Clean metals process for rare earths and other technology metals

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Metal Events 16th International Rare Earth Conference
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Ziron Tech - Liquid Cathode Assisted Electroreduction (LCE) Process

Innovative Clean Metal Electrolysis Process Agreement with Alkane subsidiary Australian Strategic Materials (ASM) signed in June 2019 to commercialise the process developed by Chungnam National University

Process

- Proprietary Electrolysis Process (LCE) using solid oxide membrane (YSZ) technology;
- Carbon free and only emission is oxygen;
- Estimated 50% of existing Kroll process costs (commonly used historic industrial process);
- Process also applicable to may other metals.

Agreement

- Ziron Tech to provide an exclusive license to the JV company RMR Tech for use of its intellectual property and expertise in relation to the Technology;
- Alkane to invest US$1.2m towards a pilot plant facility to complete late-stage piloting and feasibility study for larger scale development and commercialisation of the process.

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Development of Ziron Tech Technology

- Developed by Chungnam National University's (CNU) Department of Materials Science and Engineering in Daejeon, South Korea
- ASM has been working with senior members of CNU since 2014
- Patented carbon free process to convert metal oxides into metals through a proprietary electrolysis process
- Technology uses Solid Oxide Membranes (SOMs) to replace carbon electrodes, and produces oxygen as a by-product
- Estimated to reduce metallisation costs by 50% or more
- Main focus has been for Zr and Hf, but it is suitable and experimentally verified for **Pr, Nd and Ti**
- Suitable, but not verified for all rare earths, and theoretically possible for **Al, Mg, V, Nb, Ta**

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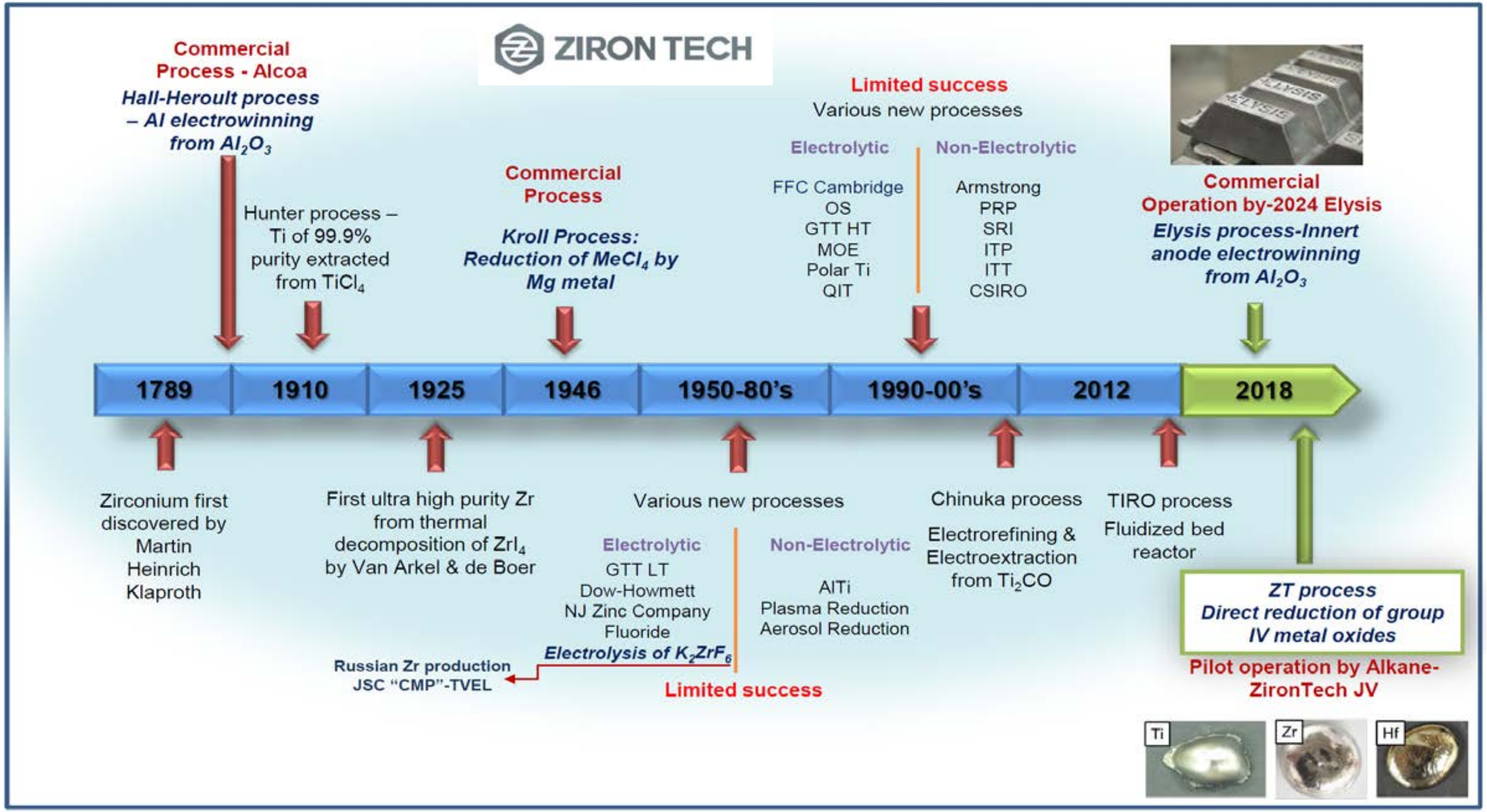
Smelting History of Group IV Metals (Al, Ti, Zr, Hf)



