Outlook for Zirconium and Rare Earth Materials until 2020

Hong Kong
November 2013

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Rare Metals – Rare Earths

- China produces 90% of world downstream zirconium chemicals & 50% of fused zirconia
- China currently produces 80-90% of world REE output
- China is limiting the export of raw rare earths materials
- Brazil produces 90% of world niobium

- **Green technology** is dependent on **rare metals and rare earths**
- **Increased demand** also driven by **changes in legislation**
- China has dominant position

...not so rare, but increasingly valuable
Zirconium industry

Applications for Zirconium Materials

- **Catalysts**
  - Automotive
  - Gasoline & diesel
  - Industrial pollution
  - Petroleum refining control
  - Fuel cells

- **Electronics**
  - Dielectrics
  - Piezoelectrics
  - Multi layer capacitors
  - Oxygen sensors
  - Sonar

- **Ceramics**
  - Ceramic colours
  - Enamels
  - Opacifiers

- **Glass**
  - Polishing Compounds
  - Optical glass
  - Cubic zirconia

- **Wear**
  - Engineering ceramics
  - Thermal Barrier coatings
  - Milling media
  - Bioceramic hips/teeth
  - Automotive brake pads
  - Fibre optic ferrules

- **Chemicals**
  - Paper coatings/binders
  - Metal treatments
  - Antiperspirants
  - Pigment coatings
  - Printing inks
  - Sorbents - carbon capture
  - Water treatment
  - Paint drying agents
  - Waterproofing agents
  - Flame retardants

- **Refractories**
  - Glass tank refractories
  - Steel making refractories
  - Flow control nozzles

Sources: General Electric, MEL Chemicals, Ferro Corporation, Arena, Zircoa, PPS, Murata, Molycorp
Zirconium Industry

Zirconium Chemicals Output
(2011 – 194,000t ZrO₂ basis CAGR 5-10%)

Global market US$3-4B
Mid 2013 consumer zircon inventories running down
- Market expected to move back into under supply 2015 - 2016
- Prices starting to recover
- 18% - 20% zircon used in zirconium chemicals
- CAGR anticipated at 5% - 8% pa

Source: Iluka, TCMS, JP Morgan
### Zirconium Demand to 2020

<table>
<thead>
<tr>
<th>Zirconium materials</th>
<th>2011</th>
<th>2012</th>
<th>2015f</th>
<th>2020f</th>
<th>2020f</th>
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<tbody>
<tr>
<td>(100% ZrO₂ basis)</td>
<td>tpa</td>
<td>tpa</td>
<td>tpa</td>
<td>tpa</td>
<td>tpa</td>
</tr>
<tr>
<td>Growth rate %/year</td>
<td></td>
<td></td>
<td>7%</td>
<td>5%</td>
<td>7%</td>
</tr>
<tr>
<td>Baddeleyite</td>
<td>7,000</td>
<td>6,000</td>
<td>8,000</td>
<td>8,000</td>
<td>8,000</td>
</tr>
<tr>
<td>Fused unstabilised zirconia</td>
<td>72,000</td>
<td>48,000</td>
<td>59,000</td>
<td>71,000</td>
<td>82,000</td>
</tr>
<tr>
<td>Fused stabilised zirconia</td>
<td>25,000</td>
<td>17,000</td>
<td>21,000</td>
<td>25,000</td>
<td>29,000</td>
</tr>
<tr>
<td>Chemical zirconia</td>
<td>40,000</td>
<td>27,000</td>
<td>33,000</td>
<td>40,000</td>
<td>46,000</td>
</tr>
<tr>
<td>Zirconium chemicals</td>
<td>50,000</td>
<td>43,000</td>
<td>53,000</td>
<td>64,000</td>
<td>74,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>194,000</td>
<td>141,000</td>
<td>174,000</td>
<td>208,000</td>
<td>239,000</td>
</tr>
</tbody>
</table>

Zircon required (65% ZrO₂) 300,000 217,000 268,000 320,000 368,000

- 21-25% of all zircon demand by 2020
  (48-72% increase from 2012)

Source: TCMS
Zirconium Issues to 2020

- Availability of premium zircon for fused zirconia
  - will require ~160-180,000t
  - low Al₂O₃ with minimal particle size < 45 micron
  - availability of zircon with <300 ppm U+Th

