Microstructure Physics and Metal Forming
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Theory and Simulation
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Analysis of Deformation Mechanisms in Gamma-TiAl by Nanoindentation Experiments and Crystal Plasticity Simulations

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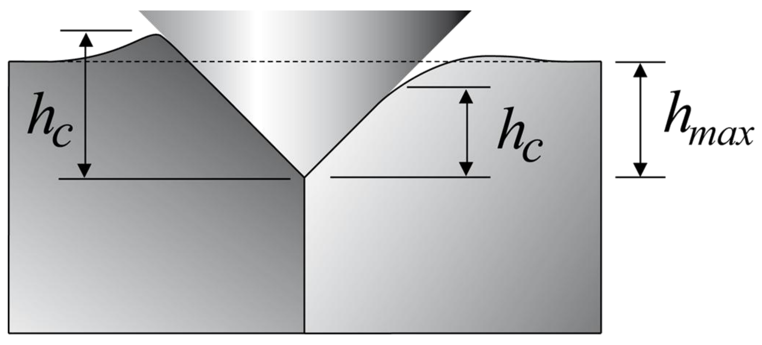
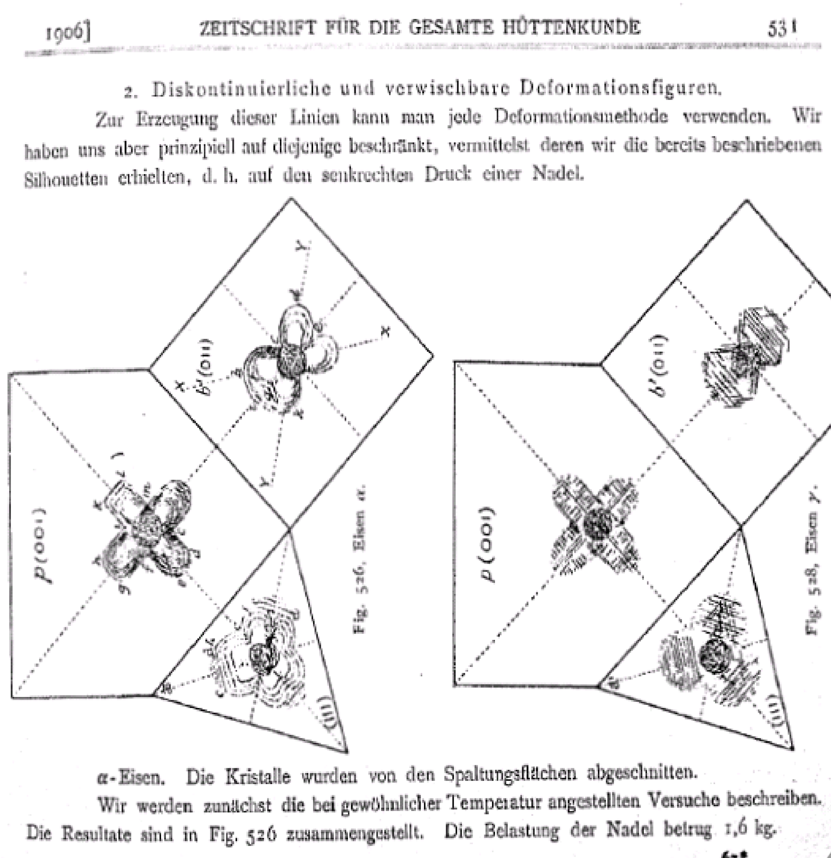
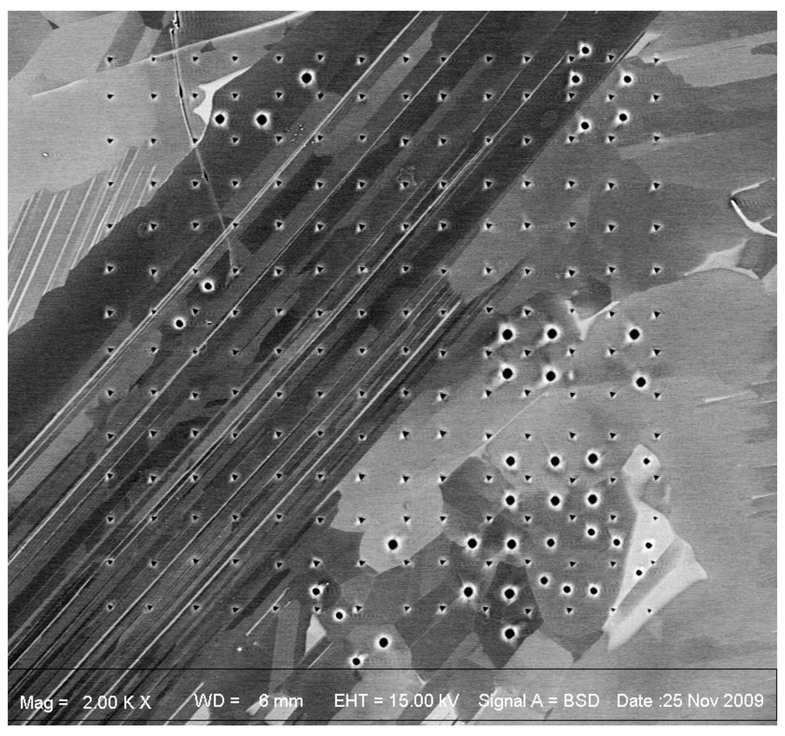
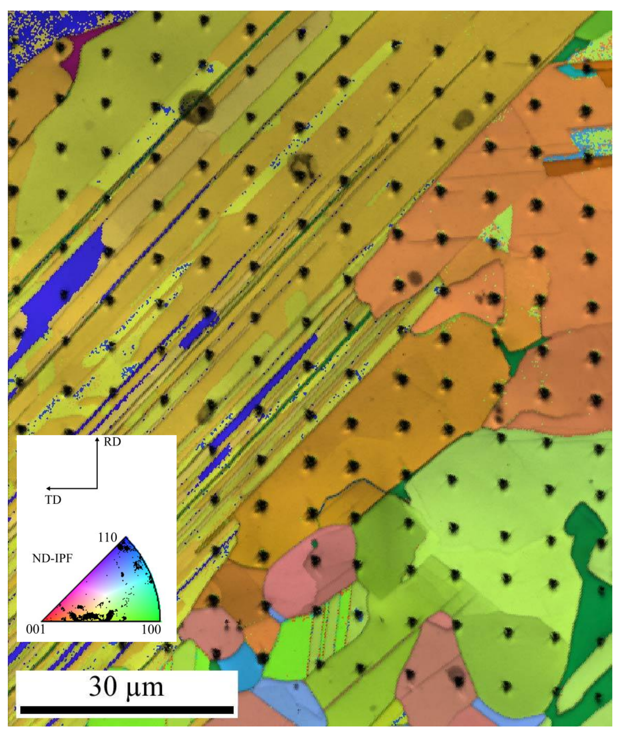
Piling-up and sinking-in is a common phenomenon during indentation of single crystals and polycrystals and can affect the contact area significantly.



