www.csiro.au

Direct Powder Rolling (DPR) of Titanium.

Light Metals Flagship

D.Cantin, P.Kean, N.A. Stone, R.Wilson, M.A. Gibson, D.Ritchie, R. Rajakumar

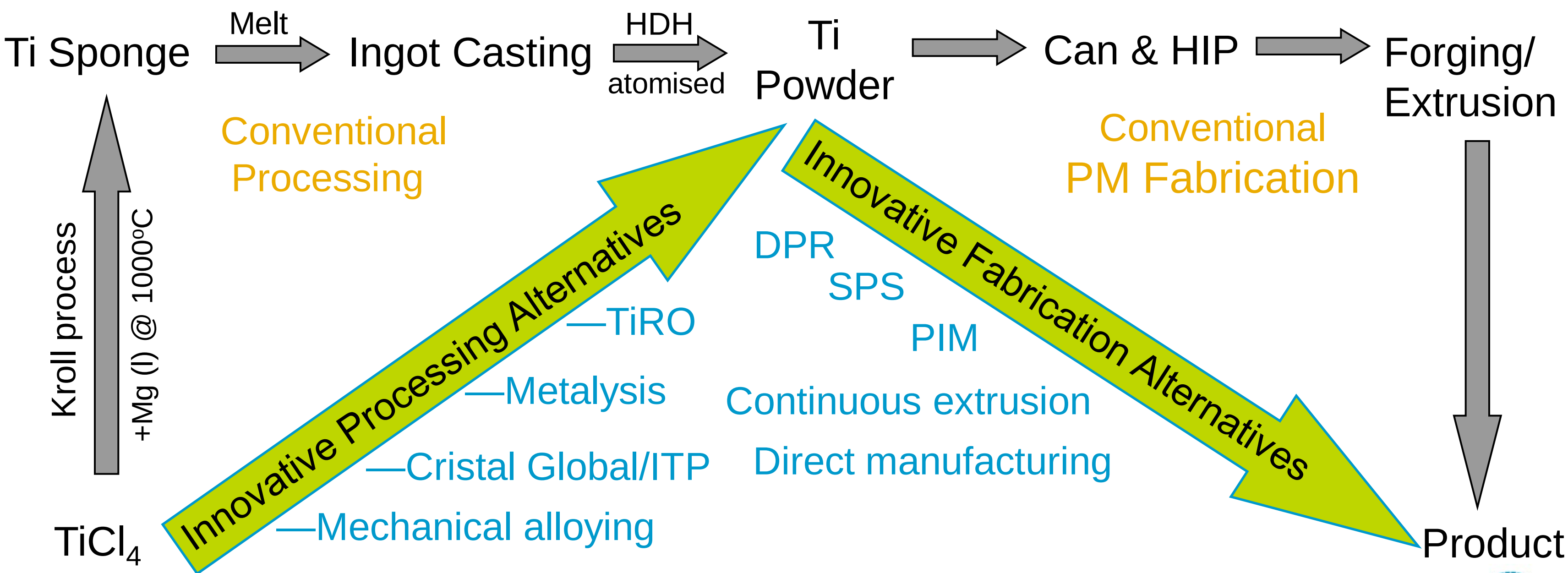
Titanium 2010
Orlando, Florida 3-6 October 2010

National Research
FLAGSHIPS
Light Metals

CSIRO

Manufacture of titanium products

- Titanium products considered very expensive due to costs of raw materials and manufacturing routes
- Drive to lower both primary and fabrication costs
- Powder metallurgical processing considered to offer significant opportunities
  - Extensive recent effort to develop **“lower”** cost powder alternatives
  - Strategy to introduce step changes rather than incremental advances
  - NNS manufacturing – reduction in buy-to-fly ratio



[After Froes and German, 2000]

Direct Powder Rolling (DPR) of Titanium Sheet.

National Research FLAGSHIPS Light Metals CSIRO

Direct powder rolling of titanium

Consolidation by direct powder rolling of strip is not new – number of processes developed especially in 1950’s-1960’s.

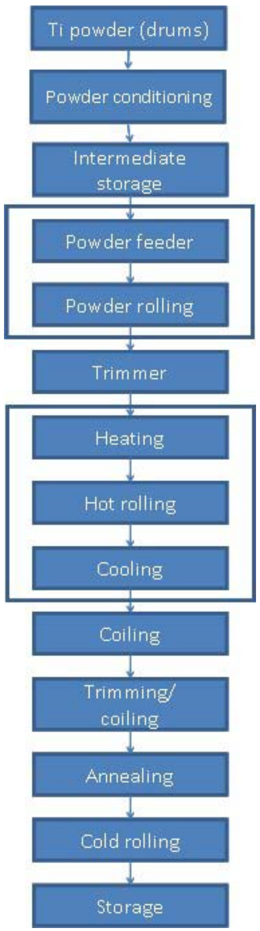
Generally involves sintering step to fully densify and homogenise microstructure followed by further hot or cold rolling.

