A Study for Dislocation-Free Plastic Deformation Mechanism in a New Beta Type Ti Alloy

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Saito et al reported a new beta type Ti alloy [1]. Typical composition of this alloy was Ti-23Nb-0.7Ta-2Zr-1.2O, and the basic structure was disordered BCC. The following properties were observed (see Fig. 1 (a)),

(1) Non-linear elastic properties and very low Young's modules

(2) High strength and no work hardening

Fabrication at room temperature by 90% reduction in area, and oxygen containing enhanced the properties indicated above. As a result of various studies, Saito concluded that this alloy possessed a dislocation -free manner in the plastic deformation mechanism.

XAFS study were performed for the sake of interpreting these phenomena, and showed the different surroundings of each atom. Near the Zr atom, it was suggested that some oxygen atoms were in octahedral sites. On the other hand, almost no oxygen was near the Nb atom (see Fig. 1 (b)). Comparing these two species of the atom, displacement of Zr caused by the fabrication seemed to be larger.

[1] T. Saito et al: *Science* **300**, 464 (2003).

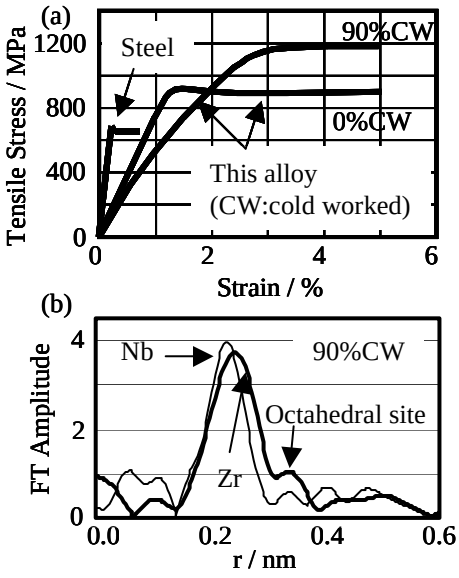

Fig.1: Mechanical properties (a) and Fourier transformed spectra (b) of this alloy.

3rd SunBeam Seminar

A Study for Dislocation-free Plastic Deformation Mechanism in a New Beta Type Ti Alloy

Sep. 5, 2003

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Yoshiki Seno

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A New Beta Type Ti Alloy

Gum Metal (Brand Name)

The Metal with Flexible and Tough Properties like Rubber

(Gum)

Authors of this Work

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Tadahiko Fruta, Jung-Hwang Hwang, Kazuaki Nishino,
Chihiro Iwamoto(*) and Takashi Saito

(*) The University of Tokyo

[T. Saito et al: *Science* **300**, 464 (2003)]

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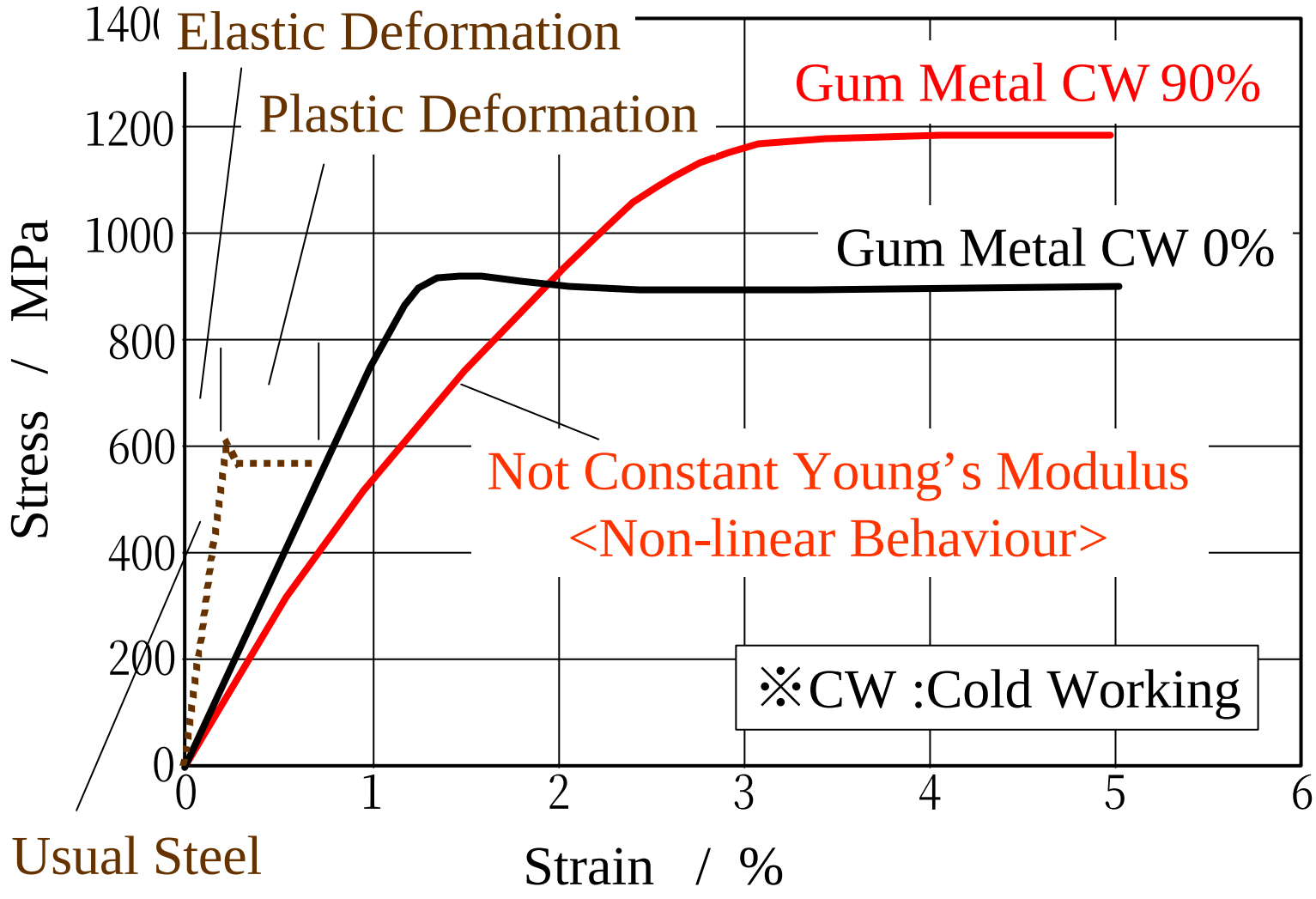
Mechanical Properties for Gum Metal



