

A New Method of Low Cost Production of Ti Alloys to Reduce Energy Consumption of Mechanical Systems

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University of Utah, Ametek, Ford, ARL

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Z. Zak Fang, PI, Univ. of Utah
Ravi Chandran, Co-PI, Univ. of Utah

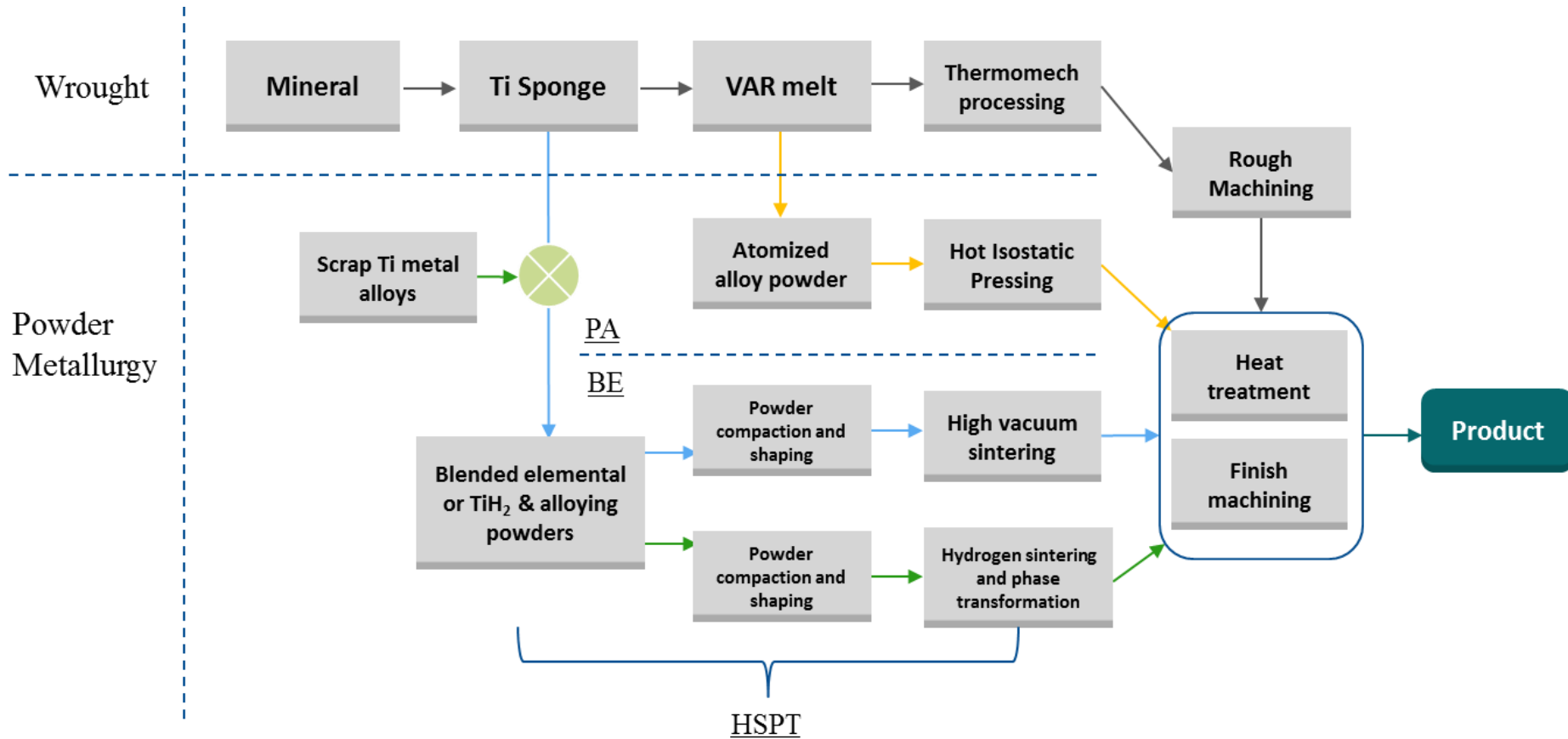
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Project Objective

