Microstructure Physics and Metal Forming
Prof. Dr. D. Raabe
Microscopy and Diffraction
Dr. S. Zaefferer

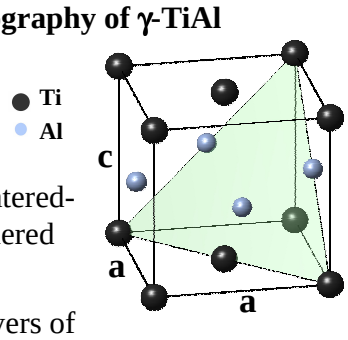
Determination of texture and microstructure of ordering domains in gamma-TiAl

C. Zambaldi[1)], S. Zaefferer[1)], S. Wright[2)]
[1)]Max-Planck-Institute for Iron Research Düsseldorf, Germany
[2)]EDAX-TSL, Draper (UT), USA
Max-Planck-Institut für Eisenforschung GmbH
Düsseldorf/Germany

Aim & Introduction

Niobium-alloyed titanium aluminides are promising candidates for material substitution in high temperature applications, e.g. in turbine blades due to their balanced mechanical performance, good oxidation resistance, low density.
Precise microstructural characterization is important for application of TiAl alloys in critical parts. This includes the identification of the order domain structure which has effects on the mechanical properties.
γ-TiAl has an ordered, tetragonal lattice structure where the c-axis is only 2% longer than the a-axis. Order domain mapping by EBSD requires the detection of this slight tetragonality. We present a successful approach to this difficult task.

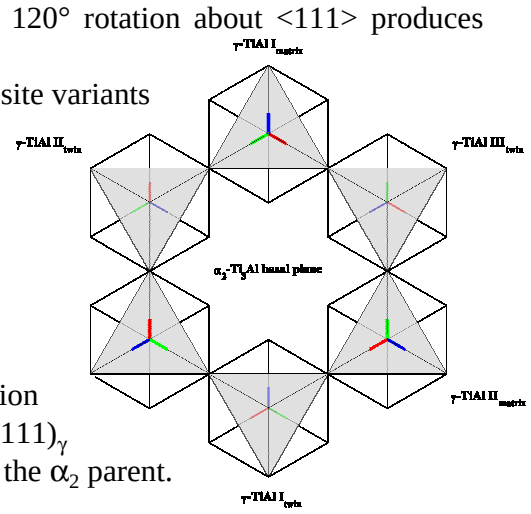
Crystallography of γ-TiAl



structure: face-centered-tetragonal, $L1_0$-ordered
c/a ratio: 1.02
stacking order: layers of pure Ti and pure Al are stacked in c-direction
deformation modes: dislocations on {111} planes with b=½[110] (ordinary dislocations), b=[101] (super dislocations) twinning on {111} with b= (a/6)⟨112]

Variants in γ-TiAl

3 order variants: A 120° rotation about <111> produces the order variants.
3 twin variant: Opposite variants with a rotation of 180° about <111> are in true twin relation.



All variants are in Blackburn orientation relationship $(0001)_\alpha \| (111)_\gamma$ $<1120>_\alpha \| <110]_\gamma$ with the α_2 parent.