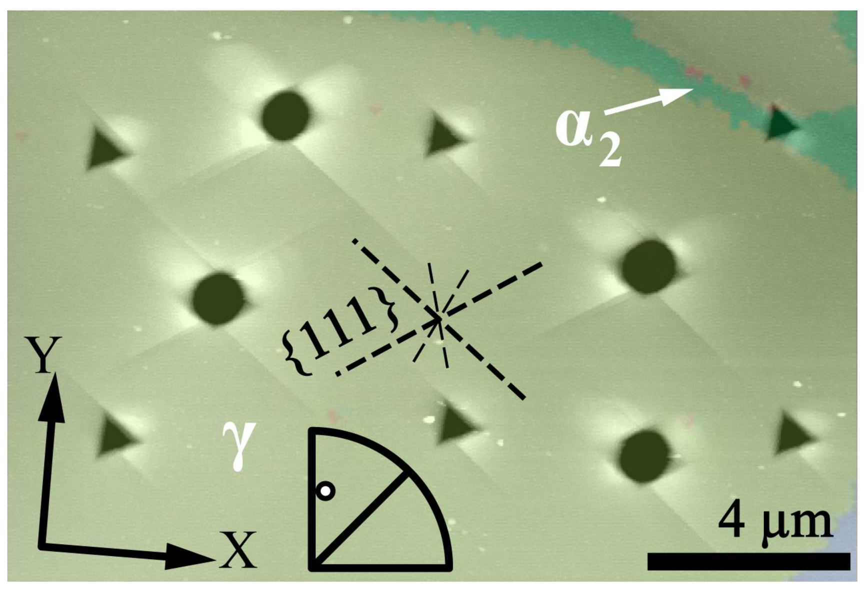

1906] ZEITSCHRIFT FÜR DIE GESAMTE HÜTTENKUNDE 531
2. Diskontinuierliche und verwischbare Deformationsfiguren.
Zur Erzeugung dieser Linien kann man jede Deformationsmethode verwenden. Wir haben uns aber prinzipiell auf diejenige beschränkt, vermittelst deren wir die bereits beschriebenen Silhouetten erhielten, d. h. auf den senkrechten Druck einer Nadel.
Fig. 526. Eisen α.
Fig. 528. Eisen γ.
α-Eisen. Die Kristalle wurden von den Spaltungsflächen abgeschnitten.
Wir werden zunächst die bei gewöhnlicher Temperatur angestellten Versuche beschreiben. Die Resultate sind in Fig. 526 zusammengestellt. Die Belastung der Nadel beträgt 1,6 kg.

Pile-up patterns from single crystal indentation are known since more than 100 years: a page from Osmond & Cartaud's work on iron in 1906.

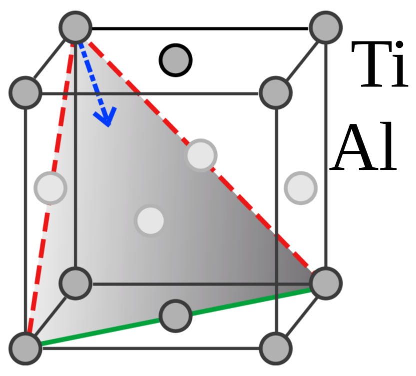




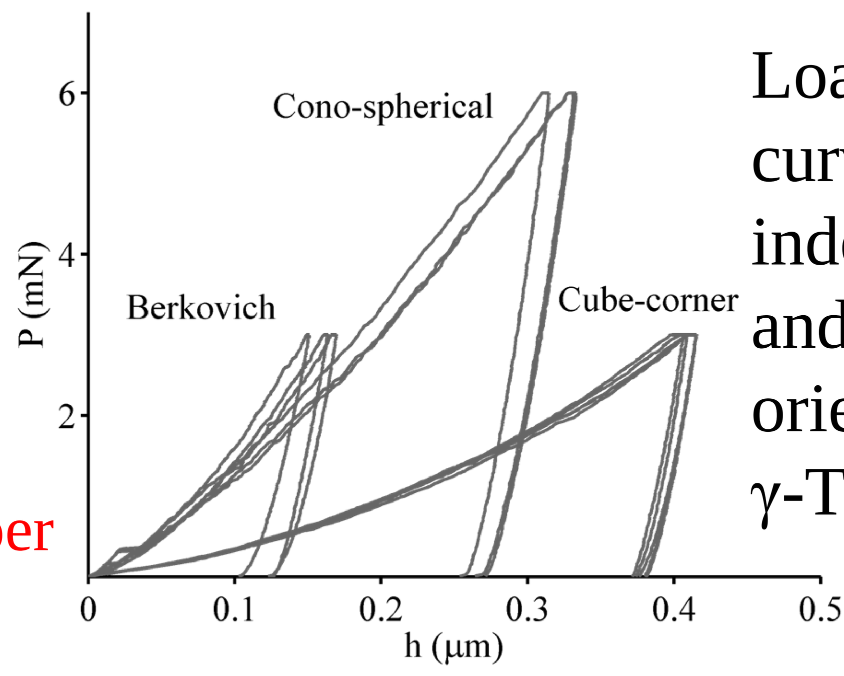
EBSD map and BSE image of a two-phase γ-TiAl based microstructure with indents.



