Beneficiation of South Africa’s Titanium Resource
A Long Term Vision is the Key to Success

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- The Additive Manufacturing Collaborators Network
Overview

• Introduction
• Sasol: A Beneficiation Success
• The South African Titanium Metal Industry Strategy
• Role of the Titanium Centre of Competence
• Government Support for Titanium Beneficiation
• Success Factors
• Impact of Successful Beneficiation
• Concluding Remarks
Introduction

• Beneficiation has been on the agenda of South African governments over the past century
• We have some good successes of beneficiation of local resources in our history
• However, more so than in the past, beneficiation has become a national imperative for sustained growth of our economy
• Let us draw inspiration from the past and take up the current challenges with confidence
Sasol: A Beneficiation Success

- Beneficiation of SA’s coal resource through commercialising the Fischer-Tropsch process – largest scale in the world
- Anglovaal started exploring the technology in the 1930s
- Sasol was established as government controlled company in 1950
- It produced the first synthetic petrol in 1955
- Sasol is listed on the Johannesburg Stock Exchange and the New York Stock Exchange
- One of the largest multi-national companies originating in SA
  - Employs 34 000 people worldwide
  - Operates in 38 countries
  - Exports to more than 100 countries

The South African Titanium Metal Industry Strategy
We recommend improvement in mineral processing technologies to enable the more cost-effective and wider exploitation of our mineral resources taking environmental requirements into account.

Government and industry should jointly support research and development in the following fields:

- Titanium and titanium oxide production from local raw materials

Ref: Mining and Metallurgy Foresight, The National Research and Technology Foresight Project, DACST 1999
The South African Titanium Opportunity

- 2nd largest Ti mineral producer
- 3rd largest V producer

Raw material → Processes & technologies

Primary Metal and Mill Products → Components and Manufactured Products

Market

Aerospace, Medical, Marine, Chemical, Automotive, Recreational, Industrial, Power
Key Properties of Titanium

- Titanium’s strength compares favourably to stainless steels and superalloys, but its density is only about 56% that of steel
  - It has the highest Specific Strength (strength/density) of all metals
- Commercial alloys of titanium are useful up to temperatures of about 540ºC to 600ºC. Some alloy systems (titanium aluminides) may have useful strengths well above this temperature.
- Titanium is exceptionally corrosion resistant - outstanding in seawater and in the human body (used for implants)
- Since the 1950s Ti has been an aircraft metal; first for military, later for commercial aircraft
The SR-71 Blackbird

Designed & built in 1959 - 1963
- Fuselage skin temperature could reach 370ºC
- Needed to be lightweight, strong and corrosion-resistant
- Constructed 90%+ from Ti alloys

Fastest airplane ever:
- Mach 3.2 (3700 km/h) at 80 000ft (~ 24 km)
- New York to Londen: 1h 55min
Need for Titanium in the South African Industry

The dti’s IPAP 2014/15 – 2016/17: Key Action Programmes (p131) Development of a Titanium Production Capability Roadmap with the focus on downstream manufacturing technologies and products

Economic rationale

• To position South Africa as a lead supply chain participant within the global titanium manufacturing industry, concentrating on aerospace and defence products and new technologies.

• To increase the spill-over effects of these new technologies into related activities and adjacent industries such as medical, energy, automotive, chemical processing, marine, oil and gas.
Cheaper Titanium Powder – Changing the Industry

Typical prices

- **Ilmenite**: 1 USD/kg Ti
- **TiO₂ Slag**: 1.45 USD/kg Ti
- **TiCl₄**: 4.4 USD/kg Ti
- **Ti Sponge**: 10 USD/kg Ti
- **Ti Powder**: 10 USD/kg Ti
- **Ti Powder**: 40 USD/kg Ti
- **Ti Ingot**: 20 USD/kg Ti
- **Ti Mill Products**: 50 USD/kg Ti
- **TiO₂ Pigment**: 5.3 USD/kg Ti
- **Final Products/Components**: USD/kg 150 - 20,000

Current SA industry
Market failure?
Our National Vision

A new Titanium Metal Industry sector in South Africa
A New South African Titanium Industry
Economic and Job Creation Opportunities

**Primary Titanium Metal Industry**
- **Titanium Metal Powder**
  - Newco 300 - 400
- **Titanium Mill Products**
  - Newco 140 - 180
- **Powder consolidation**
- **Ferrotitanium**

**Downstream Titanium Manufacturing Industry**
- **Additive Manufacturing Products**
  - Newco 40 - 70
  - Medical
  - Aerospace
- **Near-net & Net Shape Products**
  - Conventional Powder Metallurgy
  - Newco 20 - 50
- **Fabricated Products**
  - Co/Newco 180 - 220
  - Forming
  - Machining
  - Joining
- **Cast Products**
  - Foundry 15 - 20
  - Investment Casting
- **Steel Making**

**Titanium Mineral**
- CSIR-Ti Process
  - Pilot Plant
  - Semi-Commercial (Demo) Plant
  - Full Commercial Plant

**Powder spheroidisation**
- **Alloying**

**Estimated initial direct jobs**
- 700 - 950

CSIR Light Metals 2013
Role of the
Titanium Centre of Competence
Pursuing the South African Beneficiation Opportunity