In 2018, Rio Tinto, Alcoa, Canadian Govt, Quebec Govt abd Apple announced a JV to commercialise the 'ELYSIS' process to replace the existing Aluminium metal production process.

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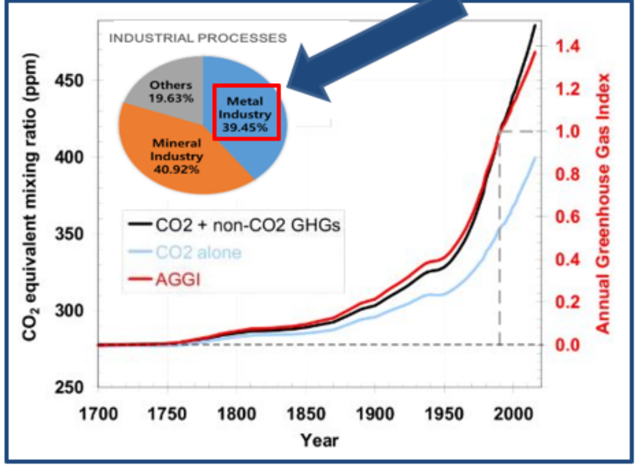
Conventional Industry

ref.https://www.nationalgeographic.com/environment/2018/09/news-air-quality-brain-cognitive-function/

ref.https://www.paho.org/hq/index.php?option=com_content&view=article&id=12918:2017-ambient-air-pollution&Itemid=42246&lang=fr

Greenhouse gas emission

Energy sector 74%	Waste 7%
Agriculture sector 13%	Industrial processes 6%

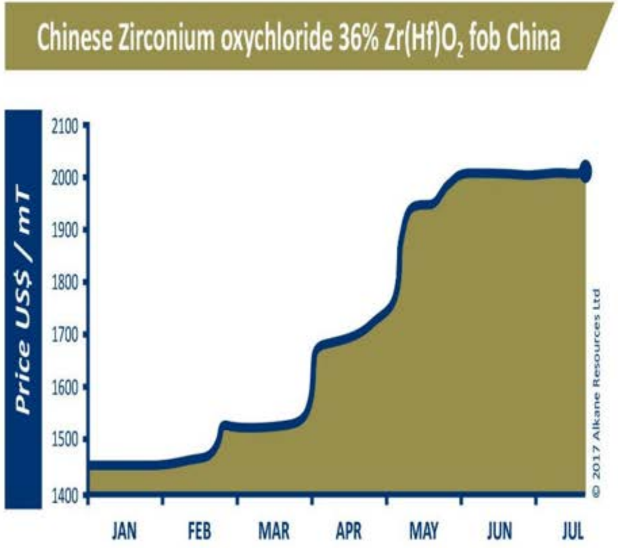


https://insideclimatenews.org/news/19052016/global-co2-emissions-still-accelerating-noaa-greenhouse-gas-index