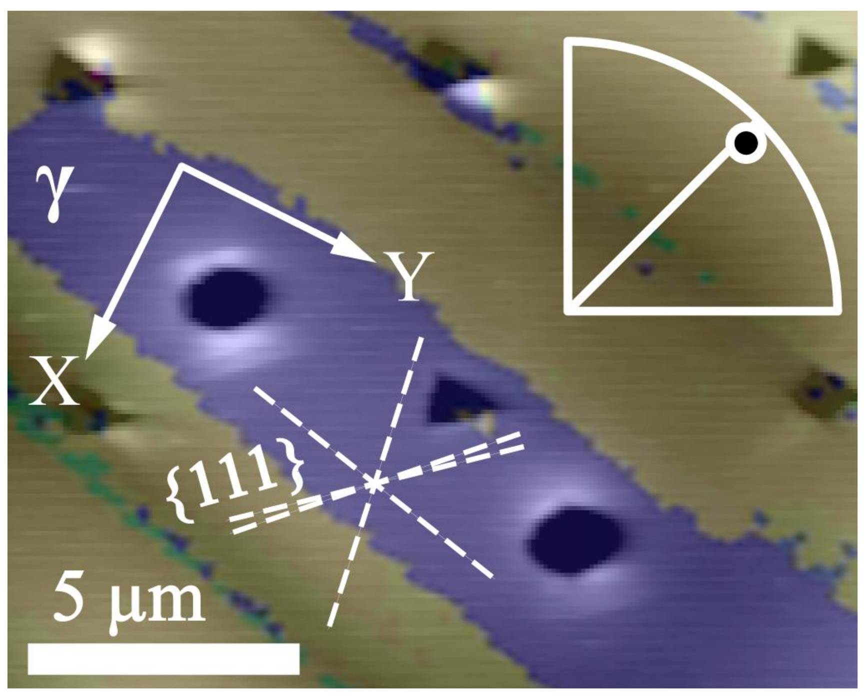
AFM characterization of the indent topography reveals the characteristic pile-up profiles of specific orientations.