The Titanium Centre of Competence integrates and coordinates R&D and commercialisation across the value chain.
Titanium Centre of Competence

Developing and commercialising technology building blocks for the South African Titanium Industry

SA Ti Industry

SA Supplier Development

Industrialisation & Commercialisation

Technology Development

Primary Metal Production
Powder Consolidation
Additive Manufacturing
Investment Casting
High Performance Machining
Friction Welding
Sheet Forming

Fabricated products
Net & near-net shape products
Mill products
Near-net shape

Ti powder

Physical Metallurgy and Characterisation
Design, Simulation and Modelling
Laboratories and R&D Facilities
Supportive Platforms

Modification of the TiCoC Model
Progressing through Technology Readiness Levels (TRLs)

Phase 1: Technology Assessment and Proving
- Level 1: Process concept proposed with scientific foundation
- Level 2: Applicability and validity of concept described and vetted or demonstrated
- Level 3: Experimental proof of concept completed
- Level 4: Process validated in laboratory using representative development equipment

Phase 2: Pre-production
- Level 5: Basic capability demonstrated using production equipment
- Level 6: Process optimised for capability and rate using production equipment

Phase 3: Production & Implementation
- Level 7: Capability and rate confirmed via economic run lengths on production parts
- Level 8: Full production capable process qualified on full range of parts for significant run lengths
- Level 9: Full production capable process qualified on full range of parts over extended period (all business case metrics achieved)
Titanium Centre of Competence

Developing and commercialising technology building blocks for the South African Titanium Industry

SA Ti Industry

SA Supplier Development

Industrialisation & Commercialisation

Technology Development

- Primary Metal Production
- Powder Consolidation
- Additive Manufacturing
- Investment Casting
- High Performance Machining
- Friction Welding
- Sheet Forming

Physical Metallurgy and Characterisation

Design, Simulation and Modelling

Laboratories and R&D Facilities

Supportive Platforms

Modification of the TiCoC Model
The South African TiCoC Resource Pool

International R&D Institutions:
- CSIRO (Australia)
- NIMS (Japan)
- ESRF (France)
- Fraunhofer IWU (Germany)
- Univ of Plymouth (UK)
- TiDA (New Zealand)

Companies:
- Airbus (Europe)
- Boeing (USA)
- Snecma (France)
- ALD (Germany)

Mobilisation and alignment of the national expertise:
- Permanent researchers: 80+
- Post graduate students: 20+
Primary Titanium Industrialisation Plan

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<tr>
<td>Phase</td>
<td>Basic Development</td>
<td>Pilot Phase (2kg/h)</td>
<td>Feasibility Phase</td>
<td>Demonstration Plant 500 tpa Commercially Pure (CP) Ti</td>
<td>World-Class Plant Production: 20 000 tpa first: CP Ti; then Ti Alloy</td>
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Primary Ti Production (CSIR-Ti Process)

- Completed
- CSIR-Ti Pilot Plant (current)
- Commercial partners

TRL Levels:

- TRL 2-4: Concept, Proof of concept, Lab validation
- TRL 5: Validation in relevant environment
- TRL 6: Demonstration in relevant environment
- TRL 7: Demonstration in operational environment
- TRL 8: System complete and qualified
- TRL 9: Deployment

部委: Science and Technology
共和国: 南非
The Power of the Titanium Centre of Competence

- Constitutes a national Titanium R&D “business”
- It embodies the national vision – the collaborators and stakeholders can identify with it
- The participants in different focus areas can share their learning
- It demonstrates the government’s long term sustained commitment
- Opportunities for industry involvement becomes clear
A Titanium Inter-departmental Task Team was established, representing the following departments:

- Department of Science and Technology
- Department of Trade and Industry
- Industrial Development Corporation
- Department of Mineral Resources
- Department of Public Enterprises

It meets regularly to facilitate cooperation of the departments.
Success Factors

- Agreement on the national strategy by all key role players
- Secure a mandate to implement the strategy
- A Champion in Government
- A Champion in each collaborating unit
- Industry involvement early on
- Share the Vision and continuously promote it
- Sustained communication
- Recognition of each contribution (on-going buy-in)
- Remain focused and persevere
Impact of Successful Beneficiation:
Additive Manufacturing from titanium powder to restore quality of life
Customised Lower Jaw Implant
UP – CUT Collaboration
Customised Lower Jaw Implant
UP – CUT Collaboration
Potential Future Impact of Successful Local Ti Beneficiation

- Titanium powder production through the CSIR-Ti process
- Alloying and spheroidisation of the locally produced Ti powder
- More affordable production of customised medical implants through Additive Manufacturing of local Ti6Al4V powder
- Large numbers of South Africans experience vastly improved quality of life
Concluding Remarks

- A long term vision is the key to success
- Establish support for the vision
- Put SA’s best resources to the task
- It does not happen overnight - persevere
- We have examples of successful beneficiation, such as Sasol
- We have the Centre of Competence model

- Let’s go and just do it!
Thank you

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