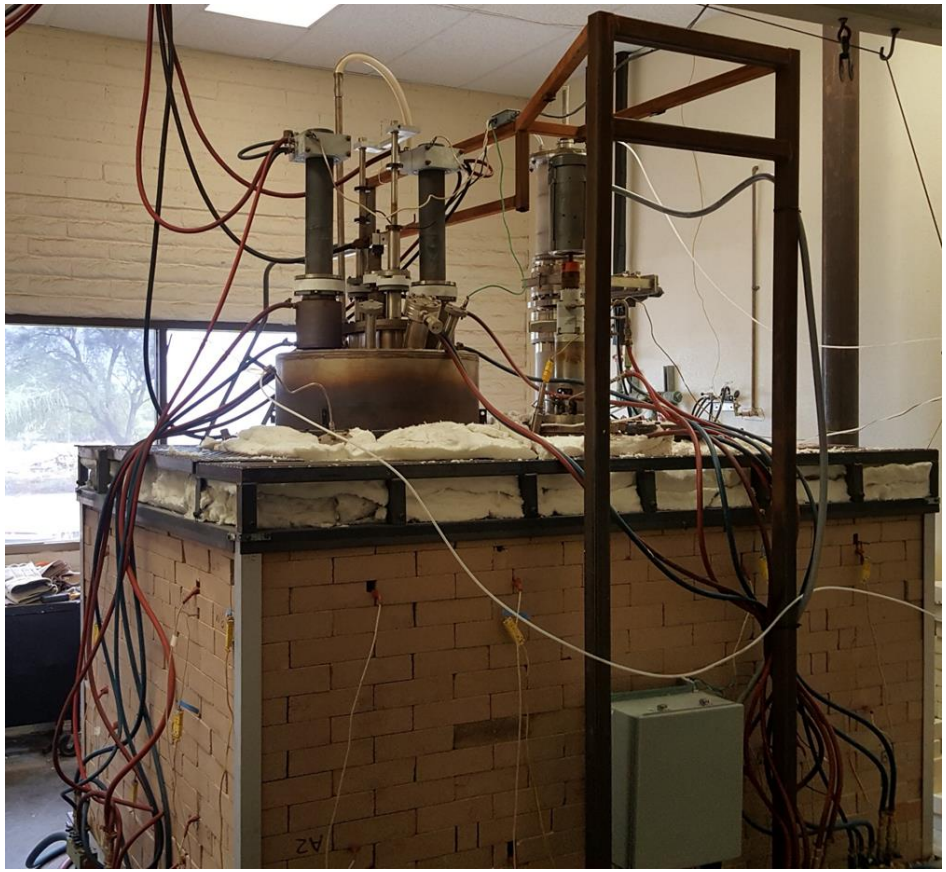
# ATS-MER, LLC

## August 24 – 25, 2016

Detroit, MI

METALS Annual Meeting



***Hot Wall Ti Electrolytic Cell Operating at 0.25 Kg/hr Using $Ti_2OC$ Feed***

# Agenda

- Team Intro
- Technical Concept
- Technical Progress to date
- TEA Highlights
- Demo Requirements
- Future Goals/Closing Thoughts
- Q&A

# Team Intro (ATS-MER, LLC)

MER

Advanced engineered materials and process organization.

R&D to production.

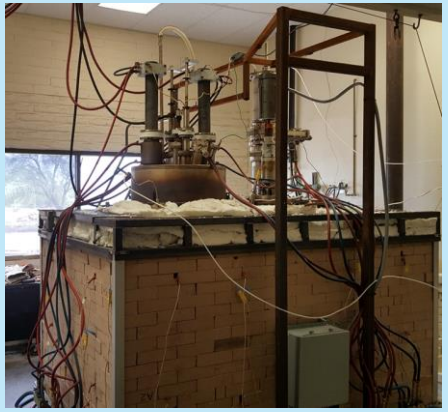
Dr. James C. Withers, ATS-MER, CEO, PI
Dr. Chris Pistorius, CMU,
Professor, Materials Science & Engineering
Purifying domestic ore as cell feed
Dr. Stephen Fox, Timet, VP, Research & Development,
Interaction relevant to commercialization and
Performing energy balances and cost estimation

<u>Current Goal</u>

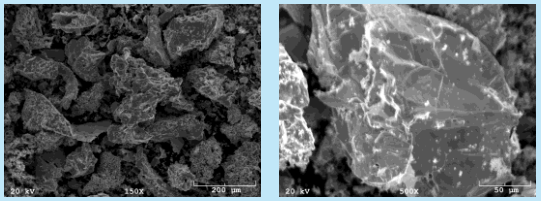
- Confirm all basic science of ore to $TiO_2$ to make $Ti_2OC$ and electrolytically produce Ti powder
- Pilot demonstrate and confirm electrolytic Ti powder can be produced much more economically than Kroll Ti sponge

<u>Project Summary</u>

- Reconfirm basic science and processing that $Ti_2OC$ electrolytically produces Ti powder
- Use domestic ore to produce purified $Ti_2OC$ (not yet confirmed)
- Design and build a hot walled 0.25 Kg/hr electrolytic cell