- Consolidation of Chinese fused and zirconium chemical industry

- Environmental and OH&S cost pressures

- Treatment of high U+Th residues for zirconium chemicals production

Source: TCMS
Applications for Rare Earth Materials

**Electronics**
- Display phosphors (CRT, PDP, LCD)
- Medical imaging phosphors
- Lasers
- Fibre Optics
- Optical temperature sensors

**Ceramics**
- Capacitors
- Sensors
- Colourants
- Scintillators
- Enamels
- Opacifiers

**Glass**
- Optical glass
- Polishing compounds
- Thermal control mirrors
- Colourisers / Decolourisers
- Cubic zirconia

**Metal Alloys**
- Hydrogen storage (NiMH batteries, Fuel cells)
- Superalloys
- Aluminium / Magnesium
- Lighter flints

**Magnets**
- Electric motors
- Disk drives
- Power generation
- Actuators
- Microphones and Speakers
- Magnetic Resonance Imaging (MRI)
- Anti-lock brake systems
- Electric drive & propulsion
- Magnetic storage disk
- Microwave power tubes
- Magnetocaloric alloys
- Magnetostrictive alloys

**Catalysts**
- Automotive catalytic converter
- Petroleum refining
- Diesel additives
- Chemical processing
- Industrial pollution scrubber

**Other**
- Fluorescent lighting
- Water Treatment
- Pigments
- Fertilizer
- Medical Tracers
- Coatings

Sources: Google images, GM, Acer
REE industry in 2013

• Global Market ‘Value’: US$3-5 B (US$30-50/kg REO)
• Estimated global demand in 2013: 110-125,000t REO
• China dominant:
  • producing 80-100% REO (80-90% of global supply)
    • almost 100% of heavy rare earths
  • consuming 80-90,000t REO (60-70% global demand)
• Japanese consumption: 10-20,000t REO
  • still replacing, reducing, and recycling
• China: cutting production, stockpiling and consolidating
  • up to 70% of heavy rare earths from illegal mining
• Lynas and Molycorp adding ~30,000tpa of LREEs over 2-4 years
• China short of HREEs. ROW devoid of HREE production

Sources: IMCOA, Metal Pages
REE Industry

**REE DEMAND 2016**

- **Catalysts**: 15%
- **Glass**: 6%
- **Polishing**: 15%
- **Metal Alloys**: 16%
- **Magnets**: 22%
- **Phosphors**: 8%
- **Ceramics**: 6%
- **Other**: 12%

**Market imbalanced but overall CAGR 6% - 12% seems likely by 2016**

- **Total REE consumption 2012 115,000t with annual growth estimated at 5-10% to be 162,000t in 2016**
- **China produces about 90% of world supply and consumed about 65%, with Japan 15% and the US 14%**
- **The REE industry is “imbalanced” with potential oversupply of light rare earths (Ce & La) and undersupply of heavy rare earths and neodymium**
- **Nd, Eu, Tb, Dy and Y are considered to be in critical supply through to at least 2020**

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© Source: IMCOA
### Forecast Supply and Demand for Selected Rare Earths in 2016

<table>
<thead>
<tr>
<th>Rare Earth Oxide</th>
<th>Demand @ 150-170,000tpa REO</th>
<th>Supply @ 180-210,000</th>
</tr>
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<tbody>
<tr>
<td>Cerium</td>
<td>50-70,000t REO</td>
<td>70-80,000t REO</td>
</tr>
<tr>
<td>Neodymium</td>
<td>30-35,000t REO</td>
<td>25-30,000t REO</td>
</tr>
<tr>
<td>Dysprosium</td>
<td>800-850t REO</td>
<td>1,000t REO</td>
</tr>
<tr>
<td>Terbium</td>
<td>450-500t REO</td>
<td>250-300t REO</td>
</tr>
<tr>
<td>Yttrium</td>
<td>9-10,000t REO</td>
<td>7-8,000t REO</td>
</tr>
</tbody>
</table>

Source: IMCOA
REE Industry in 2020

• Demand in 2020: 200-240,000 tpa REO

• Demand trends:
  • Greater availability of non-Chinese products
  • Greater total supply chain management
  • Higher consumption of HREEs if available

• Supply in 2020: 240-280,000 tpa REO

• Supply trends:
  • Limited scope for pure LREE projects outside China
  • Significant opportunity for HREE projects as availability of HREEs will remain an issue
  • Ongoing consolidation of industry worldwide

Source: IMCOA
The Dubbo Zirconia Project

• A very large* polymetallic resource of the metals zirconium (hafnium), niobium (tantalum), yttrium and rare earths

