In-situ observation of the recrystallization process of massively transformed TiAl

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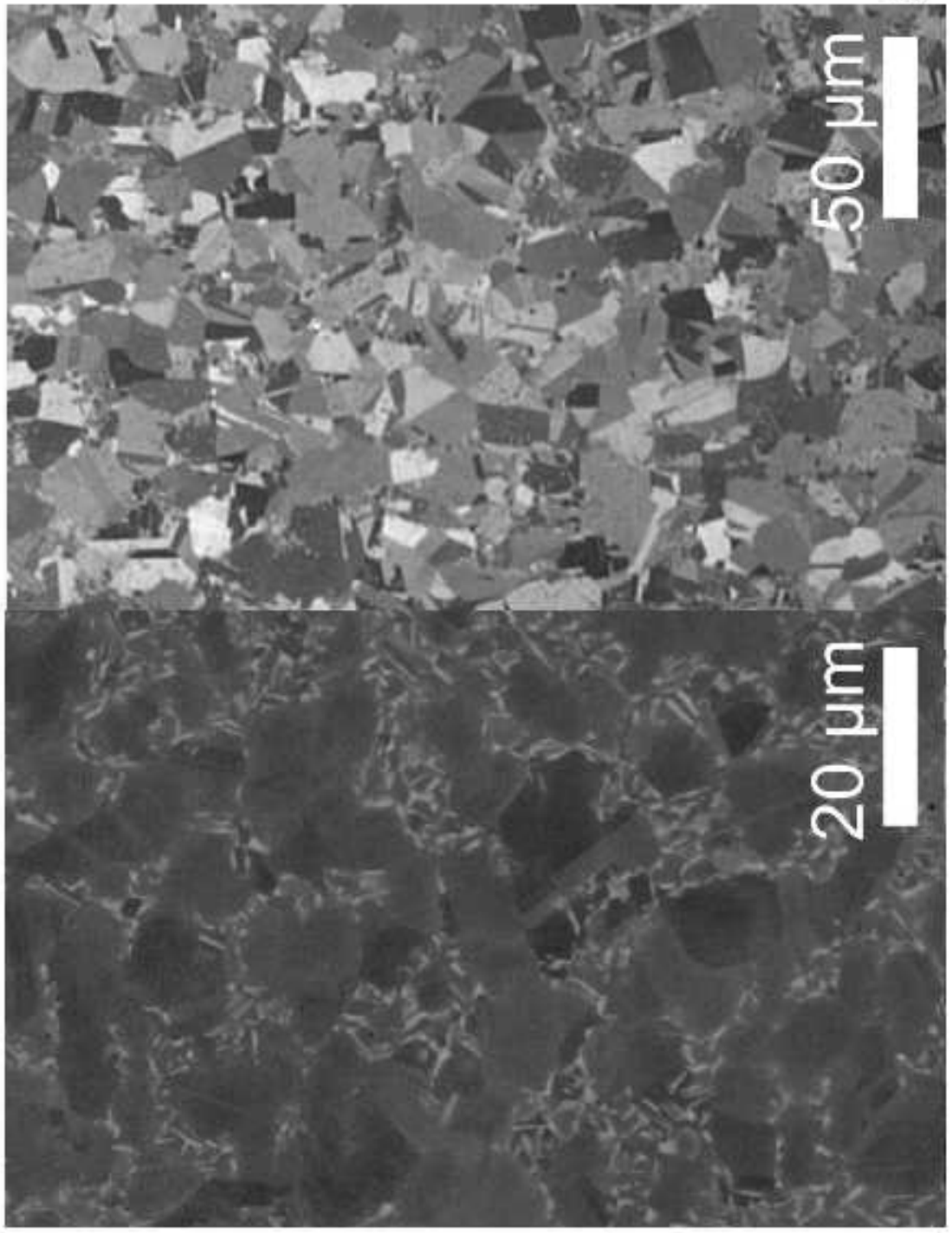
Low density, high specific yield strength, good oxidation resistance, and good creep properties at elevated temperatures make intermetallic TiAl-based alloys top candidates as structural materials for advanced jet and automotive engines as well as for future hypersonic vehicles. Huge efforts are undertaken in modern research programs to relate the microscopic properties to the mechanical behavior in production and application processes. The mechanical properties depend strongly on the composition, the admixtures and the thermo mechanical treatment of the alloy. Thus the ductility at room temperature can be improved when the Al content lies in the range of 46-48 at.%. Normally such an alloy consists of ordered tetragonal γ-TiAl (L10 structure) and ordered hexagonal α_2-Ti6Al2-phases (DO19 structure). The typical microstructures upon thermal treatment are the globular and the fully lamellar colony patterns. In fully lamellar materials the colonies consist of sequences of several γ-phase lamellae with {111} interfaces and alternating twin orientation (polysynthetically twinned) interrupted by single α_2-phase lamellae with {0002} interfaces. Additionally, three different domain orientations are observed in the γ-lamellae with an orientation rotation of 120° around [111]. Typically the colony size is about 100 – 1000 µm with average thicknesses of 100 – 1000 nm of the γ-lamellae and 50 nm for the α_2-lamellae. Several at. % of Nb sitting substitutionally on Ti sites, so-called TNB material, may alter the recrystallization processes and thus the microstructure and mechanical properties. Further, precipitates play a role in the mechanical strength as in B-added material (TAB) or, as actually investigated in another research program, additives of C.

The microstructure does not only depend on the composition, but a lot on the thermo-mechanical treatment. Thus quenching from temperatures above the a transition at T_α = 1320 K leads to microstructures, which depend on the speed of cooling. A very rapid process freezes the disordered α-phase into the ordered α_2-structure while a medium cool-down leads to a massively transformed γ-phase, which is discussed in this article. Defect engineering processes, however, do not stop at this point. More complicated microstructures are obtained when a mechanical process is superimposed to the heat treatment such as uni-axial forging, extrusion, rolling or shear treatment where textures are developed according to the microscopic deformation mechanisms.

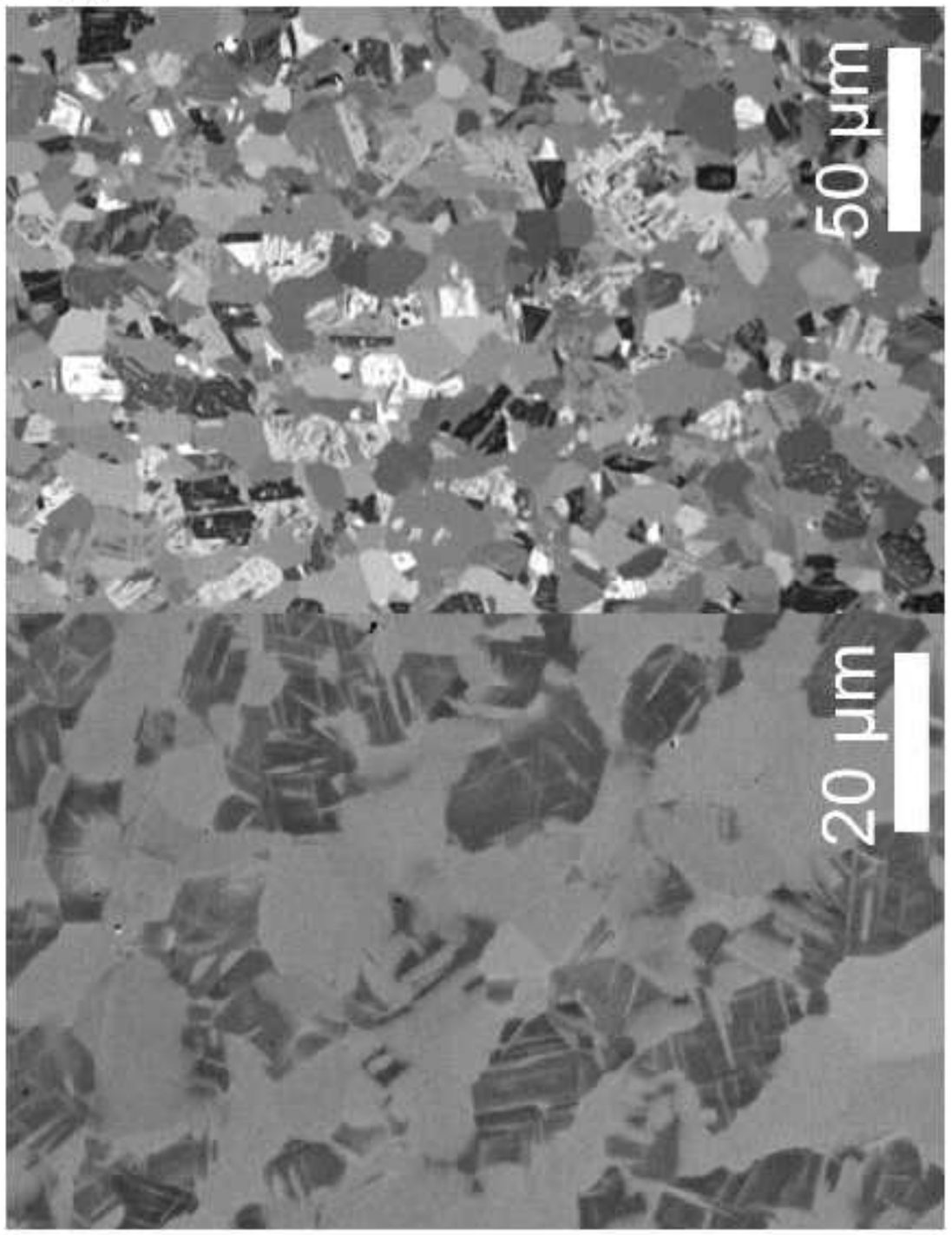
The processes are most complex and their understanding combine the classical fields of engineering, physics, chemistry and crystallography. Therefore characterization and measurements are necessary with the most different techniques as macroscopic force and strain measurements, hardness testing, light- and electron microscopy, calorymetry as well as the diffraction methods with neutrons and X-rays, to mention but a few. In particular, high-energy X-rays in the range of 100 keV and above can penetrate centimeters into light and medium heavy materials as investigated here, the high fluxes and brilliances of modern sources giving raise to highest spatial and angular resolutions at high acquisition rates. The combination of the penetration power into a bulky sample environment and the high number of photons available allow for sophisticated in-situ investigations as they have been performed in this study on massively transformed TiAl.

