

# **INFINIUM Aluminum**

**August 24 – 25, 2016**

**Detroit, MI**

METALS Annual Meeting

# Agenda

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

# The INFINIUM Team



Clean Metal Production for Clean Energy

## Aluminum Team Members

- Adam Powell, PI
- Salvador Barriga, Experimental Lead
- Uday Pal group, Supporting Experiments

## Project goals

- Produce at least 10 kg Al-2 wt% Sc master alloy
- Cell/plant design for Al-Sc master alloy production scale-up

## Project Summary

- Developed new inert anode technology for aluminum production
- Significant projected energy reduction from 18-19 kWh/kg to 12-13
- Pivoted to low-cost production of Al-Sc master alloy for high performance alloys and products
- Significant flow sheet simplification and cost reduction

# Al-Sc Motivation



## ❑ Sintered powder metallurgy parts:

Alloy	Elements	$\sigma_y$ , MPa	$\sigma_y/\rho$ , m <sup>2</sup> /s <sup>2</sup>	UTS, MPa	Ductility	Powder \$
AlSi10Mg	10% Si 0.5% Mg	255	0.94×10 <sup>5</sup>	460	6-9%	\$50/kg
Scalmalloy	3.6% Mg 1% Sc	525	1.94×10 <sup>5</sup>	575-720	10%	*
<b>Ti-6-4</b>	6% Al 4% Mg	620	1.63×10 <sup>5</sup>	724	6%	<b>\$200/kg</b>

## ❑ Welding: 2219 alloy (T87 strength 365 MPa 19.8% ductility)

- Standard 2319 filler alloy → weld strength 136 MPa, ductility 4.9%
- 2319 + 0.25% Sc → strength 162 MPa, ductility 8.4% – **20% and 70% higher**
- 2319 + 0.75% Sc → strength 268 MPa, ductility 9.7% – **both ~100% higher**

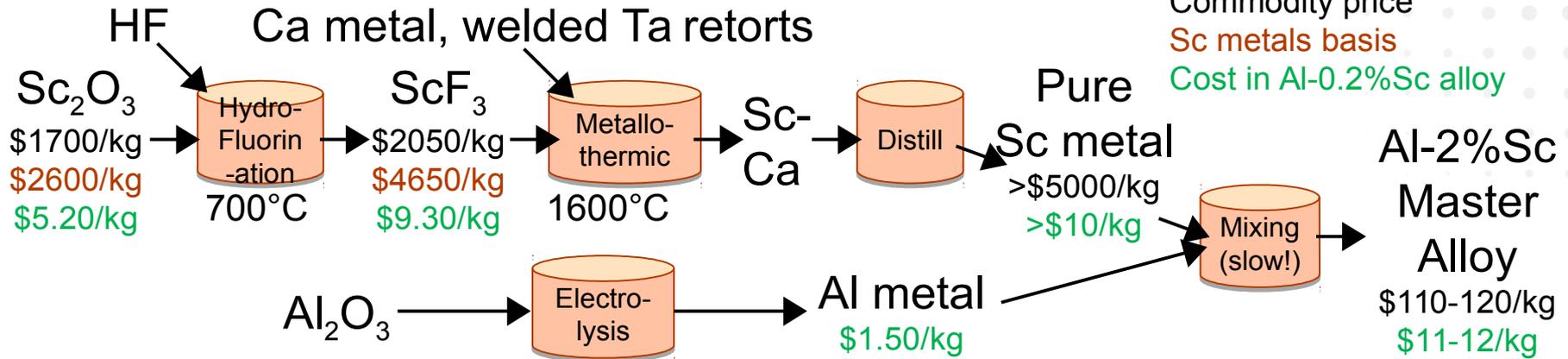
## ❑ New mines: World production will increase 2-20x within 5 years

Company	Project type (location)	Volume	Status
RUSAL	Sc from red mud	Unknown	Construction
Sumitomo Metal Mining	Ni-Co mine/plant (Philippines)	7.5 TPY	Construction
NioCorp	Nb-Ti-Sc (Nebraska)	97 TPY	Fundraising
Scandium International	Sc primary (NSW Australia)	37 TPY	Fundraising
Platina Resources	Pt-Sc (NSW Australia)	30 TPY	Fundraising
CleanTeq	Sc primary (NSW Australia)	~30 TPY	<b>Fundraising</b>

# Technical Concept



## Al-Sc Master Alloy Production Today:



Price/cost legend:  
 Commodity price  
 Sc metals basis  
 Cost in Al-0.2%Sc alloy

Even if new mines cause the price of Sc<sub>2</sub>O<sub>3</sub> to fall to \$600/kg → New mines Sc<sub>2</sub>O<sub>3</sub>  
 High processing cost (\$6-7/kg Al alloy) still leads to \$8-9/kg alloy

## INFINIUM Solution:



Single step, no HF, no reductants, no refractory metal welds

# Technical Progress to Date



## ▶ Inert Anodes:

- New tube geometry and anode material
- Lower temperature (700°C), lower anode resistance
- Significant improvement in lifetime and current density

## ▶ Al-Sc Master Alloy:

- Can repeatably make product exceeding composition specs
- Next: optimize process parameters
- Project end goal: scale up production to multi-kg quantity

## ▶ Biggest successes to date:

- Inert anodes: two orders of magnitude improvement in charge/area in the past year
- Production of Al-Sc alloy directly from oxides