- Produce quality Ti powder



***Electrolytic Ti Powder from $Ti_2OC$ Feed***

# Technical Concept

- What is the basis of your technical breakthrough?
  - Discovery of how to make $Ti_2OC$ and that it has excellent electrical conductivity
  - Carbothermic energy reduces $TiO_2$ to $Ti_2OC$
  - Electrolytic energy reduces $Ti_2OC$ to Ti powder at 1/3 energy of Kroll Ti sponge process
- Novelty of approach
  - Electrolytic Ti powder is a higher value added product form than Ti sponge
    - Direct use in powder metallurgy
    - Feed for additive manufacturing

# Technical Concept

- What is novel about your approach?
  - What are the benefits?
    - No $CO_2$ directly produced
    - Reaction products are CO possessing energy value
    - Ti Powder is a preferred morphology for virtually any downstream processing
    - Approximately 1/3 energy consumption compared to Kroll sponge production
    - Electrolysis is continuous processing compared to batch for Kroll sponge
    - Can vary output to match market demand
      - Powder size/morphology
      - Rate of production

# Technical Concept

ATS MER

- How does it compare to existing solutions?
  - Existing solution is Kroll sponge
  - Uses both thermal and electrolytic energy
  - Continuous which reduces capital and labor
  - Produces control size powder, a high value added morphology

- Why was this project considered a good fit for ARPA-E Funding?
  - Reduces $CO_2$ emission over Kroll sponge process
  - Reduces energy
  - Reduces cost
    - Dramatically expands market

# Technical Progress to Date

ATS MER

- What are the overall project phases?
  - (1) Reconfirm science, processing, energy, environmental and cost
  - (2) Demonstrate a domestic ore can be cost effectively purified to $TiO_2$
  - (3) Design, build and operate a hot wall 0.25 Kg/hr cell
  - (4) Perform environmental, energy and economic analysis

- Where do you stand vs. your project targets currently?

  The status of the project Phases 1 through 4 listed above are:
  - #1, Complete
  - #2, Not yet demonstrated at CMU/behind schedule.
  - #3, Completed 0.25 Kg/hr in a hot wall cell (shown on cover). Program is continuing with scaling to 50 tons/yr production demonstration
  - #4, In process

# Technical Progress to Date

- What would you consider your biggest successes to date?
  - Confirming operability of a hot wall 0.25 Kg/hr electrolytic cell that produces Ti powder at projected energy and cost at reduced emissions

- Where do you still have additional work to complete?
  - Redirecting program to production demonstration cell operating at approximately 50 tons/yr
  - Providing data to initiate plant at 10,000 tons/yr

# TEA Highlights

- What price range are you targeting for this product? How does this compare to current market?
  - ½ cost of Kroll sponge
- How efficient is your process from an energy perspective?

  Electrolytic production of Ti powder from $Ti_2OC$ is ~ 92 – 97%.
- What $CO_2$ emissions are you anticipating from your process?

  Kroll process consumes ~ 36 $KgCO_2$/Kg Ti.

$$TiO_2 \xrightarrow[C]{heat} Ti_2OC + \xrightarrow{Electrolysis} Ti\ powder \sim 3.6\ KgCO_2/KgTi$$

  - This accounts for $CO_2$ produced in the electrical generations used in the electrolysis to produce the Ti powder.
  - CO is produced to make $Ti_2OC$ and electrolysis at the anode. Energy of burning CO to $CO_2$ is also accounted.

# TEA Highlights

- What are other benefits of your process over a comparable process?
  - Ti powder is a higher value morphology than sponge.
    - Direct use in powder metallurgy
    - Feed for additive manufacturing
  - Ti electrolytic process is continuous versus batch Kroll.

- What scale are you targeting for optimal efficiencies?
  - Production demonstration is at approximately 50 tons/yr.
  - Initial plant is anticipated at 10,000 tons/yr.

# Demo Requirements

- What does the demo phase of this project look like?
  - Scale
    - Production demonstration system of converting $TiO_2$ to $Ti_2OC$ and electrolytic cell operating at approximately 50 tons/yr
  - Cost Range
    - Confirm all operations, energy and environmental balances and cost at ½ Kroll sponge cost
  - Projected Outcomes
    - Confirm operability at production demonstration of 50 tons/yr level providing basis to design a 10,000 ton/yr plant
- What partnership needs, if any, does your research require?
  - Supply of purified low cost $TiO_2$
  - Who wants to partner for producing 10,000 tons/yr Ti powder at ½ cost of Kroll sponge?

# Future Goals/Closing Thoughts

ATS MER

- What is the ultimate end goal for this project?
  - 10,000 tons/yr plant operating by 2020
- Where do you see yourselves in 5 years? 10?
  - 5 years:  Two 10,000 tons/yr plants by 2022
  - 10 years: Producing greater than 50,000 tons/yr
- What is the prospective impact of this project from an industry perspective? Energy perspective? CO2?
  - Lower cost Ti expanding market into automotive and other cost sensitive markets
  - Reduces energy to produce Ti by 2/3 over Kroll sponge process
  - Reduces $CO_2$ emissions by up to 90% over Kroll sponge process
- What would you like the audience to take away from this presentation?
  - Finally a process to replace Kroll sponge
  - Meets Kroll's prediction that an electrolytic process is ultimately better than magnesium reduction of purified $TiCl_4$

# QUESTIONS?