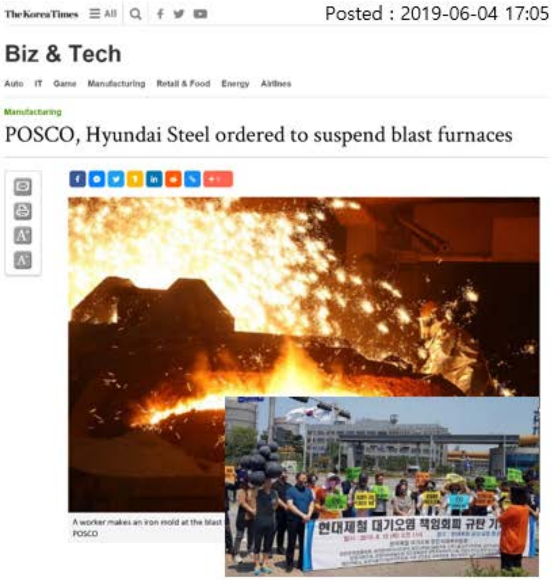
- **In the conventional metal industry, many pollutants are generated during metal production.**
- **As metal demand and production increase, environmental problems such as air pollution are becoming more important.**
- **It is necessary to develop a new manufacturing process that is economical and environmentally friendly.**

Environmental emissions

- **Pollution influence on metal industries**



Price increase of Zirconium Oxychloride (ZOC) is mainly due to environmental problem



Changes in public perceptions of the traditional steel industry

Policy trends in major countries

CN : Made In China 2025

US : Advanced Manufacturing Partnerships

EU : Horizon 2020

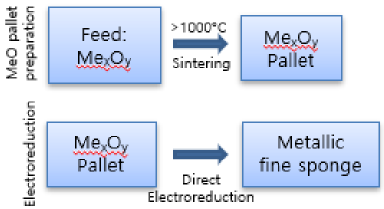
KOR : MCI 2030

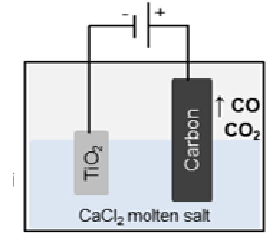
- Implementing various policies to improve technological innovation and production efficiency.
- These policies are meaningful in leading the economy by selecting and achieving strategic task goals.

Alternative Electrolytic Processes for Zr/Ti

FFC process (Electroreduction of Me oxides)

- Usage of C anode leads to direct emission of CO/CO_2
- Electrolyte contamination by carbon – low current efficiency (32.3% for Ti)
- Limited possibility of oxygen content decrease (~2000 ppm)
- Additional palletization for cathode
- Long processing time
- Fine particles of reduced metal



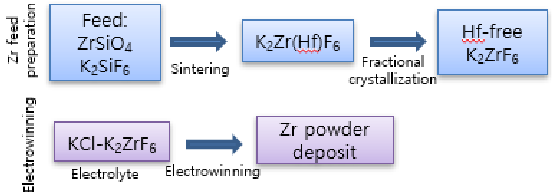


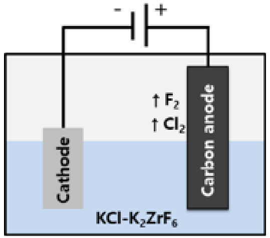
Cathode process:
1) $Ca^{2+} + 2e^- = Ca$
2) $MeO_x + xCa = Me + xCaO$