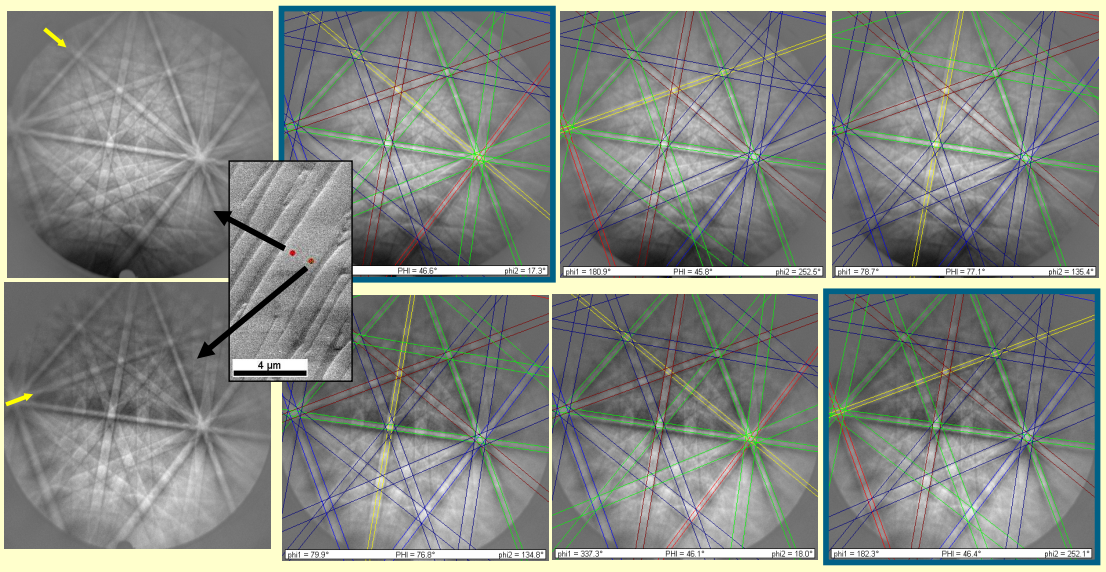
Experimental Approach

Discrimination between order variants by EBSD

The small lattice parameter difference between the c- and the a-axis is difficult to detect by automatic EBSD pattern analysis. Therefore, up to now, all EBSD work used an fcc lattice for indexing, resulting in the loss of the order variants.

Two approaches to discriminate between the order variants:
(I) Use the position of (220) superlattice reflections (marked as yellow band or by arrows in the patterns on the right side)
⇨ unique solution (if clear patterns are available)
⇨ not applicable in automatic indexing
⇨ we use the method to validate the fit rank approach.

(II)Calculation of average angular fit between the measured Kikuchi bands with the three possible indexing solutions.
⇨ The fit value is highly sensitive against the assumed position of the pattern centre
⇨ A pattern centre of highest possible accuracy must be used for indexing.

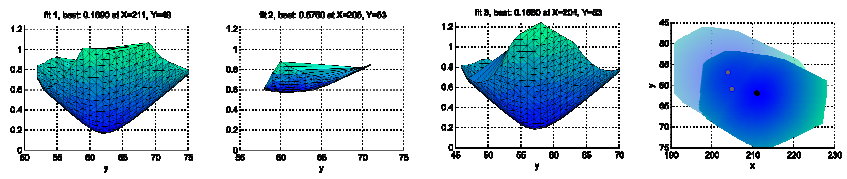


Pattern centre calibration & sensitivity analysis

The pattern centre calibration is the most critical step for a reliable discrimination of order variants. First step: pattern centre calibration using a silicon standard measured under precisely the same conditions as the sample.

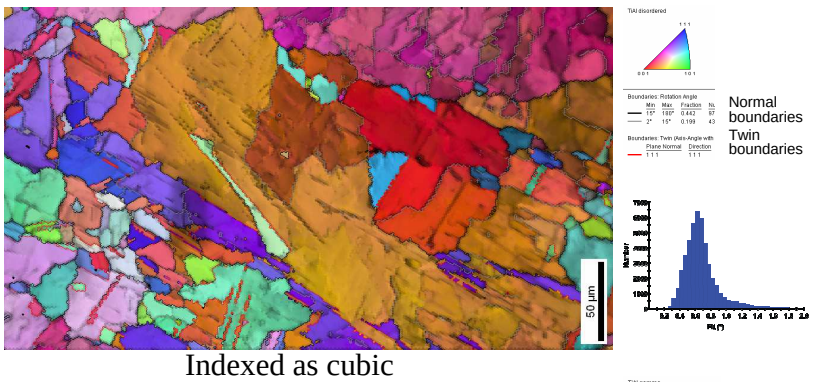
The software TOCA (S. Zaefferer) was used to generate data on systematic variation of the pattern centre. We display the sensitivity of the average angular fit measure against pattern centre variation in the projection plane. The optimum pattern centre can be directly used for reliable indexation of variants.

Pattern centre calibration on a single pattern (see pattern above): correct indexing solution #1 achieves a minimum average angular fit for a systematic variation of the pattern centre position.