Ti-Al Microstructures

$Ti_{45}\ Nb_9\ Al_{46}$



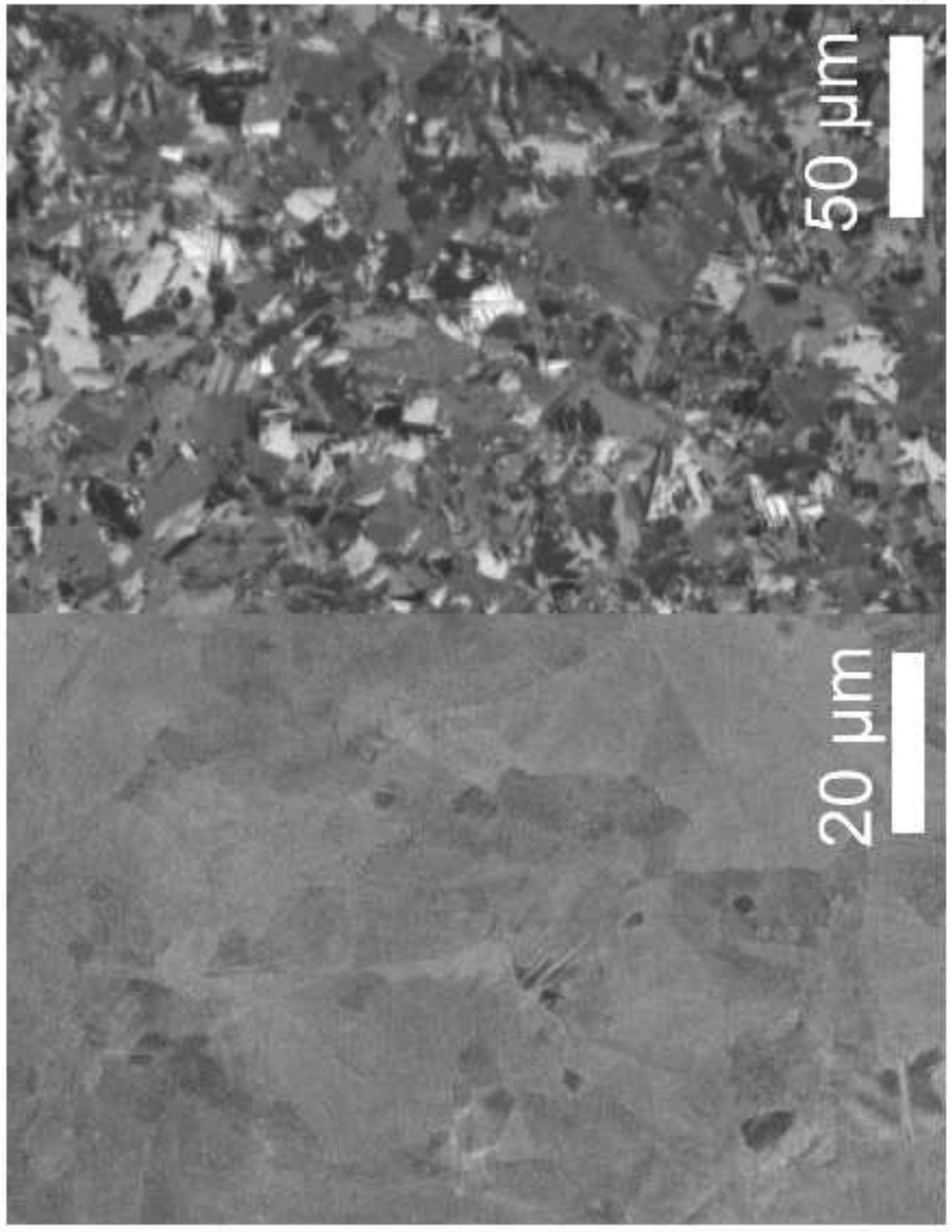
PA - primary annealed
raw sheet material



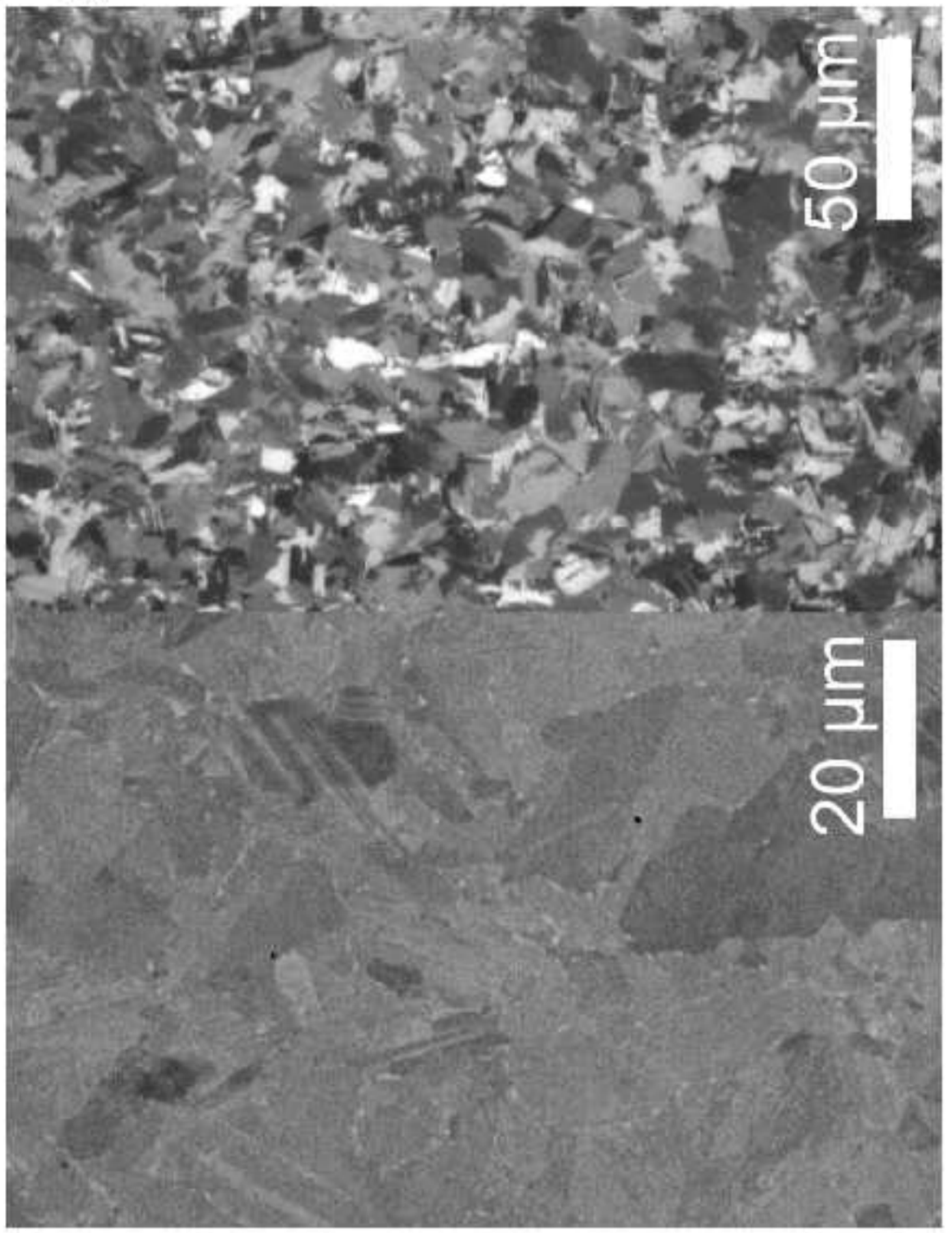
AR - α-rich
PA tempered 1280°C, oil quenched

