

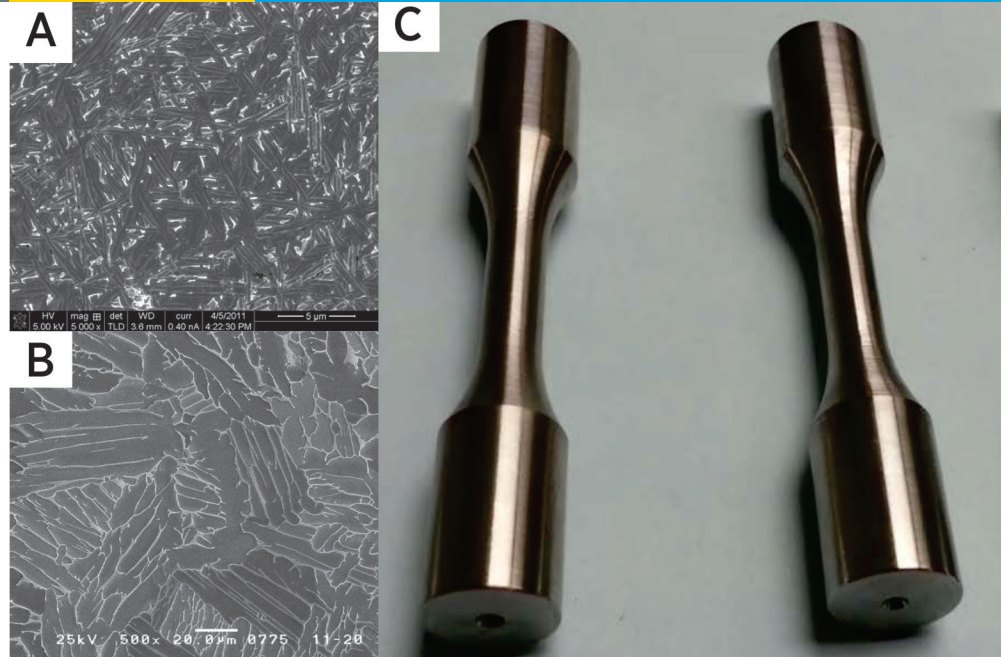
Low-Cost Titanium Alloy Production

Titanium for Energy Efficient Mechanical Systems.

Titanium (Ti) is highly valued for its strength-to-weight ratio and corrosion resistance. However, after conventional wrought processing and machining, it is typically in excess of 40 times more expensive than a corresponding steel part and nearly 20 times more expensive than an aluminum part. The high cost of Ti parts is a function of both high materials loss and multiple high temperature forging steps. This, in turn, has limited Ti to high-value-added parts, like those in the aerospace industry where a premium can be paid for its light weight.

The aerospace industry accounts for 60%–75% of Ti used currently. Having a manufacturing process with the ability to address one or both of these challenges would advance direct industrial use and open other Ti market applications. In addition, Ti's light weight would provide greater lifetime energy savings in transportation applications.

This project replaced existing melt and wrought-forming steps with a novel hydrogen (H₂) sintering near-net-shape Ti production process using low-cost powder metallurgy (PM) techniques. The hydrogen sintering and phase transformation (HSPT) process dramatically reduces energy costs, and reduces machining steps needed to fabricate a component. Processing at lower temperatures and at atmospheric pressure also reduces the energy intensity of the manufacturing process.



Scanning electron microscope images of the microstructures produced by sintering of TiH₂ in (a) hydrogen, and (b) vacuum. Machined samples of powder metallurgy hydrogen-sintered titanium (c). Images courtesy of the University of Utah

Benefits for Our Industry and Our Nation

The development of low-cost Ti-based parts could have a positive impact on manufacturing and the transportation fuel economy. Fuel consumption would be decreased by lightweighting both cars and other vehicles when heavier components are replaced by Ti. Increased fuel efficiency benefits the U.S. military by shortening supply chains and reducing the logistical burdens associated with delivering supplies to forward operating sites. Furthermore, using Ti-based components increases corrosion resistance and decreases the cost of ownership due to longer vehicle lifetimes.

Applications in Our Nation's Industry

The development of the powder-based process for manufacturing Ti parts at low cost would help all industries that can utilize the material property benefits that Ti provides, especially its high strength-to-weight ratio and corrosion resistance. In particular, the development of this process would benefit the aerospace, automotive, and defense communities that have large manufacturing footprints in the United States.

Project Description

The project demonstrated the viability of this technology by providing quantitative data that assessed the potential of the technology compared to commercial wrought materials. The research team achieved an 80% - 90% reduction in manufacturing costs of Ti with superior properties by decreasing both the cost and energy intensity of producing Ti alloy parts.

Barriers

- A link between process variables and microstructure, which ultimately impacts the physical properties of the final material.
- Understanding of component specifications needed for utilization in commercial applications.
- Synthesis of parts without requiring additional energy intensive processing steps.

Pathways

This project involved optimizing processing parameters for manufacturing Ti components from powder via cold compaction and a novel process for sintering Ti in hydrogen. Commercially acquired Ti hydride was used and during sintering the green compacts were exposed to hydrogen atmosphere to produce near-net-shaped parts with 99% to 100% density and ultrafine grain sizes. Verification of the microstructure and mechanical properties of the processed materials provided insight regarding the effect of processing parameters that will help with prototyping. Simultaneous research investigated components in both the automotive and defense supply chains that could be replaced by the Ti parts produced by this process.

Milestones

This project began in 2012 and was successfully completed in 2016. All properties below have met or exceeded project milestones, attempting to bring PM Ti into the same property ranges as wrought Ti materials at lower costs.

- Demonstrate >99 % relative density, ultrafine grain size (averages: <1.2 micrometers thick and <2 micrometers long), low oxygen content (<0.3 wt.%), and hydrogen, nitrogen, and carbon content easily surpassing the ASTM specifications using the new hydrogen sintering and controlled phase transformation technology (HSPT) (Completed).
- Demonstrate targeted mechanical properties, including static tensile (yield strength: 950MPa and elongation of 13.1%), fracture toughness of K_{Ic} at 47.8 MPa*m^{0.5}, and fatigue properties (endurance limit: ~500 MPa), using HSPT (Completed).
- Establish commercialization and licensing plans, identify end users and manufacturers, establish a path to market, provide slides describing the process, establish a conceptual production path and produce selected prototype parts for different industrial applications to demonstrate the utility of the integrated fabrication processes (Completed).

Commercialization

A techno-market analysis for the technology was developed and a number of industrial and transportation applications continue to be explored, especially those where Ti performance characteristics can replace conventional stainless steels. In addition to interest from Tier One auto parts suppliers, Reading Alloy/Ametek signed a one year licensing option with the University of Utah's Technology & Venture Commercialization Office. Markets and products outside the limited licensing agreement are being assessed and the team intends to seek out other potential licensees in the near future.

Project Partners

University of Utah
Salt Lake City, UT

Principal Investigator: Zak Fang
Email: zak.fang@utah.edu

Army Research Laboratory
Aberdeen Proving Ground, MD

Reading Alloy/Ametek Inc.
Robesonia, PA

Ford Motor Company
Dearborn, MI

For additional information, please contact

Steve Sikirica
Technology Manager
U.S. Department of Energy
Advanced Manufacturing Office
Phone: (202) 586-5041
Email: Stephen.Sikirica@ee.doe.gov ■