Advantages include:

- Capital equipment savings from a reduction in processing steps.
- Production of higher purity strip, free from segregation and with higher yield.
- Production of fine-grained, high strength strip with no preferred texture.
- Production of sheet from specialty and difficult-to-work materials.

National Research FLAGSHIPS Light Metals
CSIRO

DPR/HRD process schematic

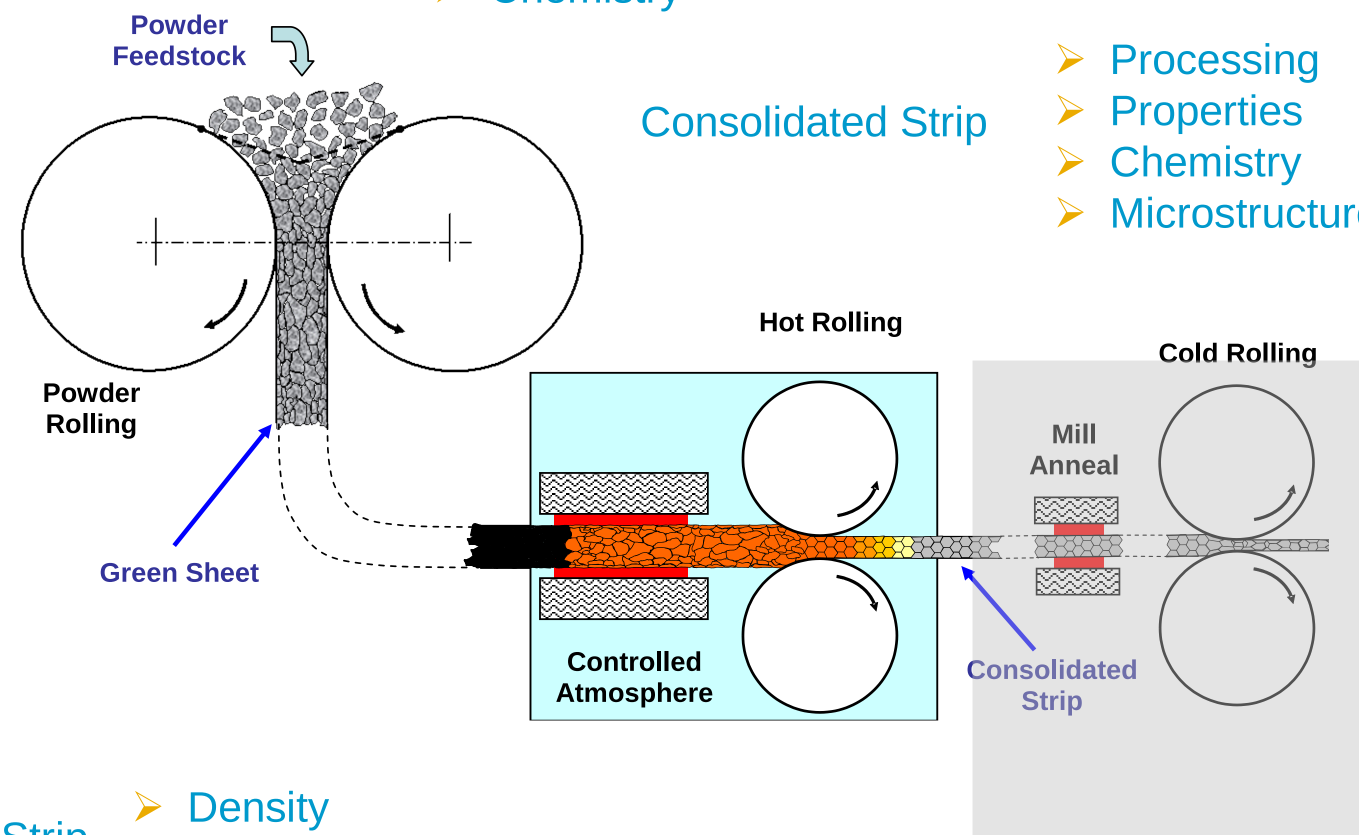


Powder feedstock

- Morphology
- Flow properties
- Fill/tap density
- Chemistry

Consolidated Strip

- Processing
- Properties
- Chemistry
- Microstructure



Green Strip

- Density
- Dimensional accuracy

Direct powder rolling - DPR

Green density ~80-85% TD.