Ti-Al Microstructures

$Ti_{45}\ Nb_9\ Al_{46}$



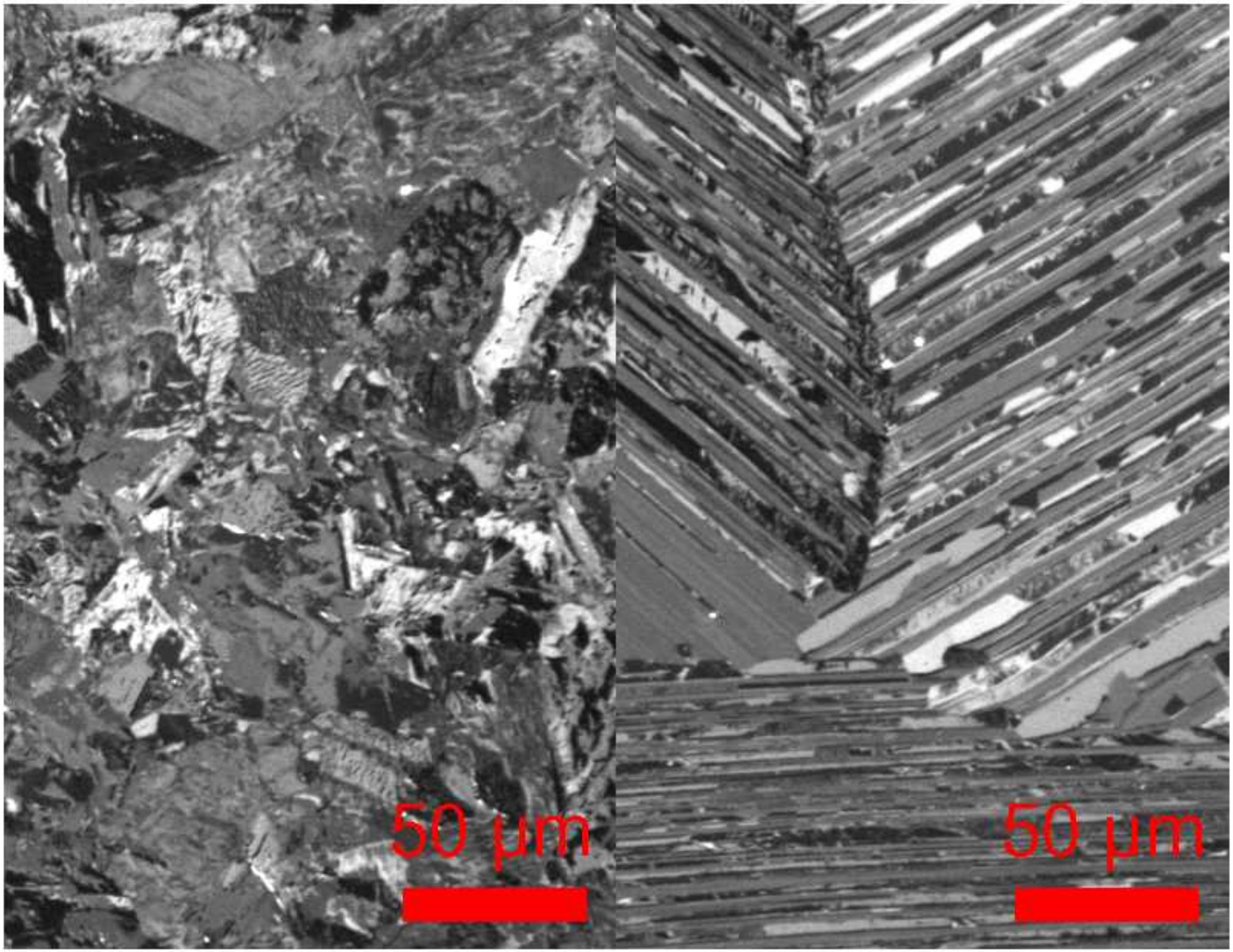
MT - massively transformed
PA tempered 1330°C, oil quenched