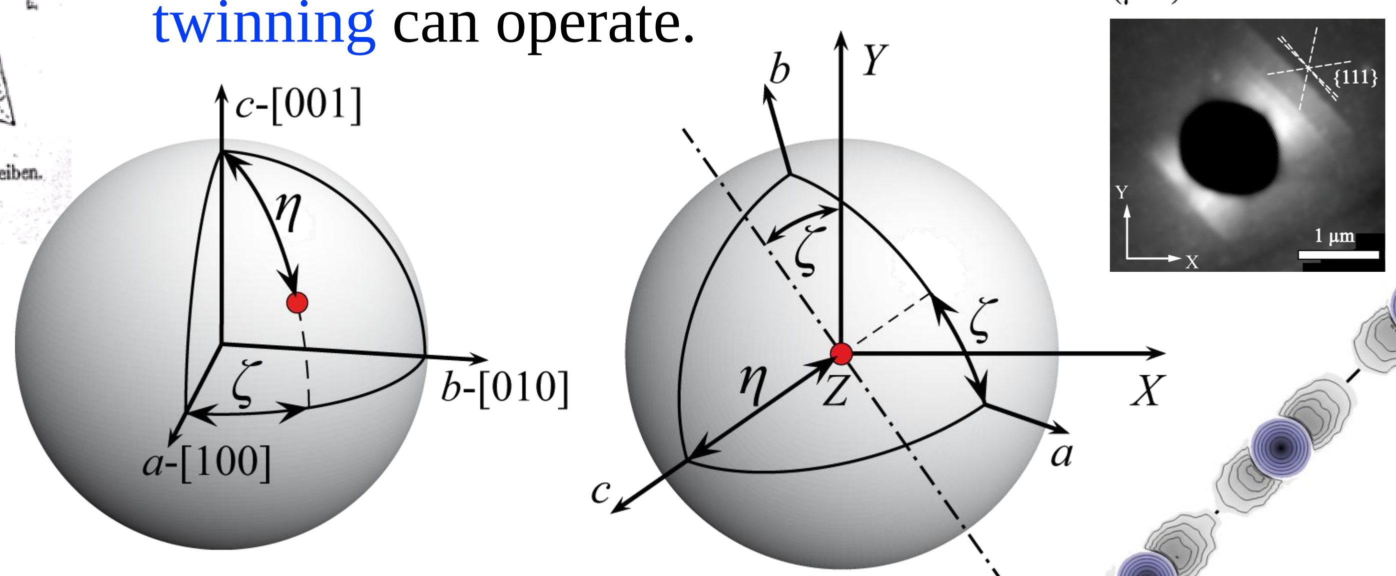


The fcc-derived $L1_0$ structure of γ-TiAl; Ordinary/super dislocation glide and twinning can operate.

