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

DE-EE005761
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2012-2015

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U.S. DOE Advanced Manufacturing Office Peer Review Meeting
Washington, D.C.
May 6-7, 2014

Project Objective

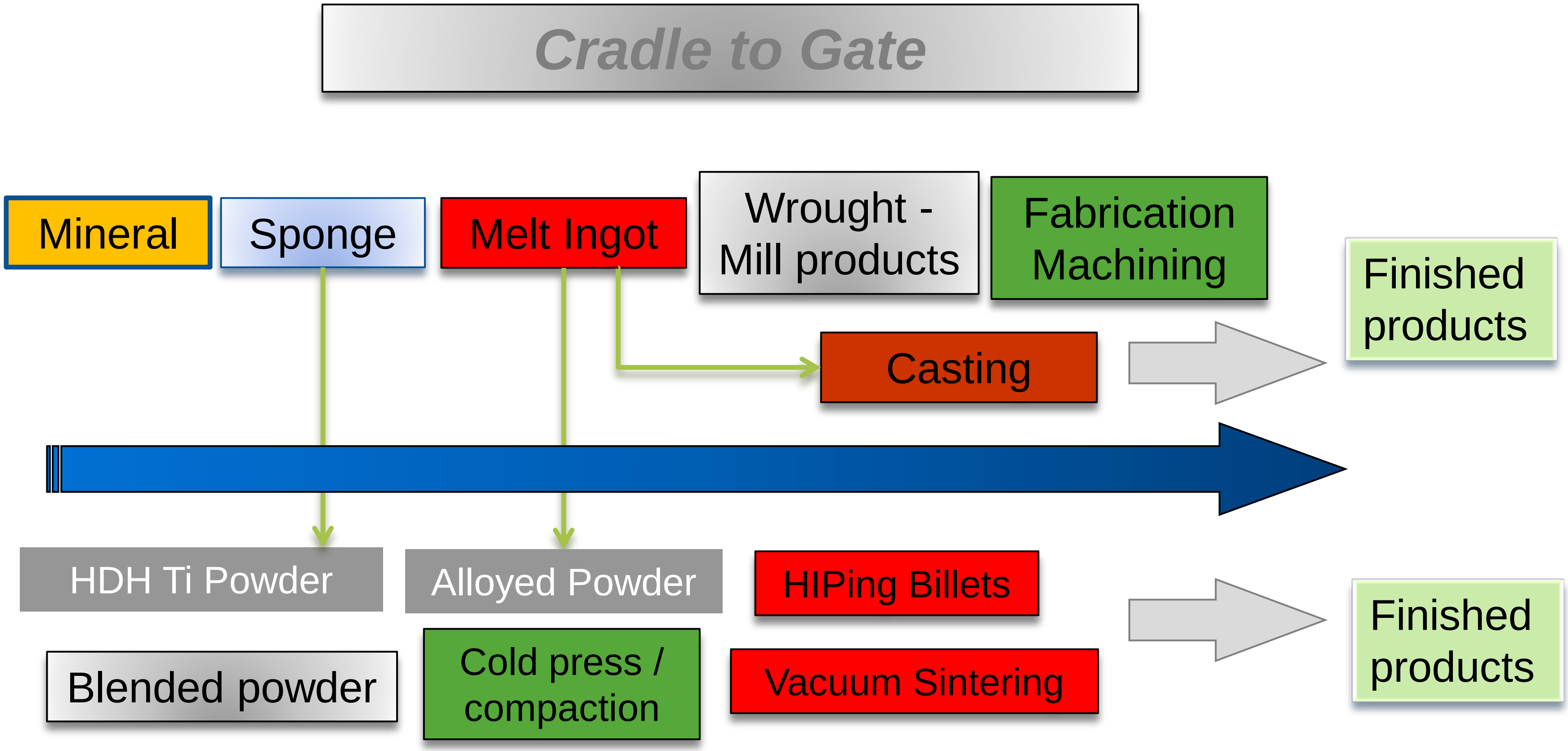
- Develop a novel low cost method for manufacturing Ti
- Demonstrate the mechanical properties of Ti using the new method to be equivalent to that of wrought Ti at a fraction of its cost.
- Demonstrate advantages of using Ti (by this technology) in automobiles, balancing the energy and cost considerations