MTA - massively transformed annealed
MT annealed 1 hr at 1000°C

Ti-Al Microstructures — in-situ-sample

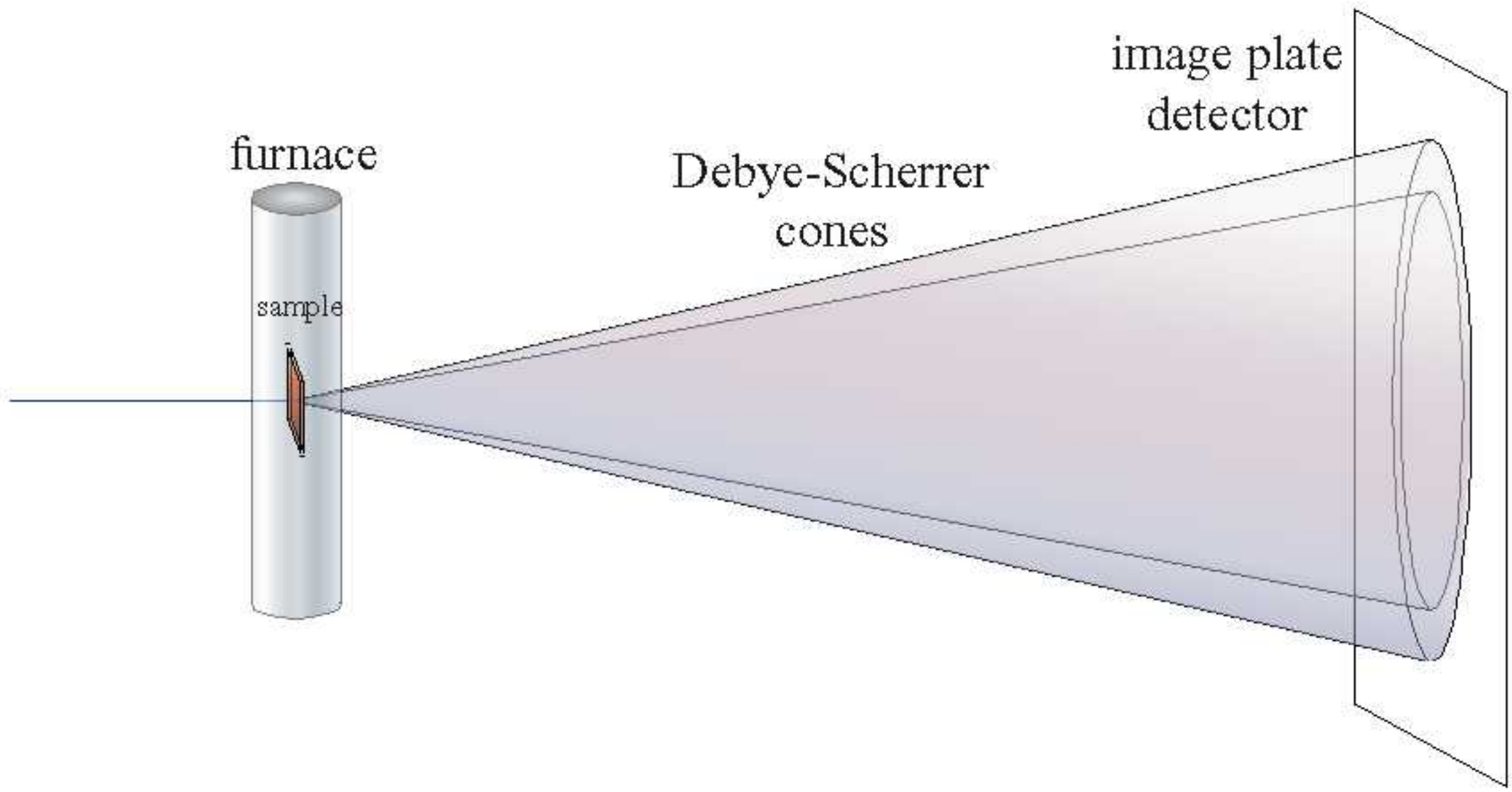
Ti_{45} Nb_9 Al_{46}



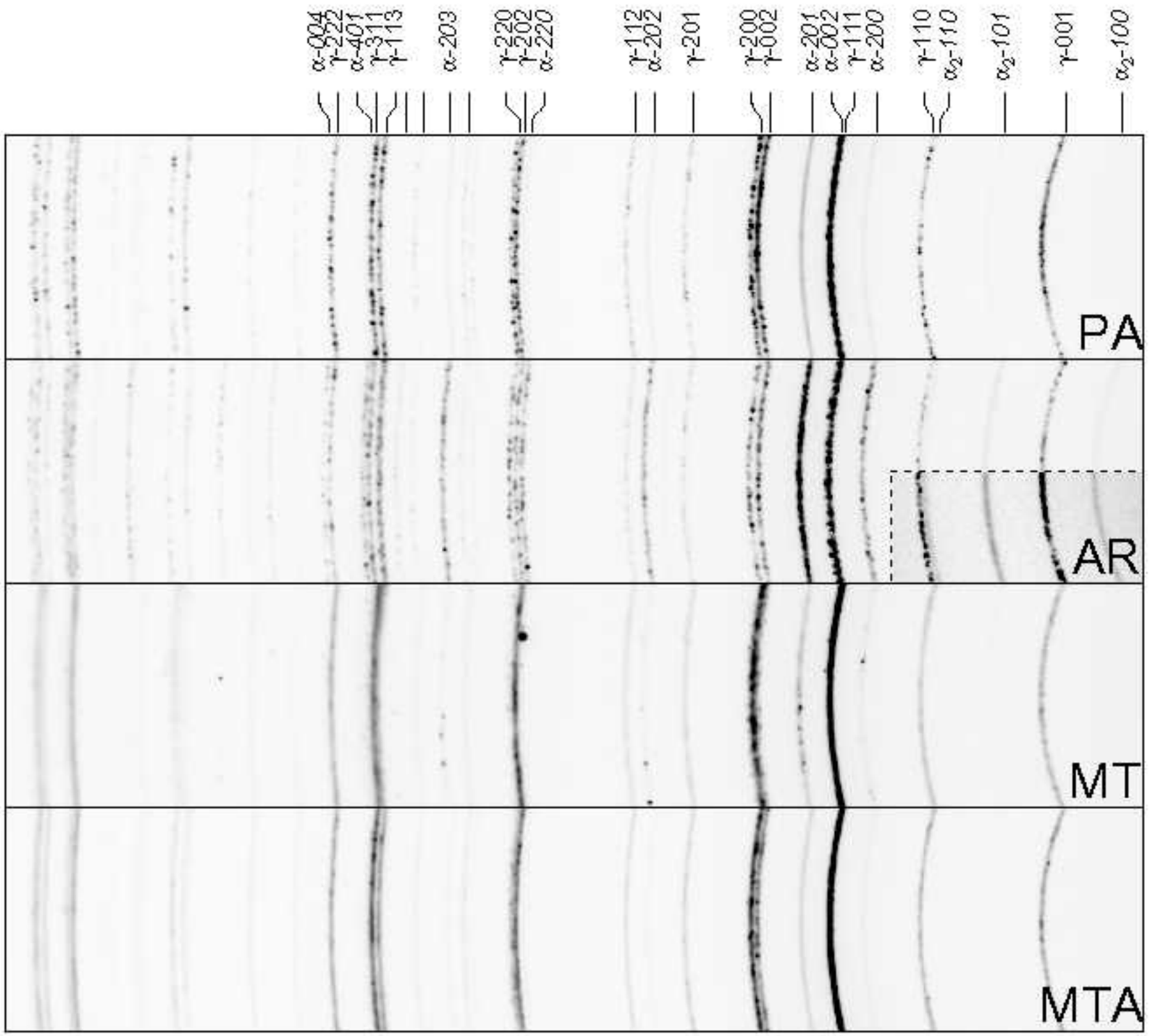
before: MT material

after heating cycle: fully lamellar

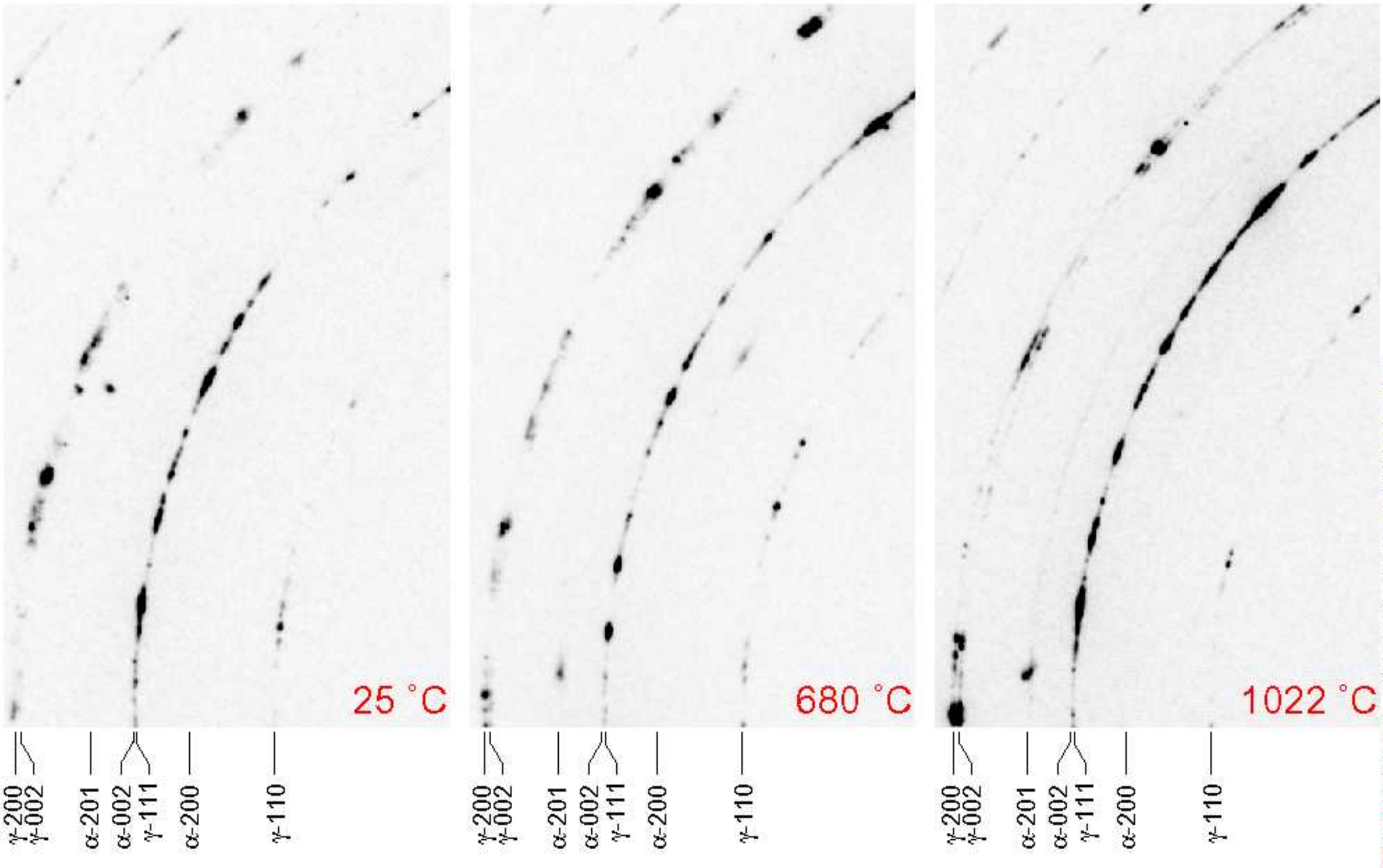
Diffraction setup with 95 keV at ID15b



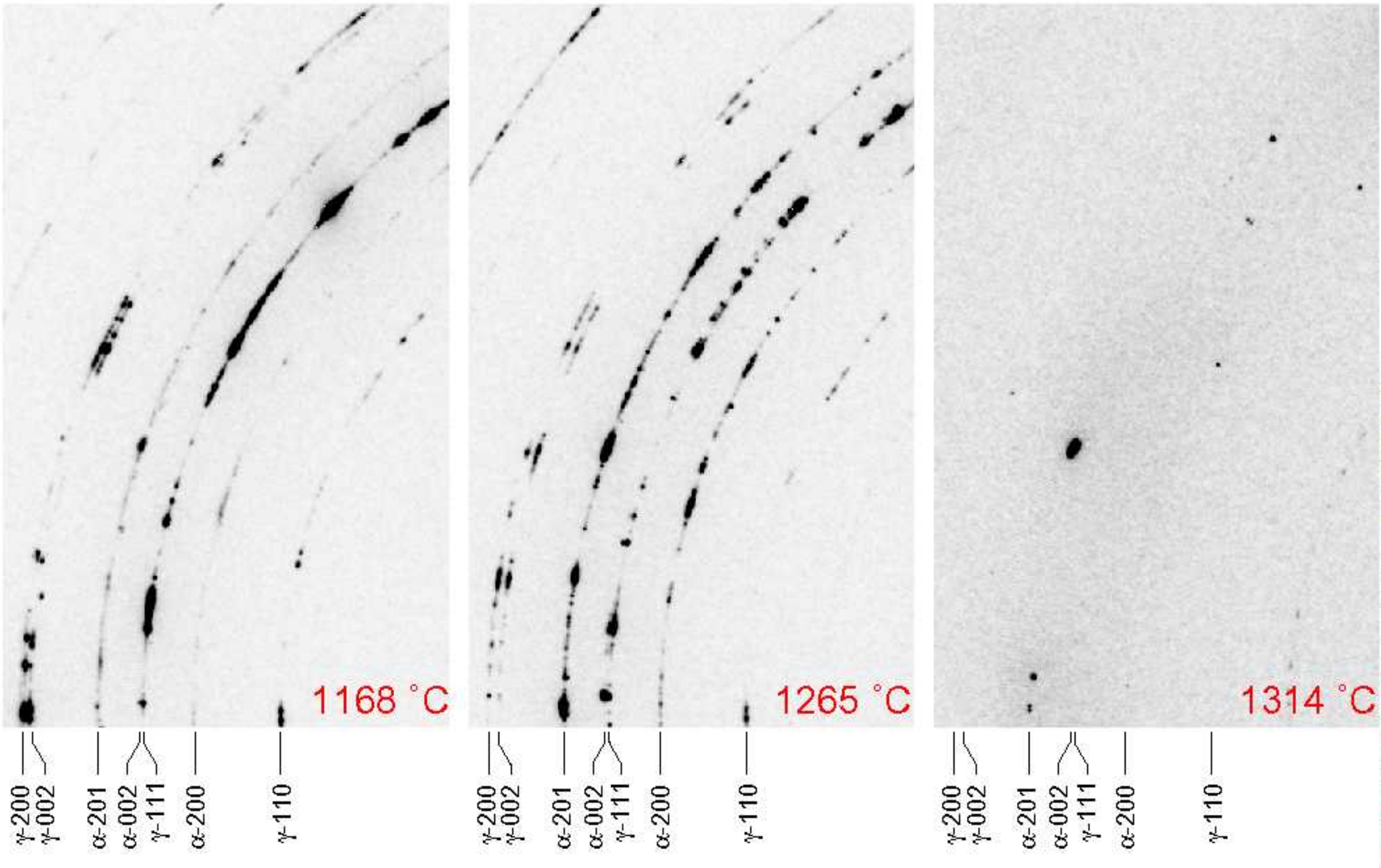
Diffraction patterns of different TiAl materials