Anode process:
1) $O^{2-} - 2e^- = O_2$
2) $O_2 + C = CO_2$
3) $\frac{1}{2}O_2 + C = CO$

Russian electrolytic Zirconium (Electrowinning)

- Usage of easily moisture absorbing electrolyte ($KCl-K_2ZrF_6$)
- Fluorine/Chlorine gas evolution on the anode





Cathode process:
1) $Zr^{4+} + 4e^- = Zr$

Anode process:
1) $4F^- - 4e^- = 2F_2$

(Simplified)

- **Importance of low moisture absorbing ability of electrolyte**

Electrolytic Zr obtained by Russian process contained over *200ppm* of Fluorine – early breakaway oxidation effect.

High content of F can be caused by remained Oxyfluorides in electrolytic Zr (*difficult to remove by vacuum distillation*)

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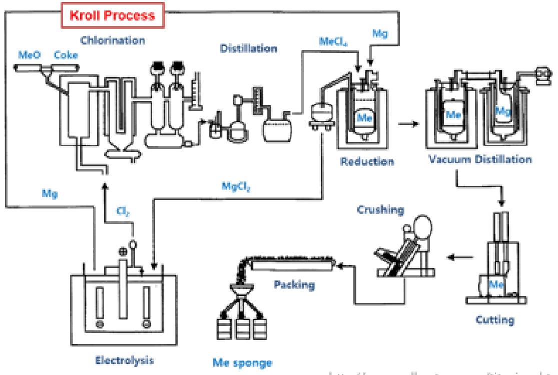
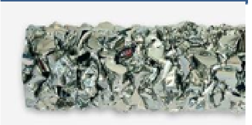
Conventional Kroll Process



http://www.wellmetusa.com/titanium.html

Zr, Hf, Ti Sponge

Crystal bar



https://en.wikipedia.org/wiki/File:Hf-crystal_bar.jpg

- Energy intensive processes
- Limitation of deceasing cost
- Requires environmental protection processes
- Contamination of Zr / Ti sponge
- Limitation to recycling

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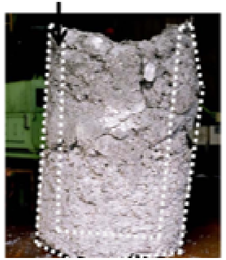
Kroll Process problems (titanium example)

- **Contamination of Ti sponge by Fe from reactor container**

Ti sponge is heavily contaminated by Fe from reaction container.



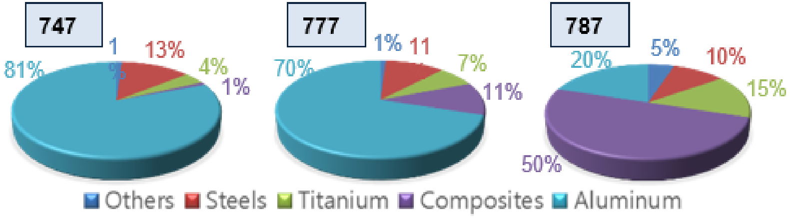
Takeda, O. & Okabe, T.H. JOM (2018)

10-20% off-grade sponge after process

(Fe < 3-4%) → Remelting with higher grade titanium scrap (VAM, EBM, PAM)

Fe >~4% Highly contaminated → Ferrotitanium alloys

- **Usage of titanium in commercial aircraft**



Only 10-20% of titanium is a final product 80-90% - titanium scrap → **Huge amount of titanium scrap** → **Remelting with higher grade titanium**

Kroll Process

Scrap and off-grade Ti / Zr generation through out the production and then also in the final product manufacturing

Electrolysis method

- **Very high capability of deoxidation**
- **Avoid both of the major impurities**

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Limitations of Existing Electrolytic Processes

◆ Controllability of F/Cl Impurity

- ✓ Multistep reduction of Zr/Hf/Ti in electrolysis process causes possibility of presence of intermediate reduction products remained in deposit in forms of subfluorides or oxyfluorides $(ZrO(Cl/F)_x$ etc.) which complicate salt separation process.