# TEA Highlights



- ▶ Partner engagement: developing relationship with a company opening a new scandium oxide mine/production facility
  - Received a large  $\text{Sc}_2\text{O}_3$  sample with more to come
  - Partner is marketing to aerospace and automotive industries
- ▶ Price range: will make final alloy very competitive with titanium
- ▶ Energy/emissions:
  - Self-heated cell energy comparable to primary aluminum
  - Direct emissions below primary aluminum
- ▶ Benefits:
  - Much lower cost than today's process due to simplified flow sheet
  - Continuous production → high yield
- ▶ Typical plant scale:
  - Aiming for 200-500 TPY Al-2Sc master alloy

# Demo Requirements



- ▶ If this project succeeds, the Demonstration phase will build and test a small pilot production cell
  - Scale: 2-10 TPY
  - Cost Range: relatively small compared with scandia cost
  - Projected Outcomes:
    - Large samples for customer trials
    - Design for full-scale production cell
    - More accurate cost model for full production
- ▶ Partnership requirements
  - Scale-up will require funding for larger cells and scandium oxide material
  - Supply agreement(s), customer off-take

# Future Goals/Closing Thoughts



- ▶ Project end goals:
  - At least 10 kg product to sample to partner and other customers
  - Design for the Demo phase pilot production cell
- ▶ 5-10 year vision:
  - 200-500 TPY production
  - Scale-up of other master alloy systems which are difficult to produce by melting alone or have other challenges
- ▶ Prospective impact:
  - Dramatically reduce costs in a key Al-Sc value chain step
  - Enable low-cost mines to produce for new lower-cost markets
  - Expand the use of this outstanding alloy system

# Aluminum-Cerium Alloys



## ► Motivation:

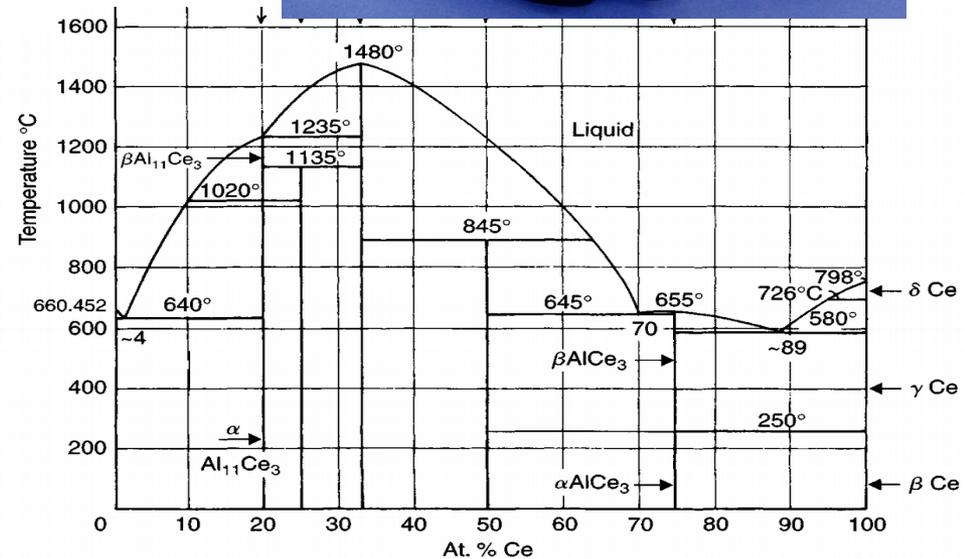
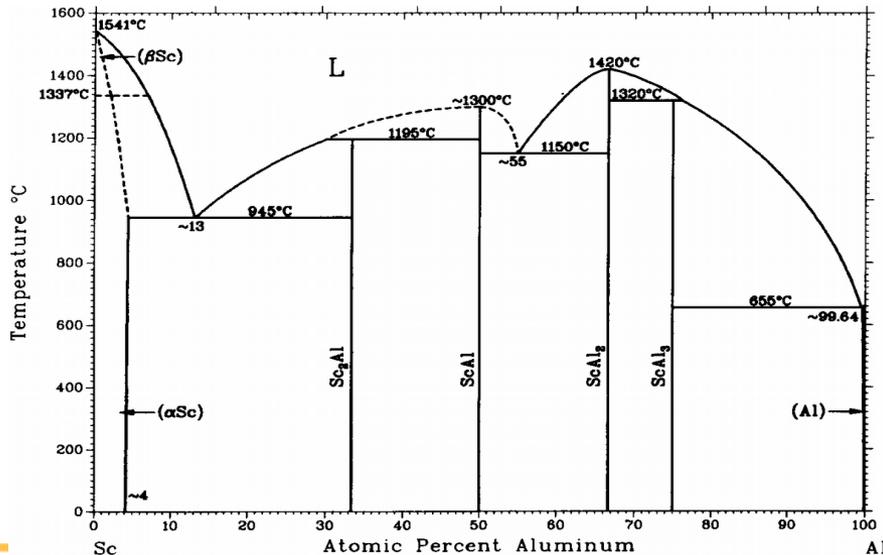
- Very good castability, high-T creep
- Potential engine applications

## ► Challenge:

- Nearly all Ce metal production is in China

## ► INFINIUM Solution:

- Directly produce alloy from oxides



# QUESTIONS?