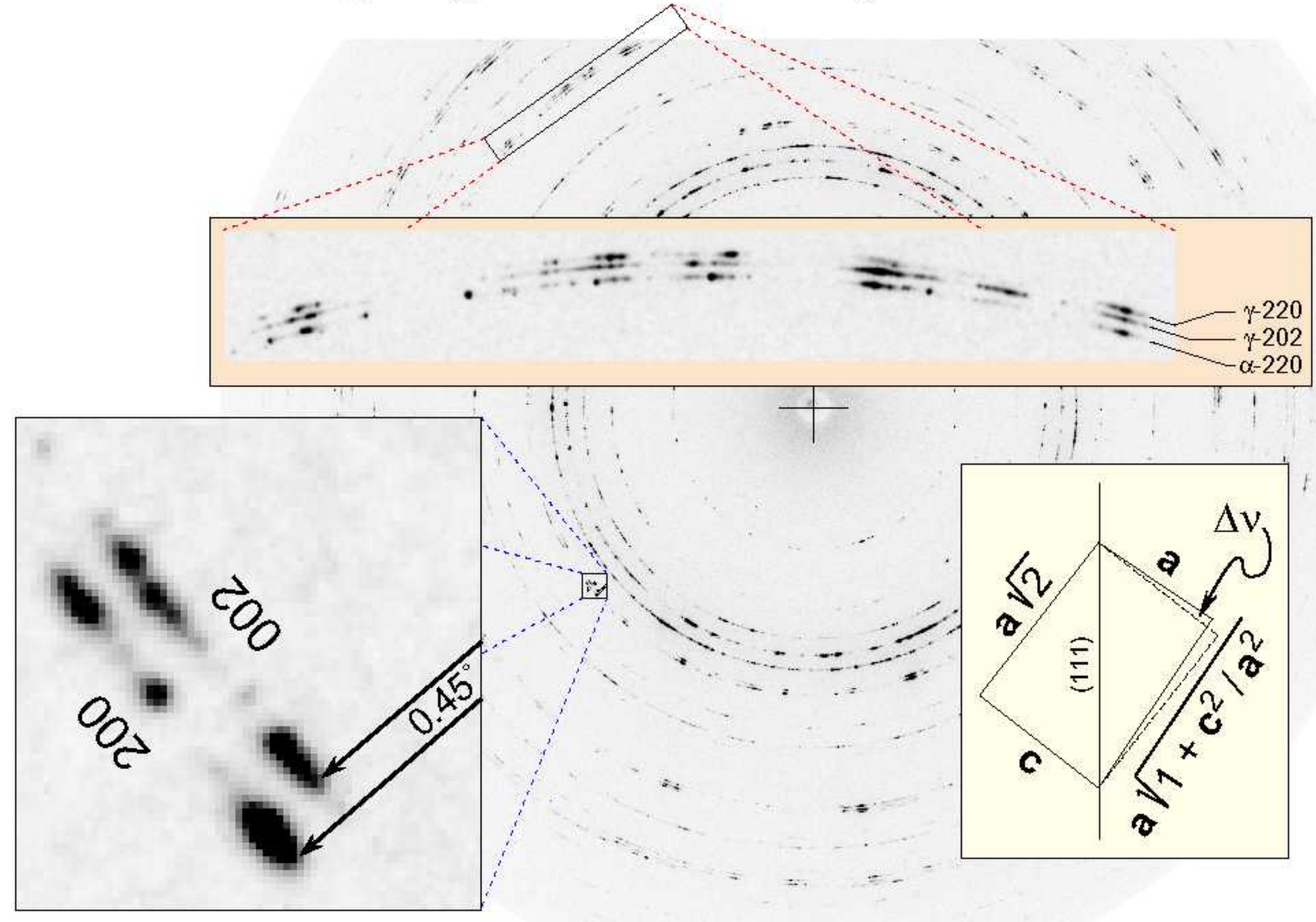
In-situ heating of massively transformed TiAl



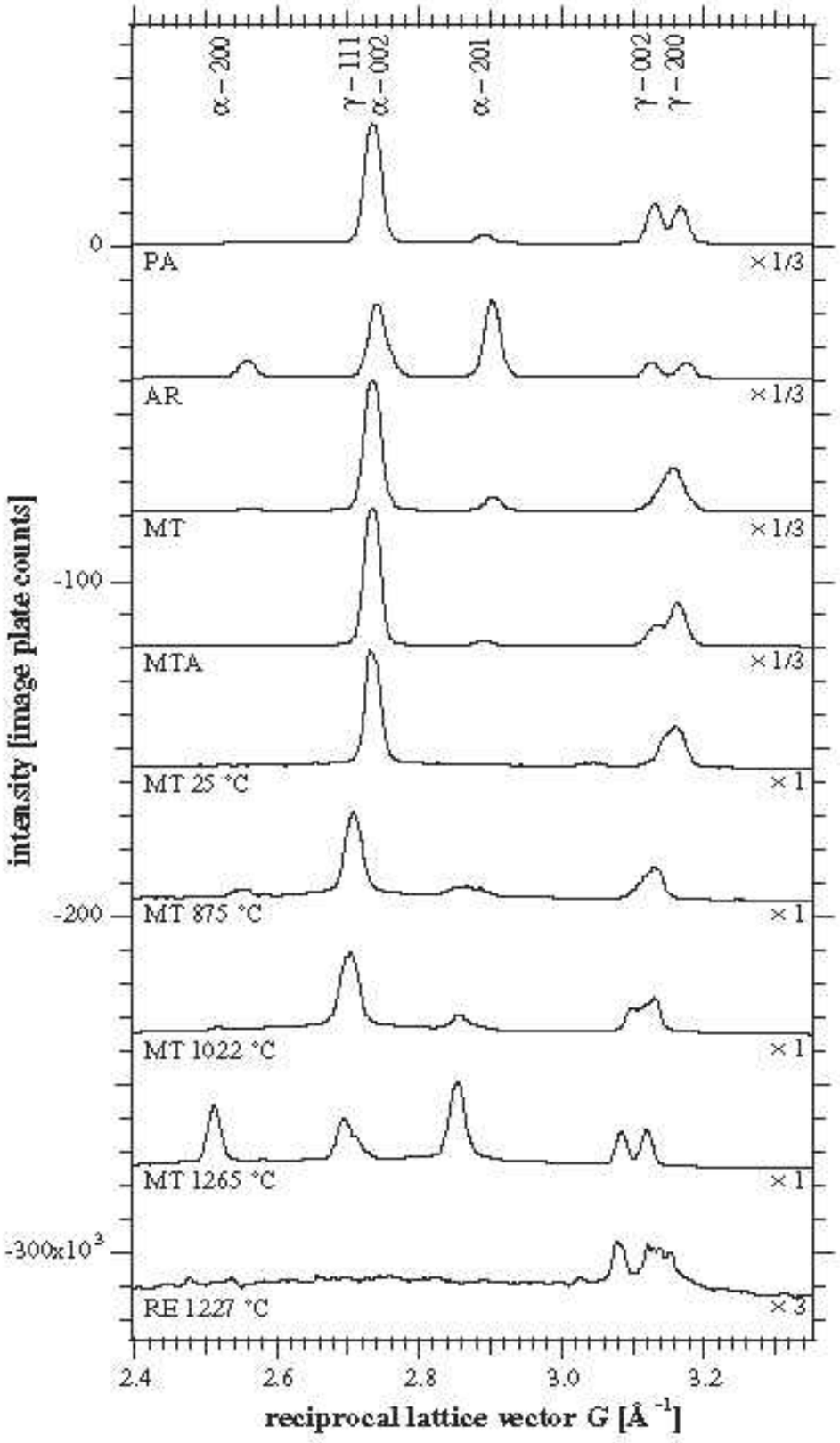
In-situ heating of massively transformed TiAl