◆ Controllability of O impurity

- ✓ Fine powders can be easily oxidized during handling separation of deposit from salt
- ✓ Electrolytes with lower ability of moisture absorption should be used in electrolysis

◆ Scalability of system

- ✓ Russian Zr production showed good example of scalability of electrolytic processes for Zr production in commercial scales
- ✓ Metalysis™ successfully scaled up its technology for metal powders, benefitting from its modular nature

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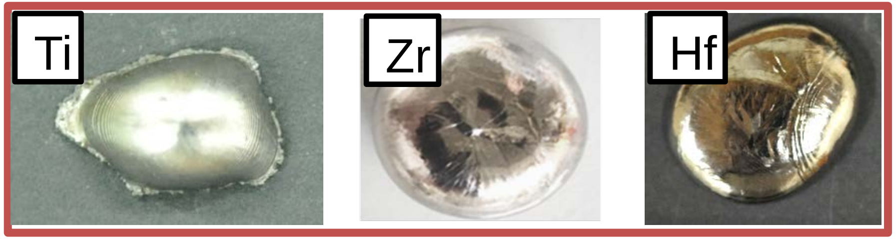
PATENTED Ziron Tech Process

- Paradigm shift in smelting industries

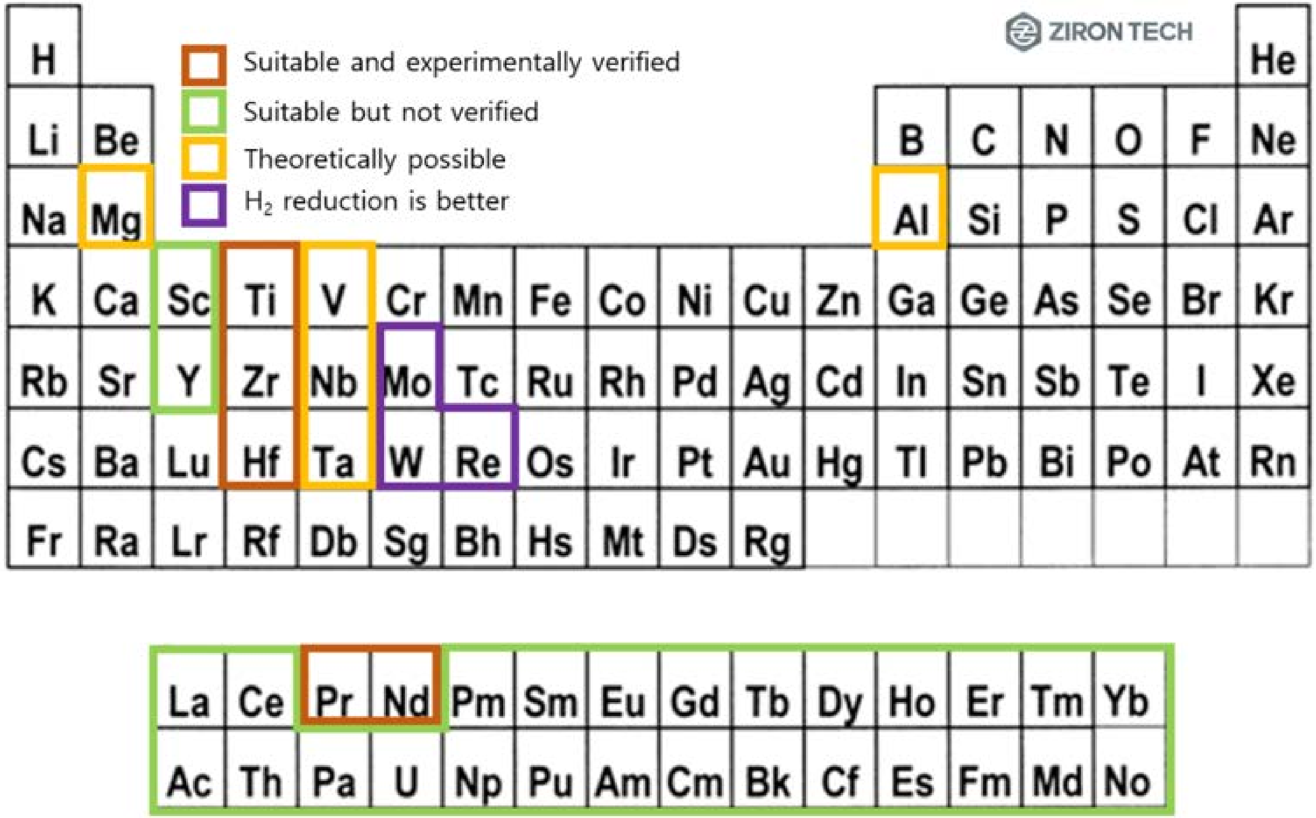
Preparation of Reducing Agent → Direct reduction of oxide feedstocks → Electrorefining



