



## Technical Data Sheet

### INTRODUCTION

ATI 15Mo™ Alloys (UNS R58150) is a beta titanium alloy capable of a wide variety of properties depending on the metallurgical condition. The achievable properties include low modulus of elasticity, high strength, excellent fatigue strength, good ductility/formability, exceptional corrosion resistance, and well-documented biocompatibility<sup>1</sup>. ATI 15Mo™ Alloys are manufactured as bar, rod, and wire product forms primarily for orthopedic, trauma, spinal, dental, orthodontic, and cardiovascular applications. Other product forms can be made available by request.

### MELTING

ATI 15Mo™ Alloy is formulated from two metals with greatly different elemental densities. To ensure complete melting and to minimize molybdenum segregation, these alloys are melted in a plasma arc furnace and re-melted in a VAR furnace. ATI has extensive experience with Mo bearing titanium alloys such as ATI 6246™ Alloy (6Mo), ATI 38-644™ Alloy (4Mo), and Stryker® TMZF® (12Mo).

Chemical Composition							
	N	C	H	Fe	O	Mo	Ti
% w/w, min.	-	-	-	-	-	14.00	Bal
% w/w, max.	0.05	0.10	0.015	0.10	0.20	16.00	Bal

### METALLURGICAL CONDITIONS

ATI 15Mo™ Alloy can be supplied to ASTM F 2066 in one of three different metallurgical conditions:

- Beta Annealed
- Alpha plus Beta Annealed
- Micrograined Alpha plus Beta Aged

The beta annealed condition consists of a fully recrystallized beta phase (bcc) structure. In this condition, the alloy has a modulus of elasticity that is about two-thirds the modulus of ATI Ti-6Al-4V Alloy, along with considerably improved ductility and corrosion fatigue properties<sup>2,3</sup>.

The alpha plus beta annealed condition consists of a beta phase (bcc) matrix with a significant volume fraction of alpha phase (hcp). Alpha plus beta ATI 15Mo™ Alloys provide a good combination of strength and ductility, whereas beta ATI 15Mo™ Alloy provides better ductility and formability.

Finally, a micro-grained alpha plus beta phase ATI 15Mo™ Alloy exhibiting very high notched corrosion fatigue strength but with remarkable ductility has been produced<sup>4,5,6</sup>. This condition provides the highest level of tensile and high cycle fatigue strengths, significantly exceeding typical ATI Ti-6Al-4V or ATI Ti-6Al-4V ELI levels.

### SPECIFICATIONS

ASTM F 2066 - Bar, Rod, Sheet, and Wire

- Beta Annealed Condition
- Alpha plus Beta Annealed Condition
- Alpha plus Beta Annealed plus Aged Condition

Condition	Thickness	UTS min ksi (MPa)	YS min ksi (MPa)	%EI min	%RA min
Beta	Up to 2.0" Contact ATI for other sizes	100 (690)	70 (483)	20	40
Alpha plus Beta		130.5 (900)	116 (800)	10	25
Alpha plus Beta + Aged		166.75 (1150)	152.25 (1050)	10	25

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1000 Six PPG Place  
Pittsburgh, PA 15222-5479 U.S.A.  
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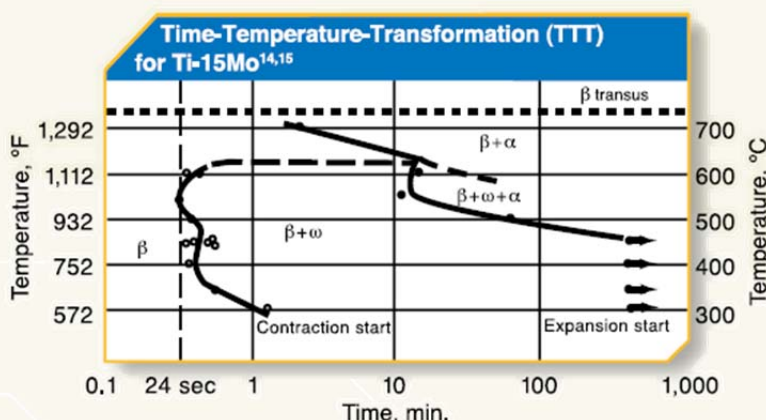
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### PHYSICAL PROPERTIES

Melting Range:	3,100 - 3,200° F (1,704 - 1,760° C)
Density:	0.179 lbs/cu. in.; 4.95 gm/cc
Beta Transus Temperature:	1,425° F (± 25 F°); 774° C (± 14 C°)
Elastic Modulus:	78 GPa in the beta annealed condition 106 GPa in the alpha plus beta annealed condition 114 GPa in the micrograined alpha plus beta aged condition

### HEAT TREATMENT

Heat treatments can be performed by methods typical for titanium alloys. Of particular concern for Ti-15Mo is the formation of the embrittling omega phase ( $\omega$ ) during cooling from temperatures near or above the beta transus. To avoid  $\omega$  embrittlement, either rapid cooling (beta annealed condition) or slow cooling (alpha/beta condition) is required.