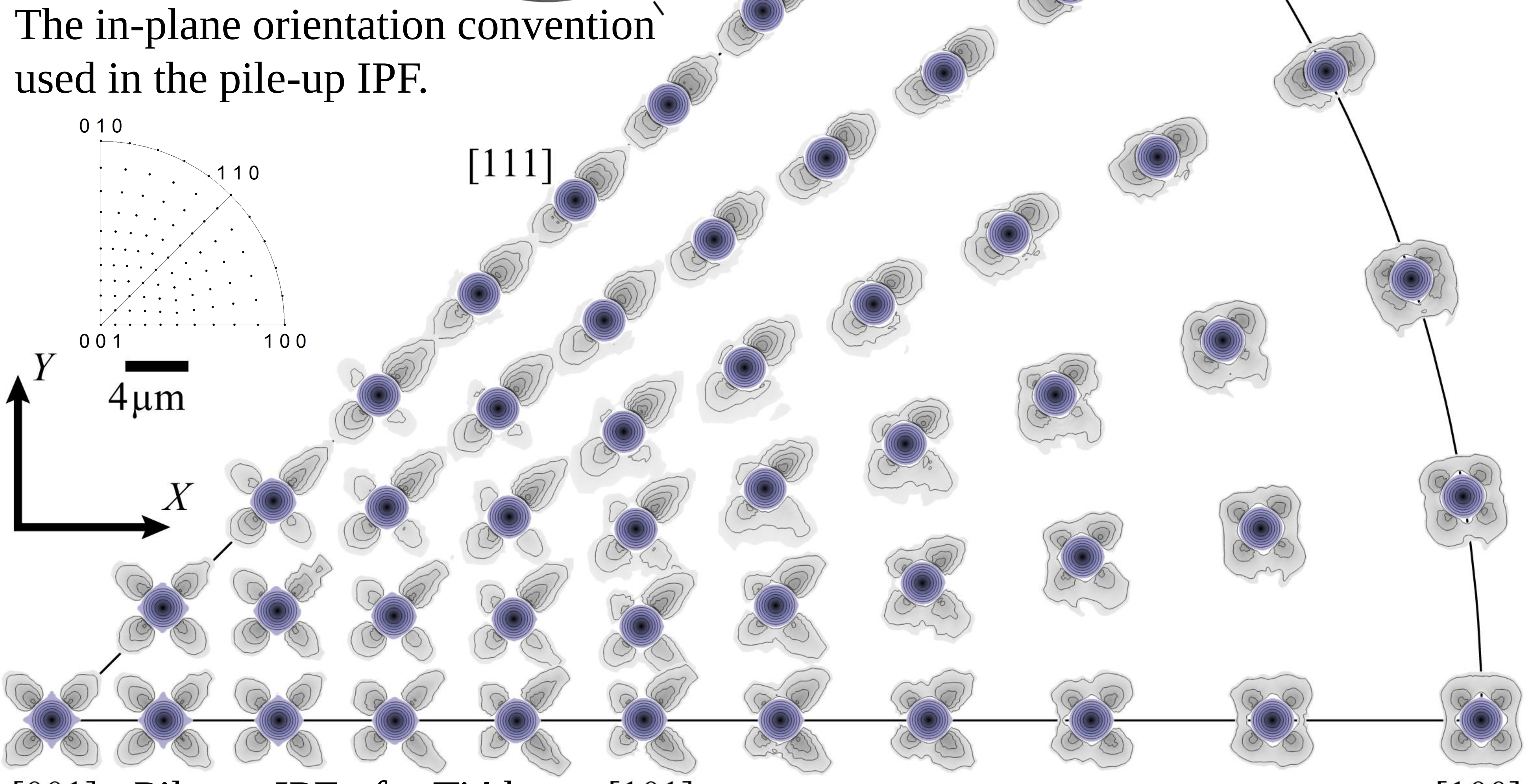


Load-displacement curves for different indenter geometries and different orientations of γ-TiAl.

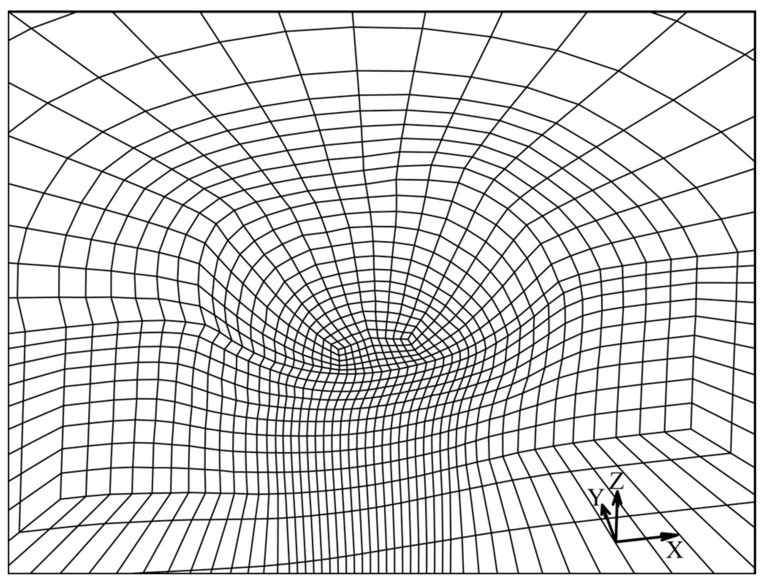




The in-plane orientation convention used in the pile-up IPF.