Issues:

Roll gap

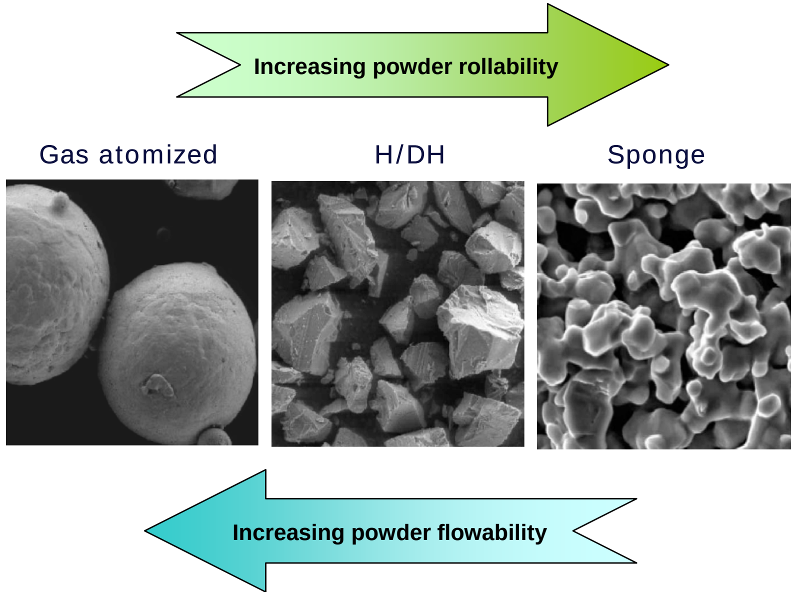
Roll speed

Hopper design and positioning (powder flow)

Edge retention

Direct powder rolling

- Influence of powder morphology and flow properties on powder rolling

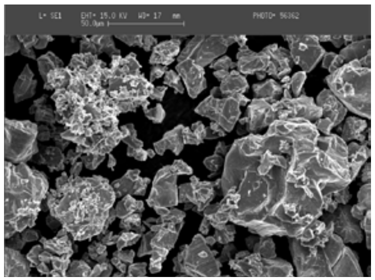


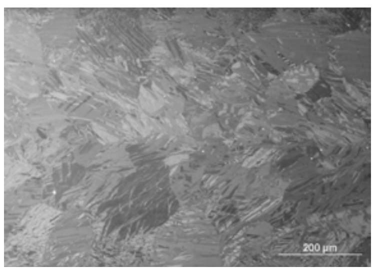
- Rolling loads and compaction behaviour/ ratio also influenced by particle size distribution, fill and tap density, interstitials content (oxygen), and composition (for example CP Ti versus PA Ti6Al4V)

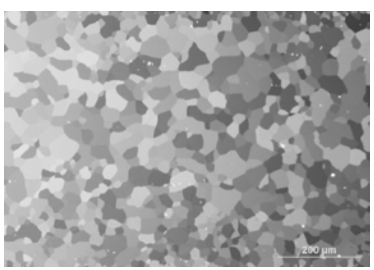
Hot roll densification - HRD

HRD - CP Ti (grade 2-3)