- **Oxygen is only byproduct**
- **Impurity levels are below industrial standards**

Ziron Tech + Alkane Joint Venture Pilot Operation in 2019

Suitability of Ziron Tech LCE Process



Next steps

- Commercial scale pilot plant being constructed and due for commissioning in the March quarter 2020.
- First priority is zirconium metal and hafnium metal, then magnet rare earths.
- Compilation of operating and process data to confirm quality and economics.
- Successful pilot plant operation to be scaled up further to commercial scale operation.
- Scale up of other metals

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Significance for ASM

- Potentially suitable for all Dubbo Project metals.
- Strong interest in sustainable processes from downstream consumers in South Korea and elsewhere.
- ~70% of all Dubbo Project revenues are ultimately in the form of metals or alloys.
- Potential for additional value capture across supply chain compared to selling chemicals or oxides.
- Commercialisation for other metals/alloys could lead to substantial revenue streams from licensing /royalties.

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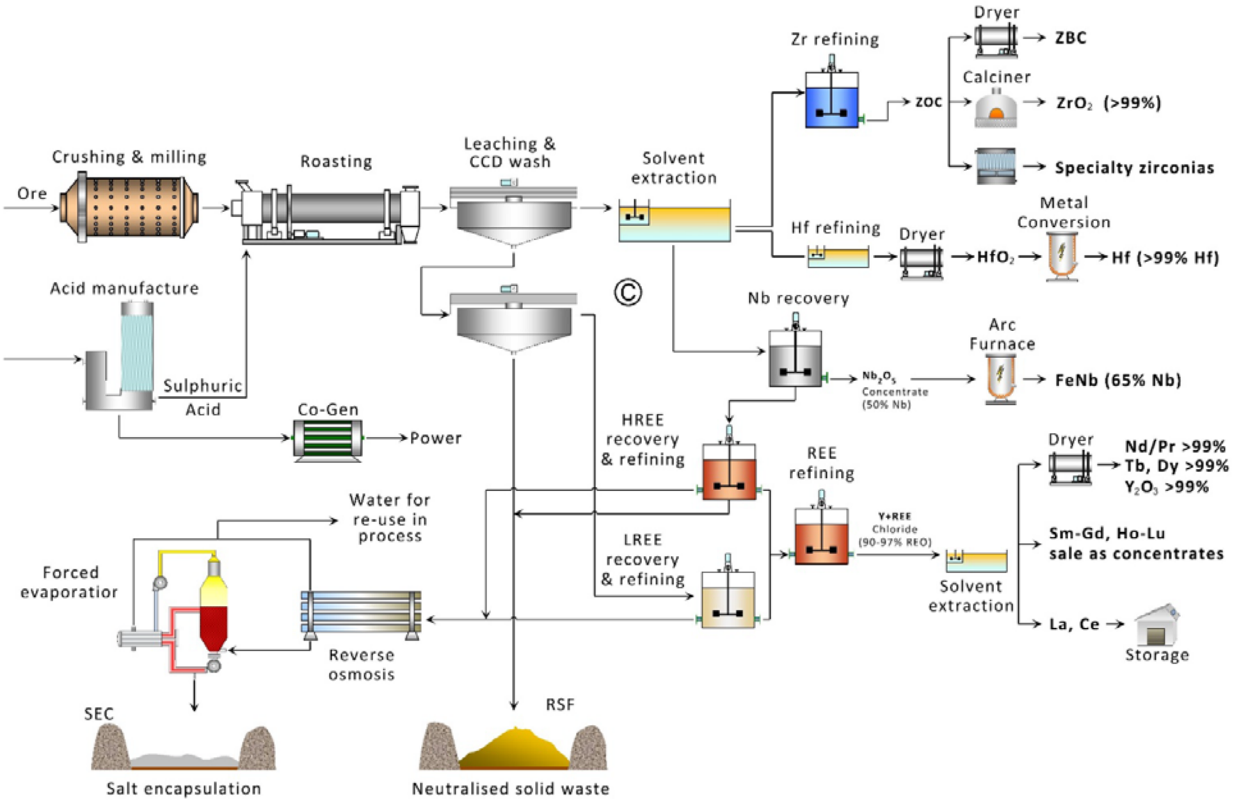
Dubbo Project –Technology Metals