- Develop a novel low cost method for manufacturing Ti
- Demonstrate the mechanical properties of Ti using the new method to be equivalent to that of wrought Ti at a fraction of its cost.
- Initiate efforts to promote the use of Ti in automobiles, balancing the energy and cost considerations
- Traditional wrought Ti is too expensive
- Traditional powder metallurgy Ti is either inferior, or lacks significant cost advantage
- Affinity of Ti to oxygen makes Ti extraction, melt refining, forging / rolling, and machining, all extraordinarily costly

Manufacturing Routes of Ti Products



Technical Approach

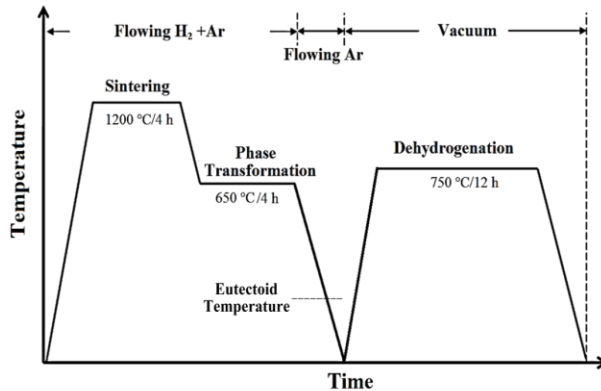
Powder metallurgy is considered a low cost alternative, but...

Issues plaguing conventional PM Ti after 4 decades

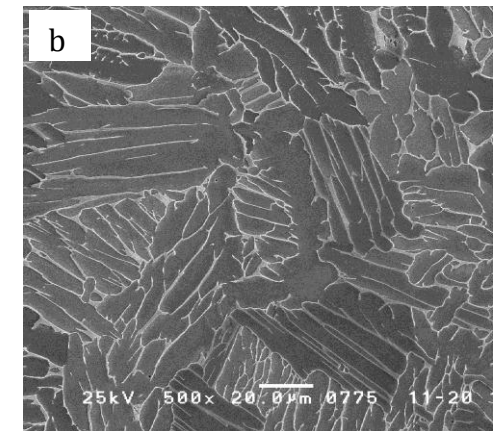
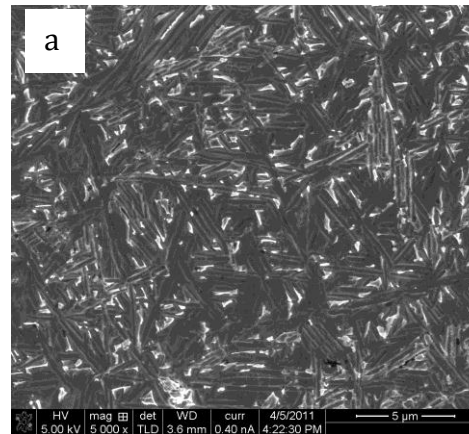
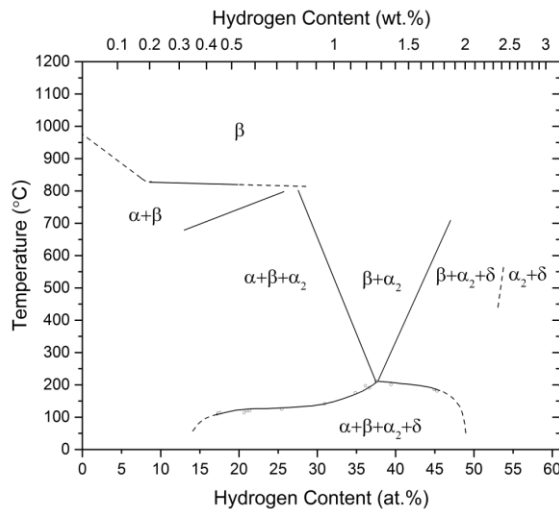
- Mechanical properties
 - Fracture toughness
 - Fatigue performance
- Microstructure
 - **Coarse lamellar as-sintered microstructure**
 - Oxygen and other impurity levels
 - Residual porosity
- Cost
 - Cost of high pressure consolidation / sintering
 - Post-sintering thermal mechanical processing cost
 - **High performance/cost ratio – P/C?**

Technical Approach

Novel innovation: Hydrogen Sintering and phase transformation (HSPT)



- Refine grain sizes by controlling H₂ content and phase transformation in as-sintered state
- High density - >99%
- Small pore size - <1 mic.
- Maximize Performance / cost ratio