CP Ti

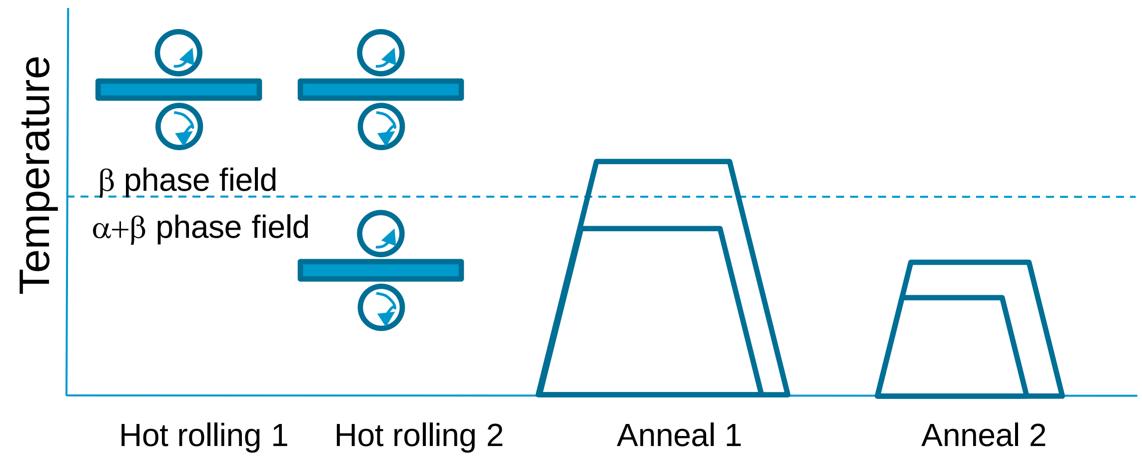






- Evaluation of process window conditions for CP Ti
- Preheat temperature > β transus temperature
- Density increase < 10% on heating only
- Rolling thickness reduction > 40%
- Counter flow inert gas, 200 ppm O_2 max pick-up.
- Sheet density > 99.5% TD
- For CP Ti, UTS ranges from 500-750 MPa and elongation to failure from 14-19% (depending on the oxygen content)
- Mechanical properties and correlation with microstructure, chemistry, texture and residual stresses

Production of Ti-6Al-4V Strip by DPR/HRD

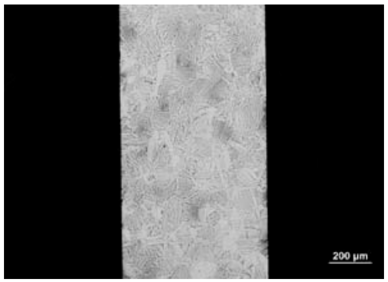


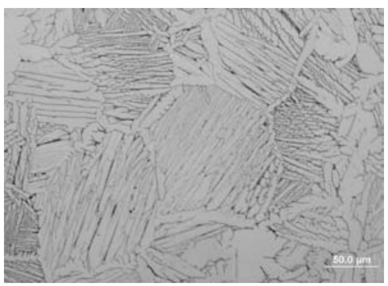
Processing Step	Parameters Tested	Levels
First hot rolling pass	Temperature, deformation, dwell time & rolling speed kept constant	-
Second hot rolling pass	Temperature Degree of deformation	Above & below β transus Two levels: <60% & >60%
Anneal 1	Temperature Hold time at temperature Cooling rate Atmosphere	Above & below β transus 20 mins & 60 mins Air cool & furnace cool Vacuum & argon
Anneal 2	Temperature Hold time at temperature Cooling rate	540ºC &750ºC 1 hr & 4 hrs Air cool and furnace cool

Results – Microstructure and Properties

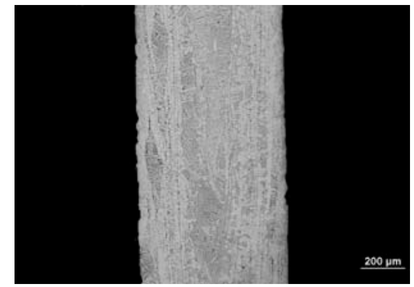
Density is 99.6%, the oxygen pick-up during the process cycle was low

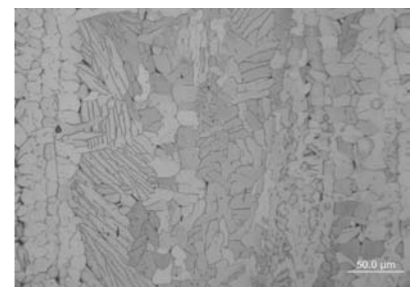
Coarse $\alpha+\beta$ lamellae, typical of furnace cooled microstructures





On going optimisation trials





UTS (MPa)	0.2% Proof Stress (MPa)	Elongation to Failure (%)	Density (%)	Interstitial Content (wt. %)	Microstructure
1061	970	8.8	99.6	0.23%O, 0.02%N, 0.018%H	homogeneous
991	915	6.8	99.4	-	inhomogeneous

Conclusions

- A **process for the direct rolling** of Titanium sheet from powder has been discussed.
- Powder morphology, flow and packing density as well as the roll mill physical characteristics **all impact** powder compaction on rolling.
- The combination of roll compaction and in-line rapid heating prior to hot roll densification (HRD) has the **potential** to reduce manufacturing costs.
- Control of heating, atmosphere and hot rolling conditions are also **essential** if the required microstructure is to be achieved.
- Work on titanium alloys such as Ti6Al4V also **very encouraging** with further work scheduled for other alloy systems.
- The DPR facility can also be applied to other metal and composite systems including functionally graded and layers structures.
- **CSIRO is actively seeking Industry participation in further development and commercialisation of the technology**

CSIRO Process Science and Engineering
Peter Kean

Business Development Manger
Light Metals Flagship

Phone: +61 3 9545 2086
Email: Nigel.stone@csiro.au
Web: www.csiro.au/group

www.csiro.au

Thank you

Contact Us
Phone: 1300 363 400 **or** +61 3 9545 2176
Email: Enquiries@csiro.au **Web:** www.csiro.au

National Research FLAGSHIPS Light Metals

CSIRO