- Critical minerals resource
  - Zirconium, hafnium, rare earths & niobium.
  - Used in clean energy, electric vehicles, super alloys & many modern technology
- Defined resource supports 70+ year open pit operation
- 400km northwest of Sydney
- Extensive piloting at ANSTO since 2008
- Full FEED with Hatch & further updates
- All major State & Federal approvals in place
- Land & resource wholly owned
- Construction ready subject to financing

Dubbo Project - Separation and Refining Process



All output can be converted to high purity metals by the Ziron Tech process with limited additional cost but substantially higher revenues.

Products closer to final end use application.

Dubbo Project - Product Output for 1.0 m tpa ore

DP Process Plant

Product	Grade	Output
Rare earth chemical concentrate	95% REO	6,664 tpa (REO units)
Zirconium as Zr chemicals & zirconia	99% ZrO_2	16,374 tpa (ZrO_2 units)
Hafnium as HfO_2 99%	99% HfO_2	50 tpa * (Hf units)
Niobium as ferro-niobium	65% Nb	1,967 tpa (Nb units)

Total output approximately 25,200 tpa of all products

Tonnage based upon recoveries developed from mass balances of the demonstration pilot plant.

* Start up output. 200tpa potential depending upon market demand

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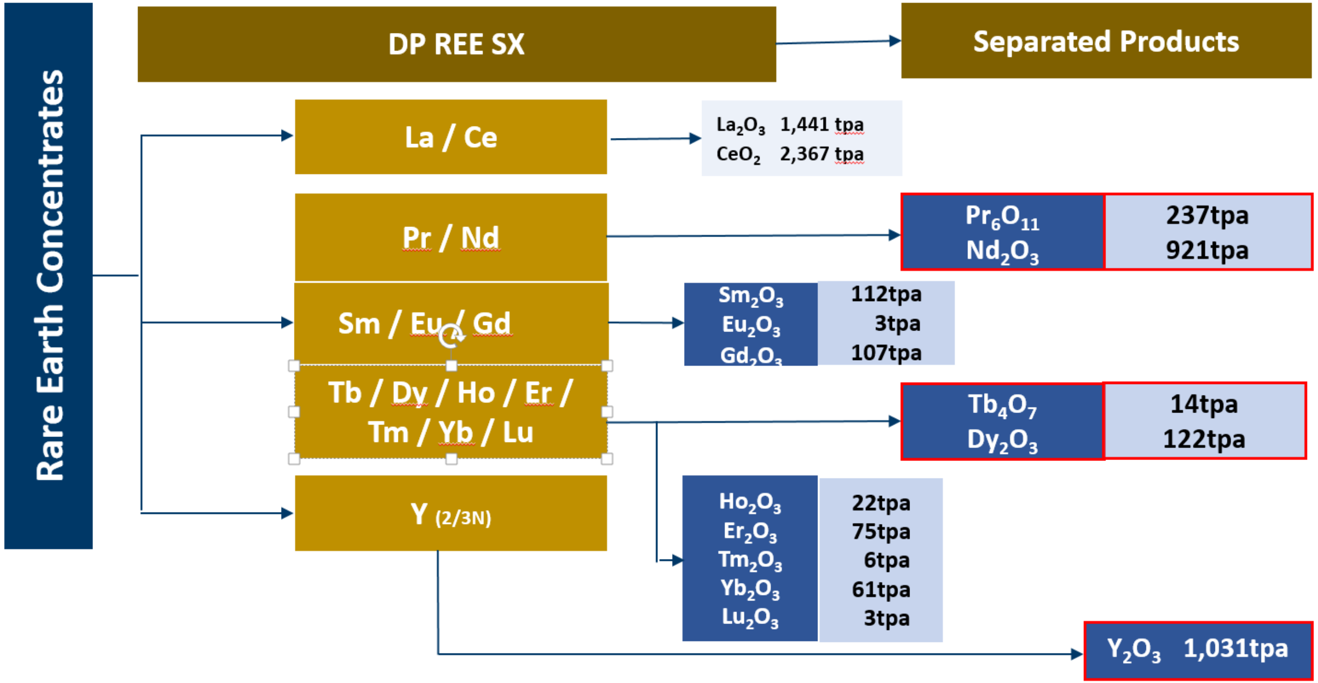
Dubbo Project - Rare Earth Output



Tonnage based upon recoveries developed from mass balances of the demonstration pilot plant & solvent extraction stages on site at the DP.

Total saleable RE products from site ~1,030 tpa and off site ~ 1,675 tpa.

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Competent Person

