance of 316L-SCQ®

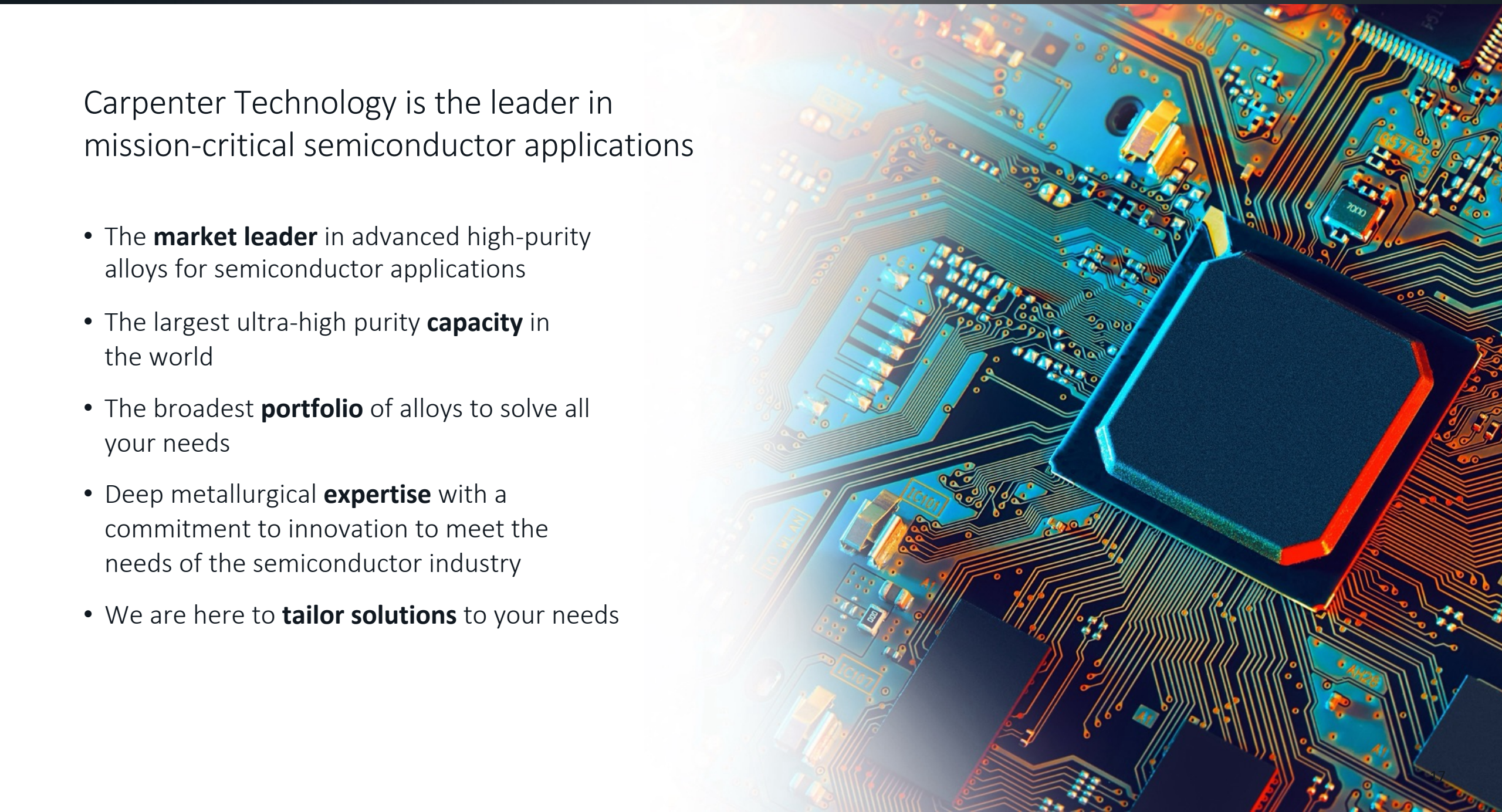
ASTM G48 Method A		
Grade	**Corrosion Rate**	
	mg/cm^2	g/m^2
Standard 316L Stainless	7.28	72.80
ARC + VAR 316L-SCQ®	< 0.70	< 7.00
VIM + VAR 316L-SCQ®	< 0.60	< 6.00

ASTM G48 Method A – Ferric Chloride Pitting Test
6% $FeCl_3$ concentration, 22°C (71.6°F), 24 hr

Note: All variants of 316L-SCQ® have 1/10th or better the corrosion rate of standard 316L SS

Carpenter Technology is the leader in mission-critical semiconductor applications

- The **market leader** in advanced high-purity alloys for semiconductor applications
- The largest ultra-high purity **capacity** in the world
- The broadest **portfolio** of alloys to solve all your needs
- Deep metallurgical **expertise** with a commitment to innovation to meet the needs of the semiconductor industry
- We are here to **tailor solutions** to your needs



Thank you

Carpenter Technology is located at booth #L1205

For additional information, please contact

info@cartech.com | 610 208 2000