#### Beta Annealed ATI 15Mo™ Alloy

- Anneal: 1,475 - 1,800° F (802 - 982°C), 0.5-1 hour, rapid quench to below 1,025° F (552°C).
- Stress Relief: 1,500° F (816°C), >10 minutes, rapid quench to below 1,025° F (552°C).

ATI 15Mo™ Alloy that is processed above the beta transus and is slow cooled will have an alpha plus beta phase structure.

- Anneal: 1,475 - 1,800° F (802 - 982°C), 0.5-1 hour, slow cool to below 1,025° F (552°C).
- Stress Relief: 1,500° F (816°C), >10 minutes, slow cool to below 1,025° F (552°C).

ATI 15Mo™ Alloy that is processed below the beta transus will have an alpha plus beta phase structure.

- Anneal: 1,000 - 1,200° F (538 - 649°C), >4 hour, air cool

Contact ATI for questions about micrograined alpha plus beta aged condition heat treatment.

### HARDNESS

Ti 15 Mo Condition	HRc Range
Beta Annealed	22 - 26
Alpha plus Beta	32 - 38
Alpha plus Beta + Aged	36 - 40

### FORGEABILITY/FORMABILITY

Hot and cold workability characteristics of ATI 15Mo™ Alloy are very good, which is typical for beta titanium alloys<sup>7,8</sup>. In the beta annealed condition, the low elastic modulus and exceptional ductility of this alloy are properties that contribute to an unusual springiness or “spring back” in forming and in machining. ATI 15Mo™ Alloy can be forged above the beta transus from temperatures above 1,500° F (816°C) or below the beta transus from temperatures between 1,200 - 1,375° F (649 - 746°C). An immediate water quench minimizes the formation of omega phase in thin sections of this alloy, depending upon the microstructural properties desired.

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### MACHINABILITY

ATI 15Mo™ Alloys can be machined with new and sharp tools using higher feed rates and reduced machining speeds. It is important to irrigate the tooling and work piece well with large amounts of non-chlorinated cutting fluid. Alternative metal removal methods such as water jet cutting, wire EDM, and plasma cutting have been used successfully on ATI 15Mo™ Alloy components. Take special care to avoid hydrogen, oxygen, and nitrogen pick-up at exposed surfaces when performing machining, cutting, or grinding operations.

### SPECIAL PRECAUTIONS

ATI 15Mo™ Alloys can be subject to hydrogen contamination during improper pickling and to oxygen, nitrogen, and carbon pickup during forging, heat treating, grinding, etc. This contamination may cause a reduction in ductility which could adversely affect notch sensitivity and forming characteristics.

### CORROSION RESISTANCE AND BIOCOMPATIBILITY

The passive oxide film on the surface of titanium and titanium alloys is resistant to tarnish and corrosion, and also contributes to biocompatibility and osseointegrability. A tenacious mixture of metal oxides forms rapidly on the surface of any CP grade or alloy of titanium. The chemical make-up of this adherent oxide layer is a function of the chemical composition of the titanium base metal. ATI 15Mo™ Alloys and ATI CP titanium exhibit better corrosion resistance in phosphate buffered saline solutions than ATI Ti-6Al-4V ELI and ATI Ti-6Al-7Nb. Anodic polarization measurements show that ATI 15Mo™ Alloy performs better in a test corrosive environment than ATI Ti CP-4, ATI Ti-6Al-4V ELI, and ATI Ti-6Al-7Nb Alloys<sup>9</sup>.

### NOTCH SENSITIVITY

Test method ASTM E8 is used for tensile testing of smooth tensile specimens, and method ASTM E 602 is employed for sharp-notch tensile specimens. ATI 15Mo™ Alloys, in the beta and the alpha plus beta conditions, have superior notch sensitivity resistance when compared with conventional  $\alpha + \beta$  titanium alloys, ATI Ti-6Al-4V ELI and ATI Ti-6Al-7Nb<sup>10</sup>.