Unless otherwise stated, the information in this presentation that relates to mineral exploration, mineral resources and ore reserves is based on information compiled by Mr D I Chalmers, FAusIMM, FAIG, (director of the Company) who has sufficient experience which is relevant to the style of mineralisation and type of deposit under consideration and to the activity which he is undertaking to qualify as Competent Person as defined in the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves. Ian Chalmers consents to the inclusion in the presentation of the matters based on his information in the form and context in which it appears.

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Dubbo Project – Resources & Reserves

Dubbo Project – Mineral Resources

Resource Category	Tonnes (Mt)	ZrO_2 (%)	HfO_2 (%)	Nb_2O_5 (%)	Ta_2O_5 (%)	Y_2O_3 (%)	TREO* (%)
Measured	42.81	1.89	0.04	0.45	0.03	0.14	0.74
Inferred	32.37	1.90	0.04	0.44	0.03	0.14	0.74
Total	75.18	1.89	0.04	0.44	0.03	0.14	0.74

**TREO% is the sum of all rare earth oxides excluding ZrO_2, HfO_2, Nb_2O_3, Ta_2O_5, Y_2O_3*

Dubbo Project – Ore Reserves

Reserve Category	Tonnes (Mt)	ZrO_2 (%)	HfO_2 (%)	Nb_2O_5 (%)	Ta_2O_5 (%)	Y_2O_3 (%)	TREO* (%)
Proved	18.90	1.85	0.04	0.440	0.029	0.136	0.735
Probable	0						
Total	18.90	1.85	0.04	0.440	0.029	0.136	0.735

**TREO% is the sum of all rare earth oxides excluding ZrO_2, HfO_2, Nb_2O_3, Ta_2O_5, Y_2O_3*

Note: Full details including Competent Person statements in ASX announcement 19 September 2017 - the Company confirms that all material assumptions and technical parameters underpinning the estimated Mineral Resources and Ore Reserves, and production targets and the forecast financial information as disclosed continue to apply and have not materially changed

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