• Important and strategic metal mix, including 25% heavy rare earth

• Open pit life of at least 70 years

• Demonstrated flow sheet with pilot plant and products for market evaluation

• Robust technical and financial feasibility completed
  • Strong market interest in products
  • Growing and diverse markets

*resource and reserve statement appended
Simple open cut mining operation
Crushing and grinding
Sulphuric acid, roast, leach whole of ore
Solvent extraction, separation & refining
DZP Pilot Plant

DPP Filtration, PLS, SX, Zr and Nb recovery

Y and HREE refining and recovery

Zirconium refining and precipitation

Reverse osmosis and water recycle

Operating at ANSTO Since 2008
Product Output @ 1Mtpa

- **Production Output**
  - ZrO2: 23,768t (67%)
  - Nb metal: 1,309t (20%)
  - LREO concentrate: 1,967t (8%)
  - HREO concentrate: 4,665t (31%)

- **Revenue Breakdown**
  - 95% yttrium, dysprosium, terbium (28.5% of revenue)
  - 90% neodymium, praseodymium (21.6% of revenue)

**The DZP has a diversified revenue stream**
AZL MoU’s and Agreements to secure 100% of output

Zirconium (Zr)
- Leading chemical company to develop applications and markets in Asia for zirconia produced by DZP
- European manufacturer/trading company to market DZP products in Europe and North America
- Ceramic colours laboratory developed in Perth to produce test products for ceramic tile industry

Niobium (Nb)
- JV with European Treibacher Industrie AG to produce and market ferro-niobium
- Test work for tantalum recovery

Light rare earths
Heavy rare earths
- Japan’s Shin-Etsu Chemical toll treatment JV for separation and sale
# DZP Major Milestones

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<td>Environmental Impact Statement</td>
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<td>Project Approval Process</td>
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<tr>
<td>Project Financing Program</td>
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<tr>
<td>EPC / EPCM tender → award</td>
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<tr>
<td>Detailed design / Long lead orders</td>
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<tr>
<td>CONSTRUCTION</td>
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<tr>
<td>PRODUCTION</td>
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### Dubbo Zirconia Project – Mineral Resources

<table>
<thead>
<tr>
<th>Deposit</th>
<th>Tonnage (Mt)</th>
<th>ZrO₂ (%)</th>
<th>HfO₂ (%)</th>
<th>Nb₂O₅ (%)</th>
<th>Ta₂O₅ (%)</th>
<th>Y₂O₃ (%)</th>
<th>REO (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>35.70</td>
<td>1.96</td>
<td>0.04</td>
<td>0.46</td>
<td>0.03</td>
<td>0.14</td>
<td>0.75</td>
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<tr>
<td>Inferred</td>
<td>37.50</td>
<td>1.96</td>
<td>0.04</td>
<td>0.46</td>
<td>0.03</td>
<td>0.14</td>
<td>0.75</td>
</tr>
<tr>
<td>Total</td>
<td>73.20</td>
<td>1.96</td>
<td>0.04</td>
<td>0.46</td>
<td>0.03</td>
<td>0.14</td>
<td>0.75</td>
</tr>
</tbody>
</table>

These Mineral Resources are based upon information compiled by Mr Terry Ransted MAusIMM (Alkane Chief Geologist) who is a competent person as defined in the 2004 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves. Terry Ransted consents to the inclusion in the report of the matters based on his information in the form and context in which it appears. The full details of methodology were given in the 2004 Annual Report.

### Dubbo Zirconia Project – Ore Reserves

<table>
<thead>
<tr>
<th>Deposit</th>
<th>Tonnage (Mt)</th>
<th>ZrO₂ (%)</th>
<th>HfO₂ (%)</th>
<th>Nb₂O₅ (%)</th>
<th>Ta₂O₅ (%)</th>
<th>Y₂O₃ (%)</th>
<th>REO (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proved</td>
<td>8.07</td>
<td>1.91</td>
<td>0.04</td>
<td>0.46</td>
<td>0.03</td>
<td>0.14</td>
<td>0.75</td>
</tr>
<tr>
<td>Probable</td>
<td>27.86</td>
<td>1.93</td>
<td>0.04</td>
<td>0.46</td>
<td>0.03</td>
<td>0.14</td>
<td>0.74</td>
</tr>
<tr>
<td>Total</td>
<td>35.93</td>
<td>1.93</td>
<td>0.04</td>
<td>0.46</td>
<td>0.03</td>
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