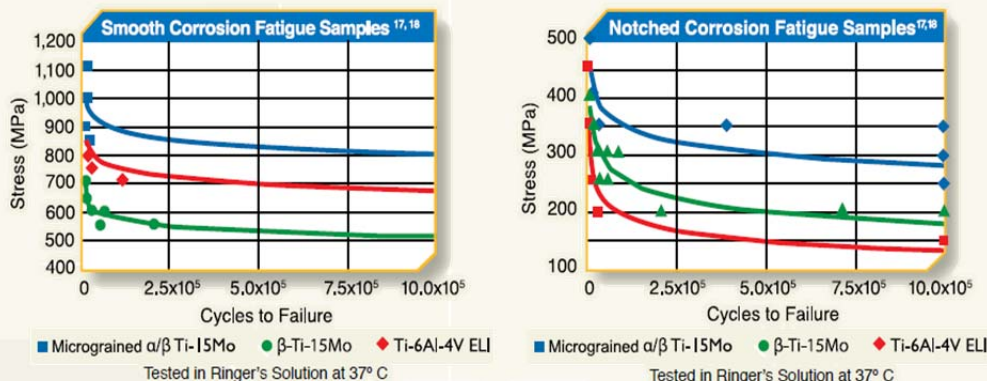
### STRESS CORROSION CRACKING (SCC) RESISTANCE

The stress corrosion cracking properties of four implantable titanium grades was investigated at the University of Mississippi Medical Center<sup>11, 12, 13</sup>. Comparable test data were generated for ATI Ti CP-4, ATI Ti-6Al-4V ELI, ATI Ti-6Al-7Nb, and both the beta and alpha plus beta annealed conditions of ATI 15Mo™ Alloy. ATI 15Mo™ Alloys are not susceptible to SCC under the conditions tested at UMMC, nor are any of the other three tested titanium grades.

### MICROGRAINED ATI 15Mo™ ALLOY STRESS CORROSION CRACKING AND FATIGUE STRENGTH<sup>4, 15</sup>

Zardiackas et. al. studied ATI 15Mo™ Alloy in both the beta and micrograined alpha plus beta aged condition with comparisons to wrought ATI Ti-6Al-4V ELI. Corrosion fatigue testing was performed in tension-tension on smooth and notched samples in both aerated distilled/de-ionized water and aerated Ringer's solution at 37°C. Fatigue testing followed the guidelines of ASTM F1801 using the given R ( $\sigma_{min}/\sigma_{max}$ ) value of 0.053.

Fatigue curves for the smooth samples show higher fatigue strengths for the micrograined alpha plus beta aged ATI 15Mo™ Alloy compared with the other titanium alloys. In the smooth condition, tested in Ringer's solution, the ATI 15Mo™  $\alpha/\beta$  Alloy had a fatigue run out limit of 800 MPa<sup>16</sup>. In the notched condition, tested in Ringer's solution, the ATI 15Mo™  $\alpha/\beta$  Alloy had a fatigue run out limit of between 250 MPa and 300 MPa.



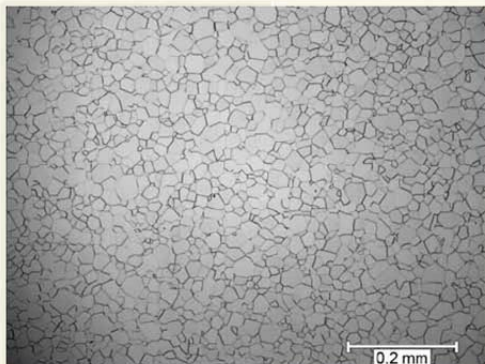
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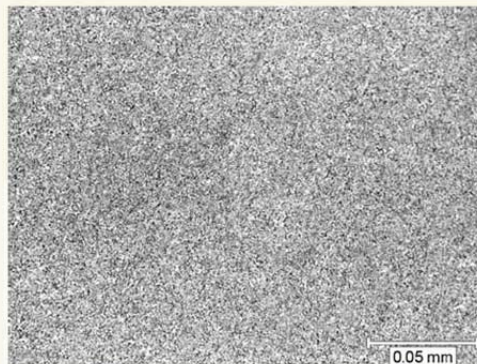


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## METALLOGRAPHY



ATI Ti-15Mo Beta Titanium Alloy, 100 X



ATI Ti-15Mo Micrograined Alpha + Beta Titanium Alloy, 500X

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