Microstructures produced by sintering of TiH₂ in (a) hydrogen, (b) vacuum (SEM)

Transition and Deployment

- Who cares?
 - Light weight/high specific strength
 - High temp. corrosion resistance
- Who is the end user?
 - Aerospace, chemical processing, bio medical
 - **Automobile:** reciprocal weight – fuel economy
exhaust components – high T corrosion
all other PM steel components
- Technology licensed to Ametek – a tier one supplier
 - Fully proven in the lab. If there will ever be Ti used in automobiles, this is the best technology.
- Market barriers and response:
 - Why people, including the user industry and even DOE, are not really embracing, promoting, or using it?
 - Need the right messenger?
 - Need marketing campaign to educate end users, part makers, funding agencies, and investors.
 - Identify key market entry points, grow market to reach economy of scale

Measure of Success

- Primary goal is to produce Ti with superior properties at $1/10^{\text{th}}$ to $1/5^{\text{th}}$ cost of current state-of-the-art.

If we are successful -

- Automobiles can and will start using Ti to replace steel
 - ORNL case study estimates life cycle energy savings through use phase when substituting 18 kg HSPT or Kroll-wrought-machined Ti for 36 kg steel in vehicles:
 - 3,500 MJ savings per HSPT vehicle
 - Energy penalty of 157,000 MJ per Kroll-wrought-machined Ti vehicle
 - Benefits in “use phase” of Kroll/wrought Ti does not outweigh the energy consumption of manufacturing, but,
 - HSPT Ti breaks even in six years compared with using steel
 - At US LDV fleet level, savings of ~ 50 TBtu annually by 2050 with HSPT

Project Management & Budget

- Duration of the project – 3 years
- Project task and key milestone schedule

	Description	Schedule
Milestone I	A single source of powder selected for the project	Dec. 1, 2013
Milestone II	Ti-6Al-4V microstructure targets: >98% density, Grain size < 2 μm , Oxygen % < 0.3%	Aug. 30, 2013
Milestone III	Mechanical property targets: Tensile – 900 MPa, Elongation >10%, Fatigue limit: 500-600 MPa	Aug. 30, 2014

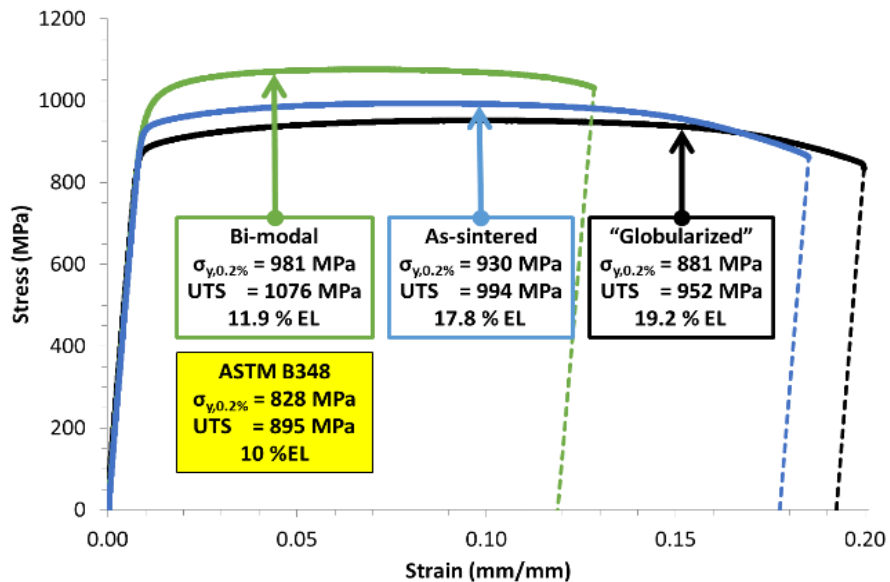
- Project budget

Total Project Budget	
DOE Investment	\$1,460,285
Cost Share	\$370,000
Project Total	\$1,830,285

Results and Accomplishments

- The process technology has been repeatedly demonstrated, robust
- Wrought-like microstructure achieved
- Wrought-like mechanical properties including both static and fatigue strength targets achieved

Static tensile properties



Fatigue endurance limit