- 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

Technical Approach

Conventional Manufacturing Routes



Technical Approach

Powder metallurgy is considered a low cost alternative, but…

Issues plaguing conventional PM Ti after 4 decades

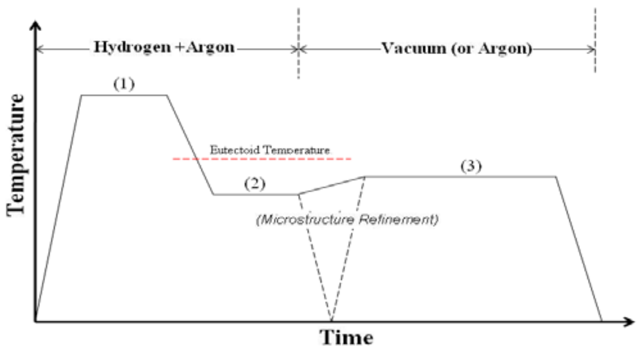
Microstructure
- **Coarse lamellar as-sintered microstructure**
- Oxygen and other impurity levels
- Residual porosity

Mechanical Properties
- Fracture toughness
- Fatigue performance

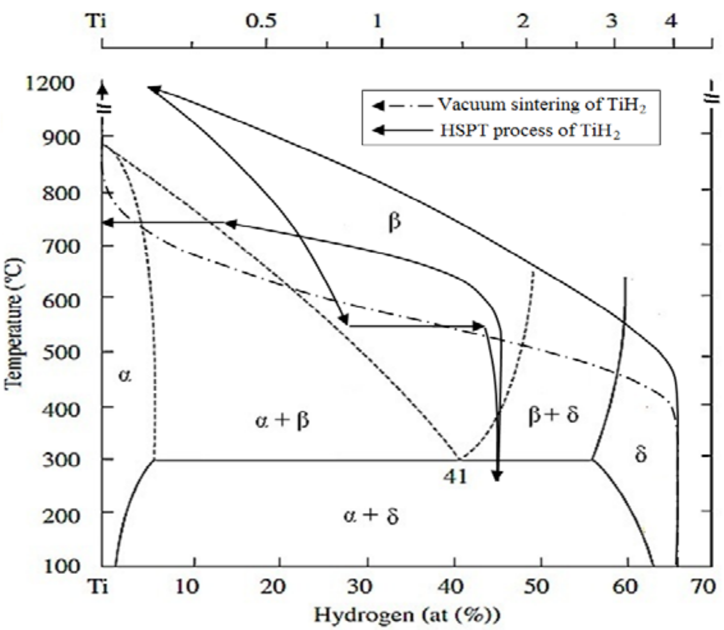
Cost
- Cost of high pressure consolidation / sintering
- Post-sintering thermal mechanical processing cost
- **High performance/cost ratio – P/C?**

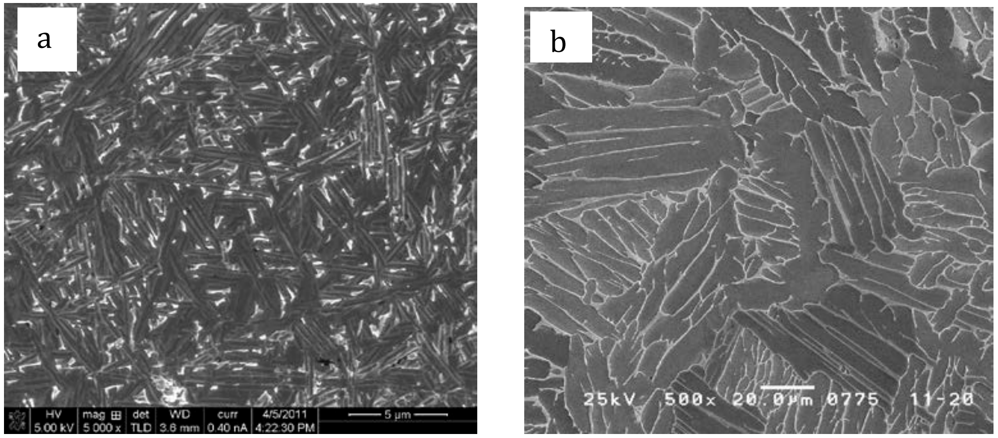
Technical Approach

Our novel innovation: **Hydrogen Sintering and phase transformation (HSPT)**



- Refine grain sizes by controlling H_2 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 TiH_2 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
- Partnering with tier one suppliers and end users
- Leverage the advantages of the technology, identify key market entry point, grow market to reach economy of scale

Measure of Success

- Primary goal is to produce Ti with superior properties at 1/10th to 1/5th 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
- Microstructure goals achieved
- Static mechanical property targets achieved
- Work to be completed:
  - Full demonstration of fatigue properties
  - Auto parts prototypes