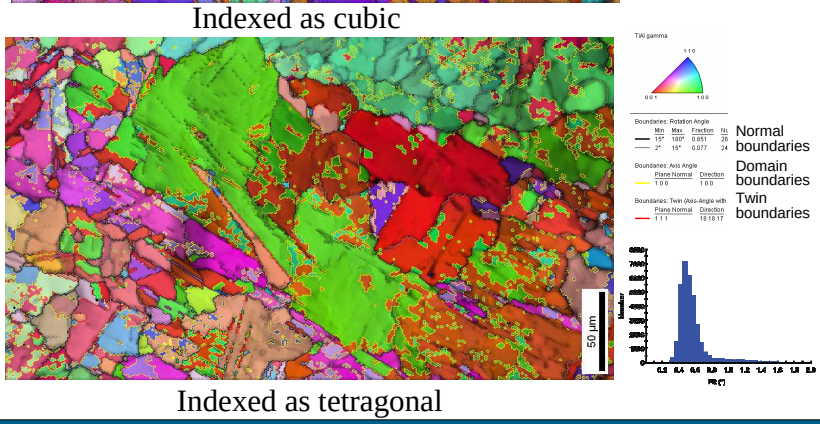


Results

α_2-solution treated, quenched, annealed; massive microstructure

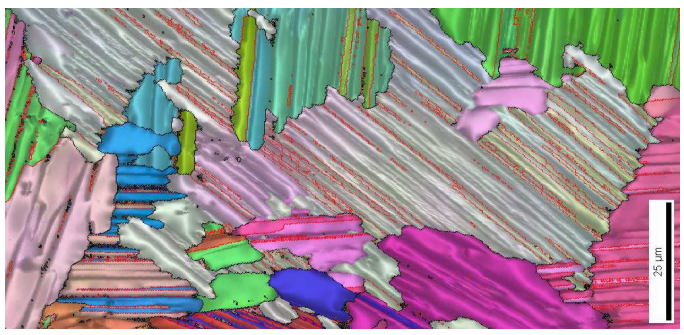


Indexed as cubic

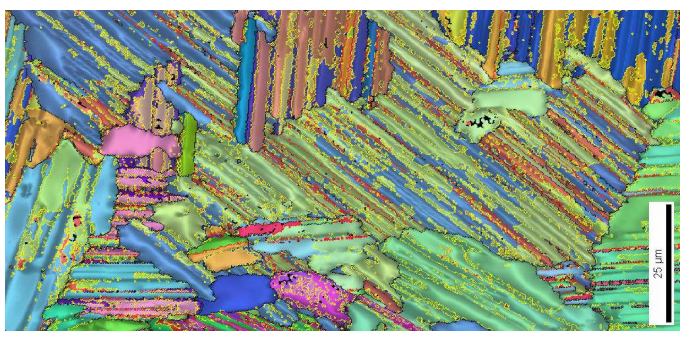


Indexed as tetragonal

as cast; lamellar microstructre



Indexed as cubic



Indexed as tetragonal

Measurement parameters
High accuracy data on the position of the Kikuchi bands is required.
FEG-SEM (JEOL 6500 F): 30 kV, WD 15 mm
EBSD camera (TSL DigiView): no binning (900 × 900 pixels), exp. time 0.5 s

Analysis parameters
EBSD analysis software (TSL-OIM): Hough transform 240 pixel × 0.5°; large (13x13) convolution mask; 16 bands used for indexing
Indexing: Use the angular fit as discriminator between solutions.

- Fit-value distribution is significantly sharpened when indexing as tetragonal structure.
- The tetragonal orientation maps show very strong differences from the cubic ones indicating the importance of tetragonal structure mapping.
- Generally, the appearance of the tetragonal-indexed structure is realistic, thus indicating the correct reconstruction of the microstructure.
- Detailed checks are still to be carried out!

Conclusions

- A determination of order domain microstructure is possible. We use the slight distortion of the patterns to determine the correct solution → "fit ranking"
- A high precision pattern centre calibration is crucial to the correct indexing. We have developed our own PC calibration tool which does not only fit the pattern centre but also determines the correct tetragonal solution.
- The patterns indexed with tetragonal crystal structure have little similarities with those indexed with cubic structure. Since different order domains have very different mechanical behaviour their correct determination is of great importance.

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