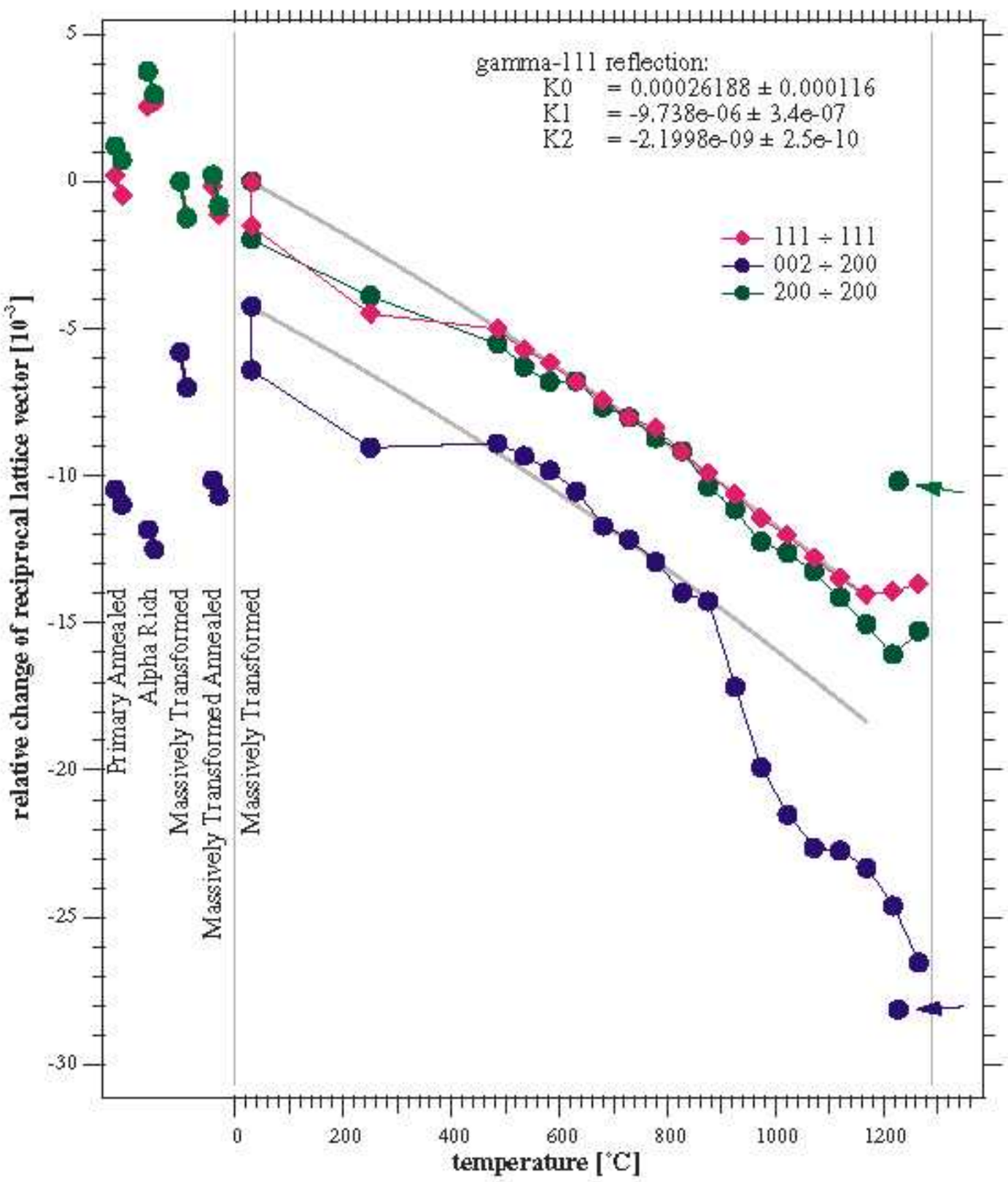


Small angle grain boundary at domain wall

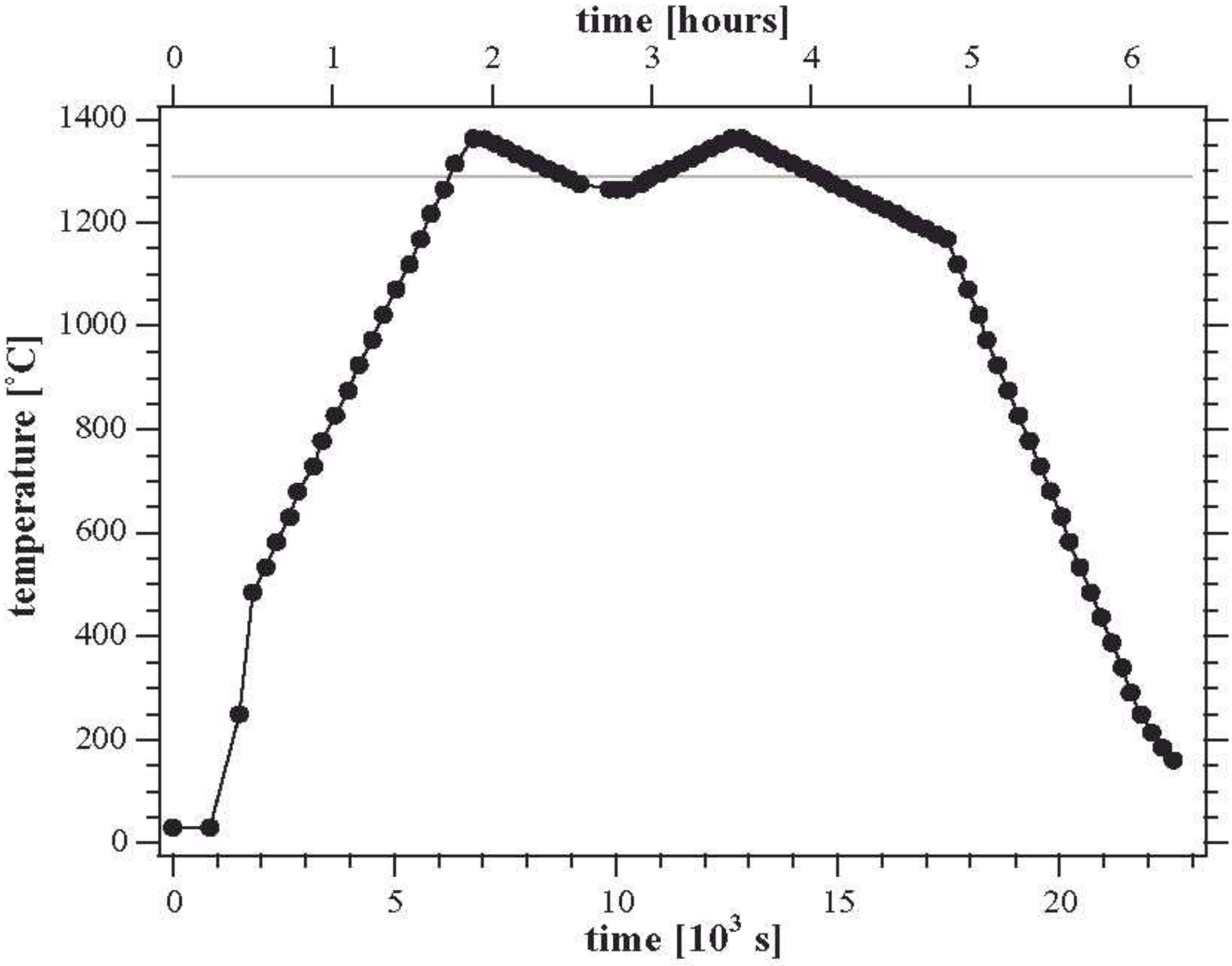


Longitudinal evaluation - strain

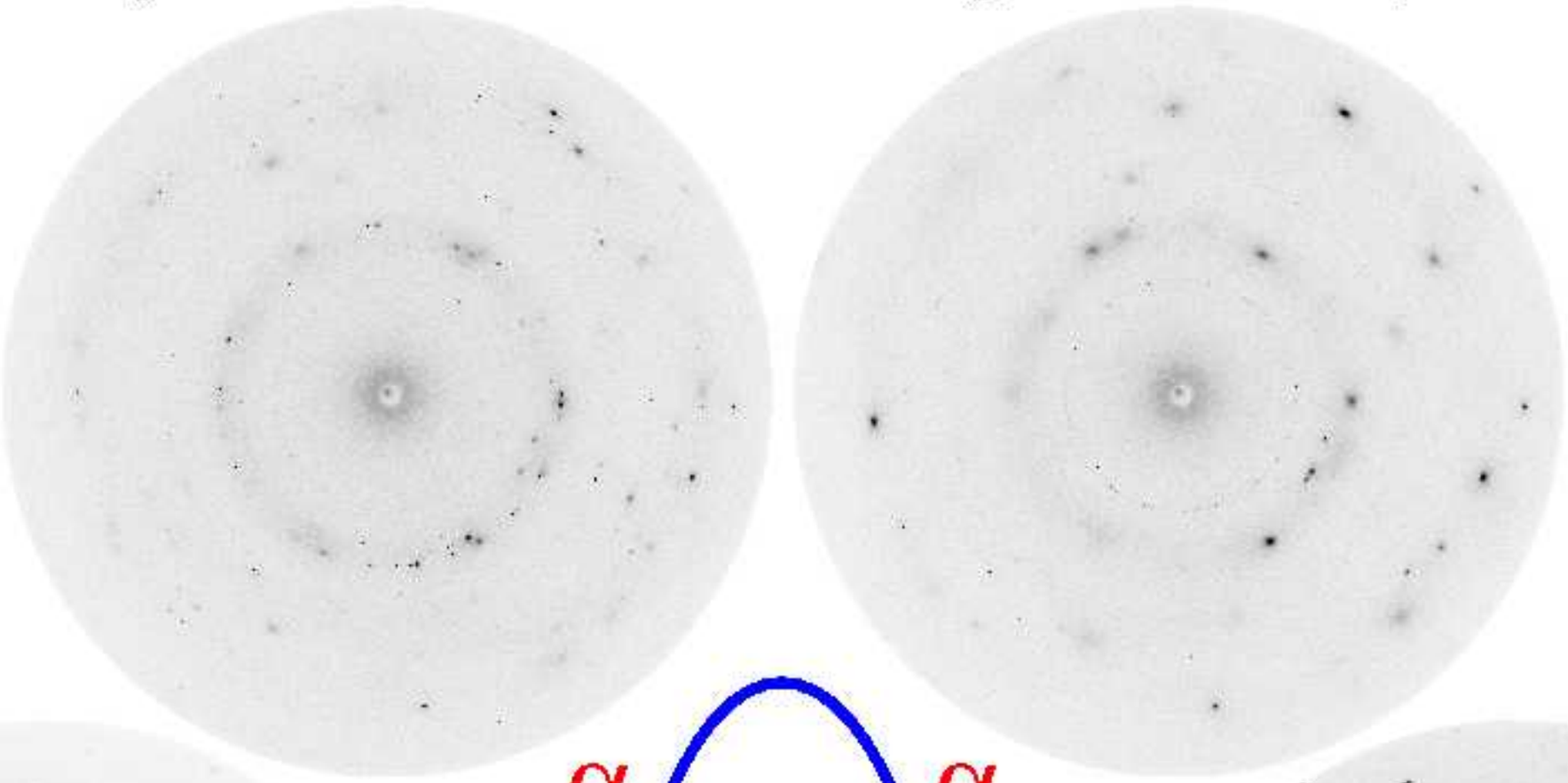


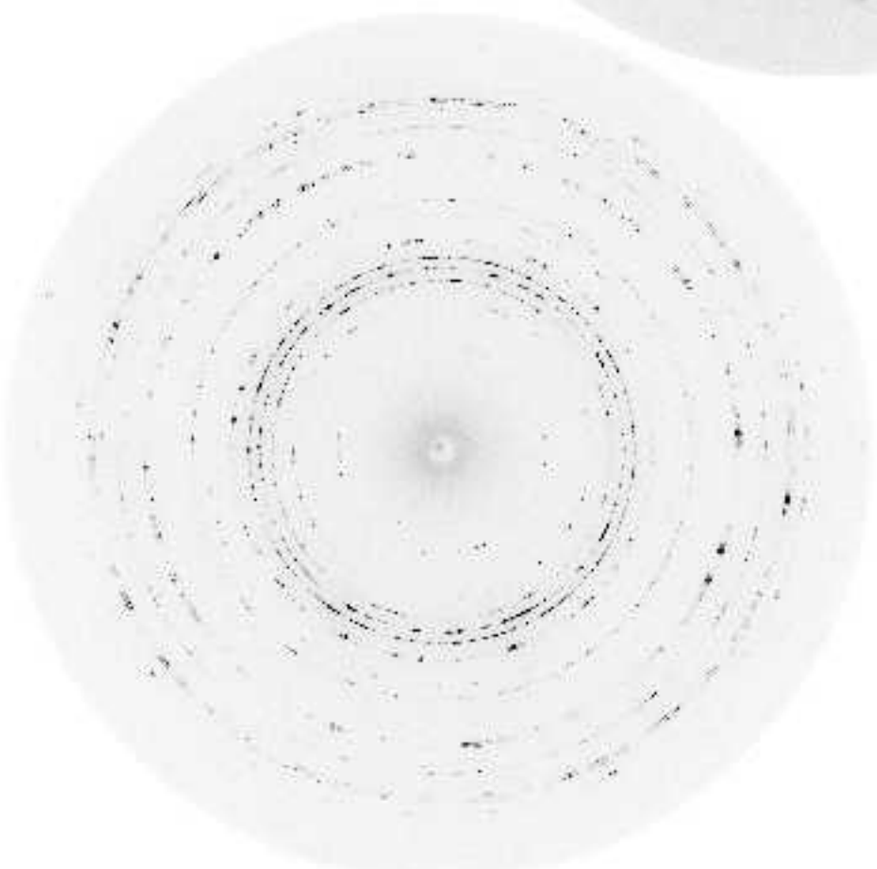


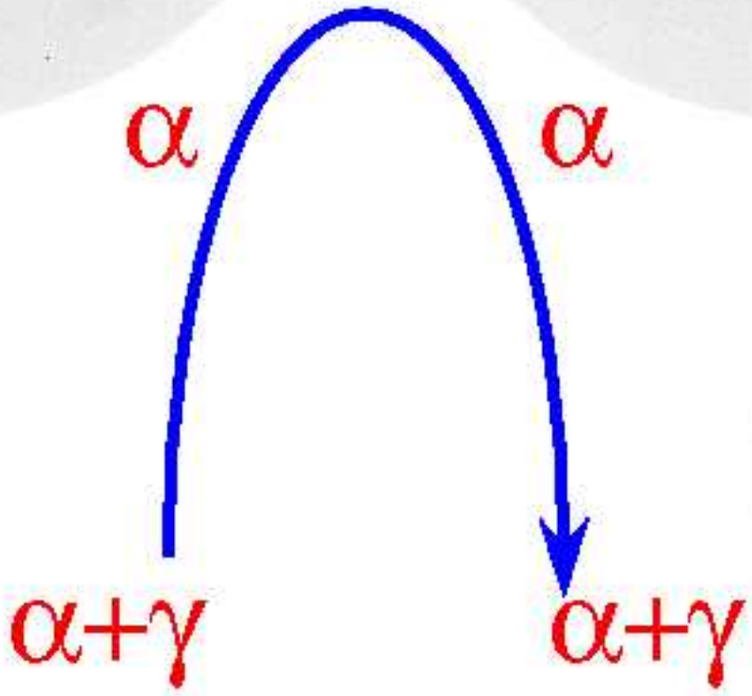
Temperature program

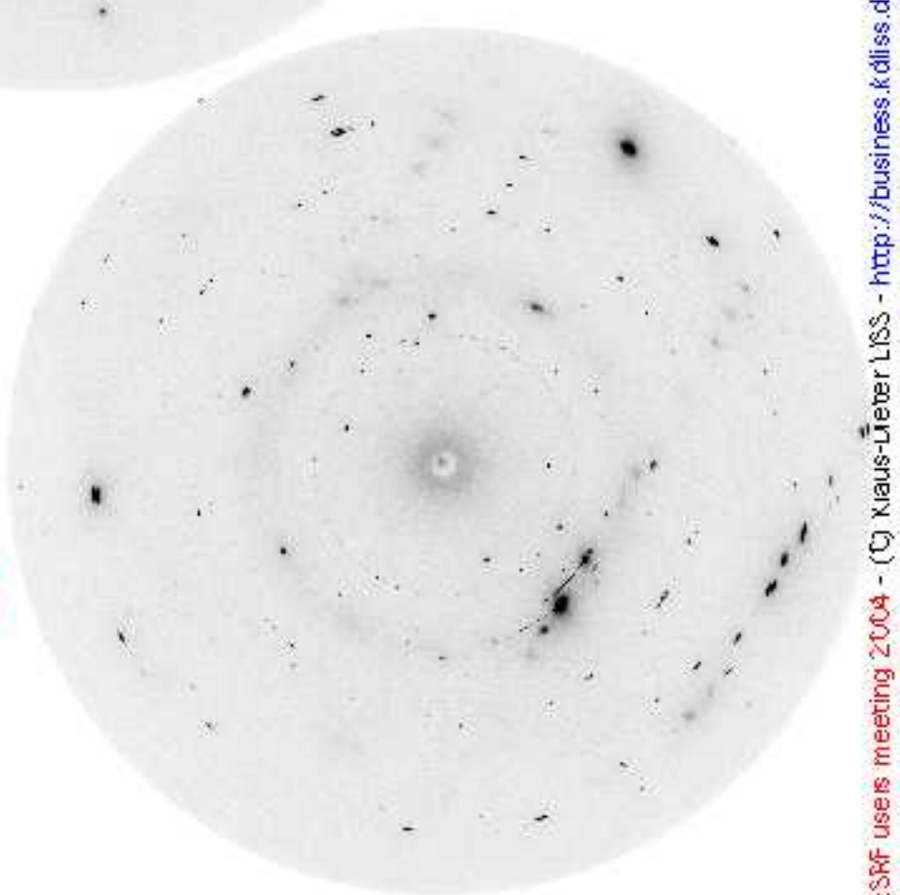