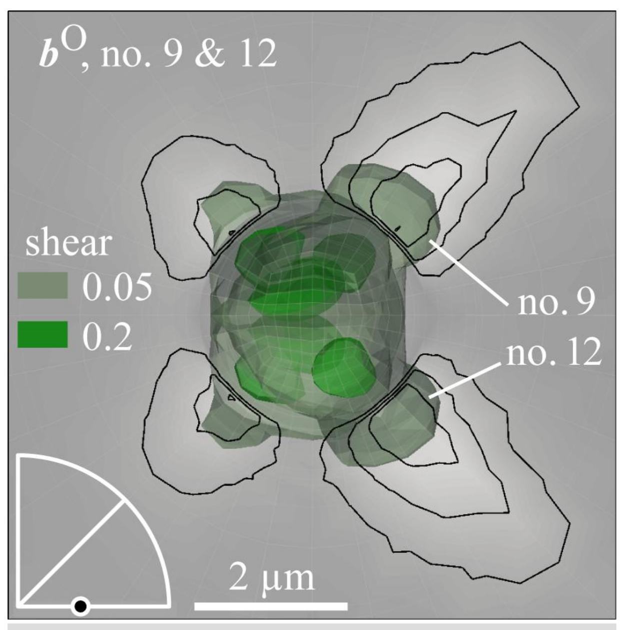


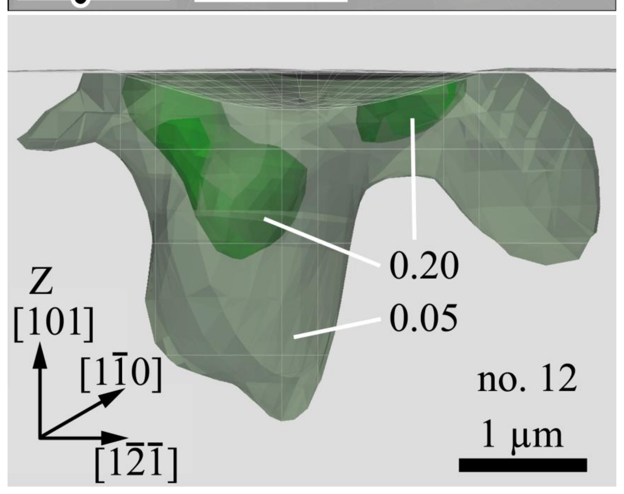
[001] Pile-up IPF of γ-TiAl [101] [100]

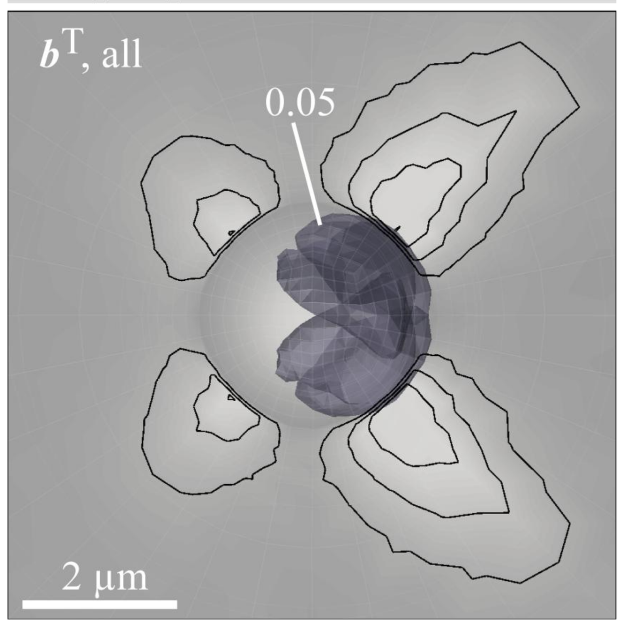


Discretization of the indentation process into 15060 hexahedral finite elements.

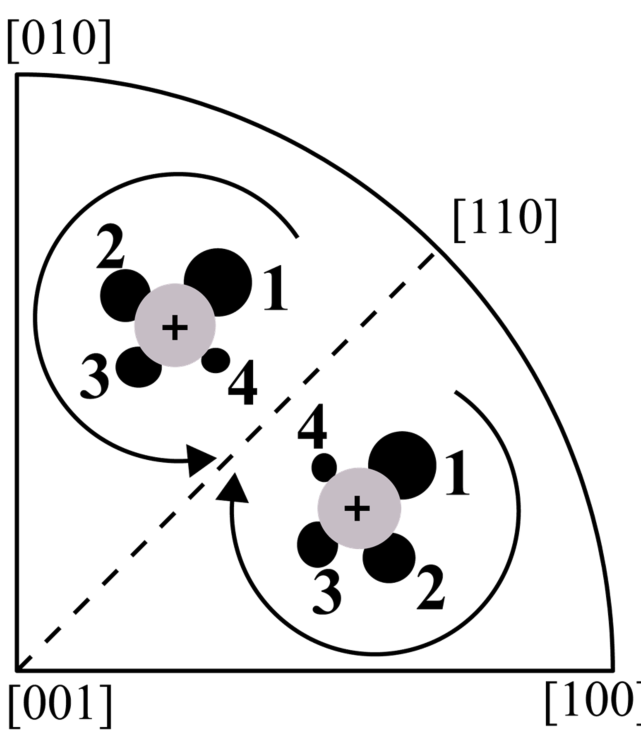
The *inverse pole figure of pileup patterns* was developed, based on a in-plane orientation convention and the representation of pile-up topographies at the stereographic projection of their indentation axis in the inverse pole figure. This graphical representation of the orientation dependent pile-up behavior can be used for any crystal structure indented with tools of arbitrary -- but preferably axisymmetric – geometry.



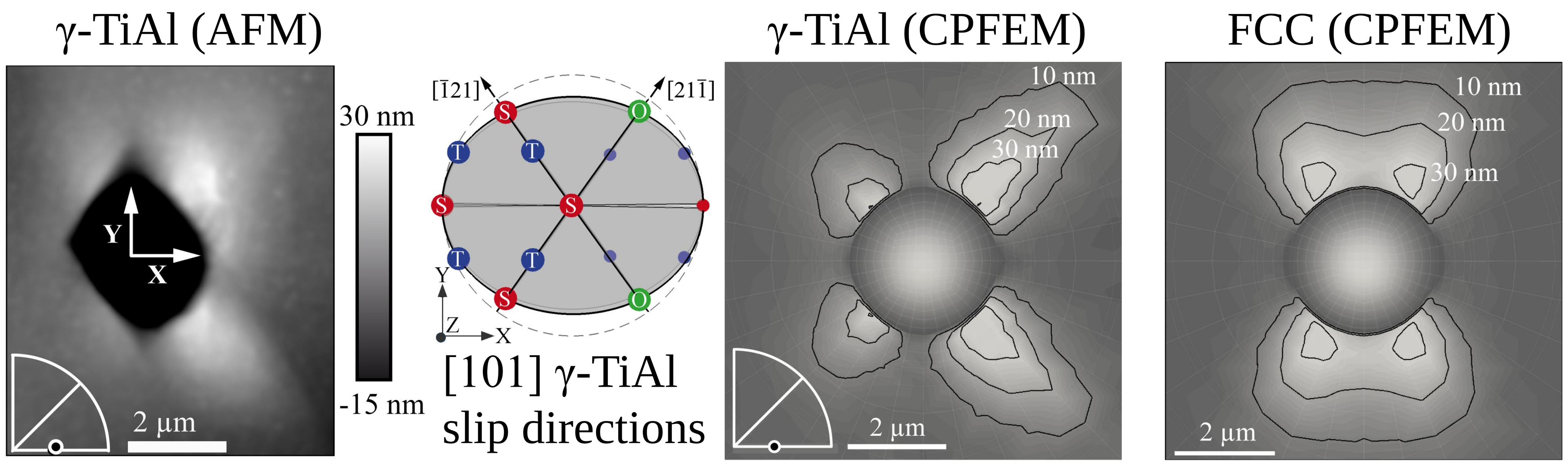




Crystal plasticity finite element simulation of the indentation process can explain the formation of the pile-up patterns based on the activation of different deformation mechanisms.



While scalar quantities, such as the unidirectional stiffness, are invariant under an improper symmetry operation acting on the crystal, the pile-up changes its handedness. This holds for any crystal structure.



The [101] indentation axis was found to be characteristic for the easy activation of ordinary dislocations. In comparison to the known fcc pile-up shape the γ-TiAl pattern exhibits pronounced piling up in the slip directions of ordinary dislocations.