Recrystallization through the α-phase

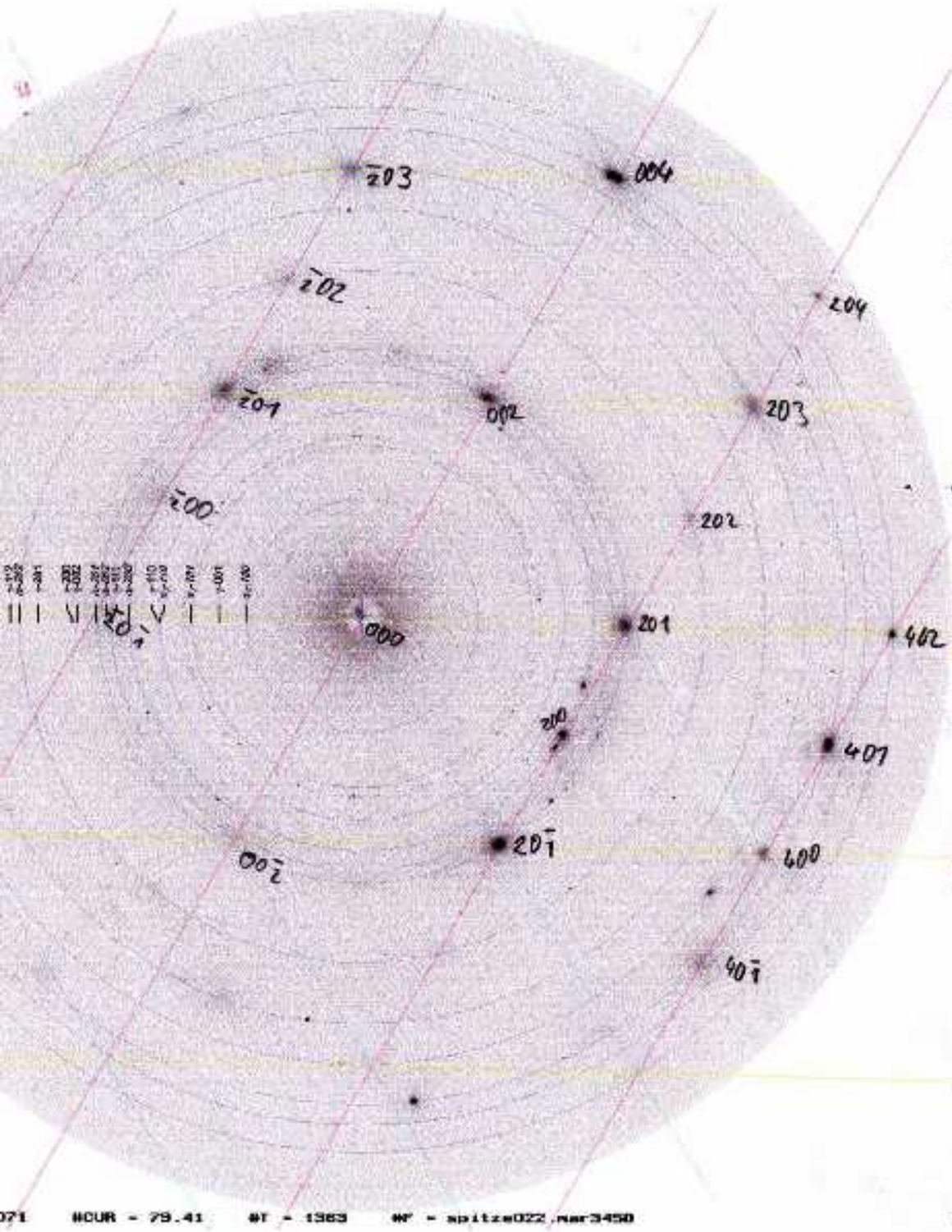


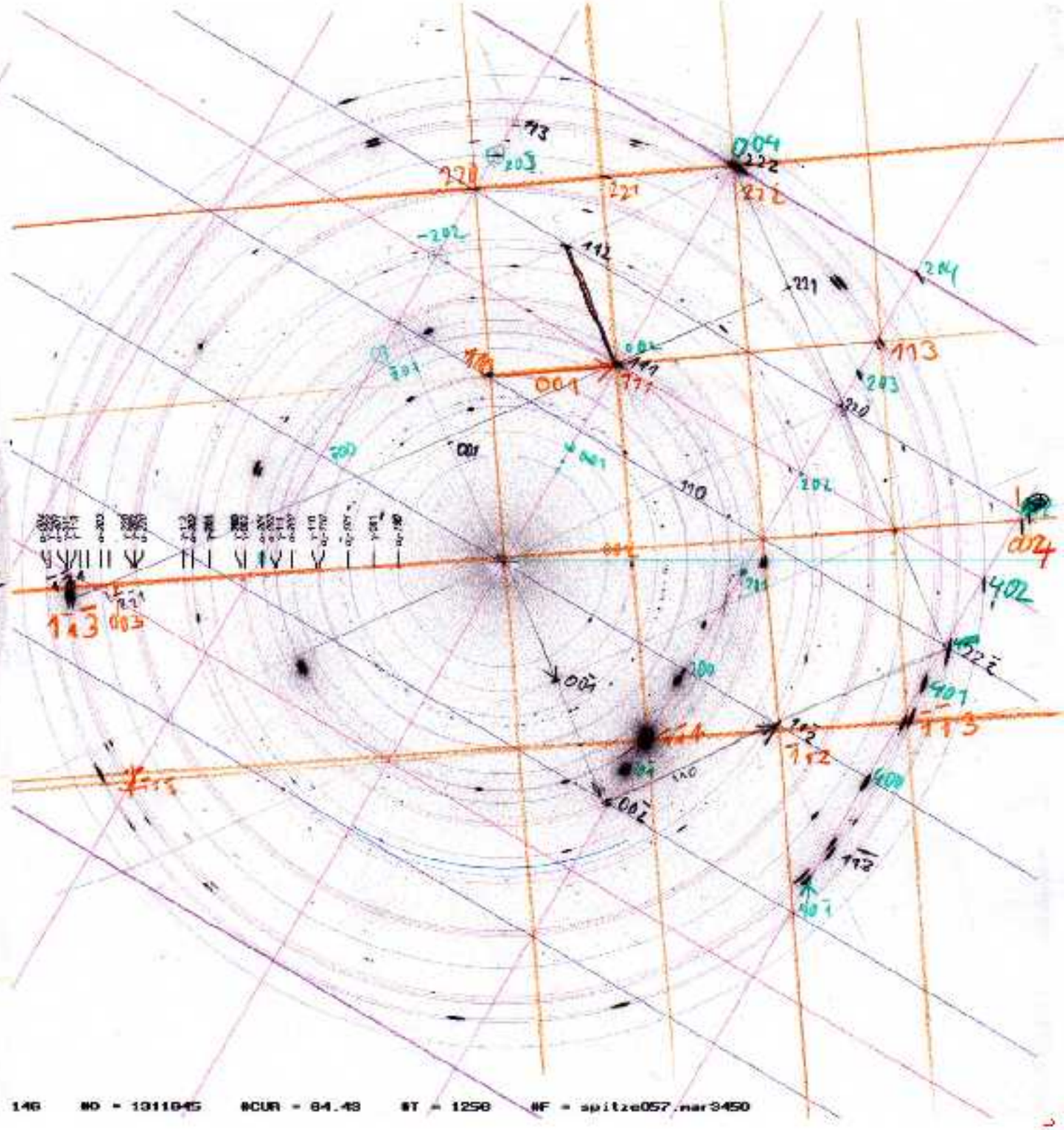






Indexation of the α and γ-phases





071 #COUR = 79.41 #T = 1363 #F = spitze022.mar3450

146 #D = 1311045 #COUR = 84.48 #T = 1258 #F = spitze057.mar3450

ESRF L

Results

- MT material is stressed and has a high degree of disorder
- chemical separation upon heating in the γ-phase
- coherent domain walls
- stress between coexistent γ- and α-phases
- strong recrystallization and huge grains in the α-phase
- coherent recrystallization from the α- towards the γ-phase
- α-phase determines two twin directions with 3 domains in γ-phase

the work is under publication and can soon be downloaded under

http://business.kdliss.de/