Typical Composition :Ti-30Nb-10Ta-5Zr (+ O)

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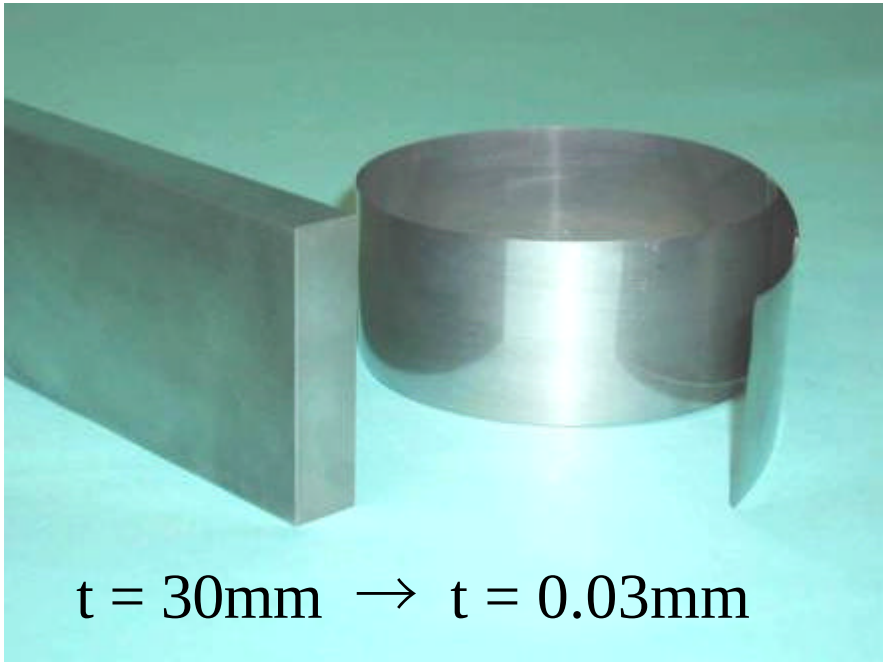
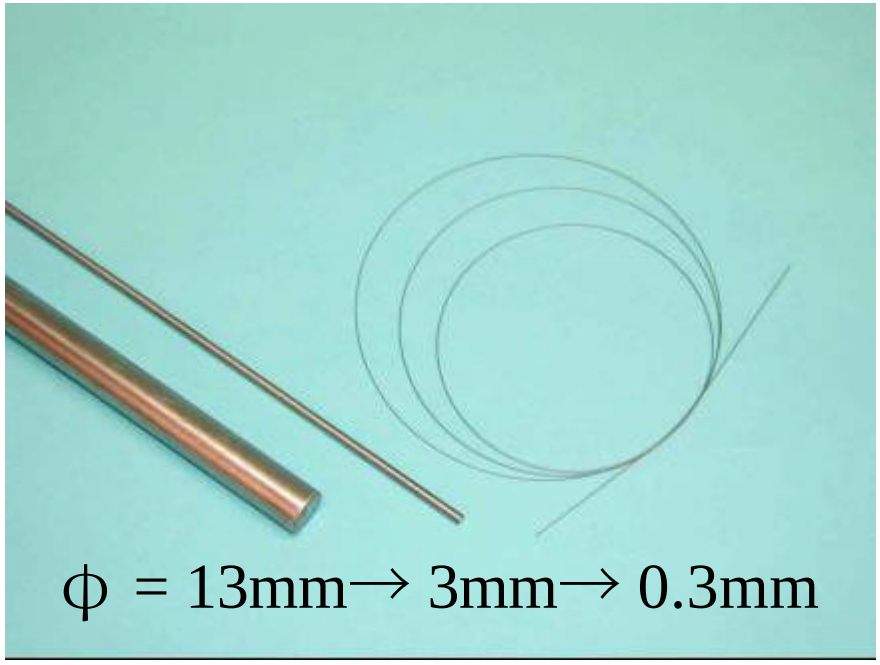
Cold-Workability of Gum Metal

Cold Rolling



【99.9%】

Cold Wiredrawing



【99.95%】

Reduction Rate of Cross Section Area

These Fabrications can be done without any Heat-Treatments.

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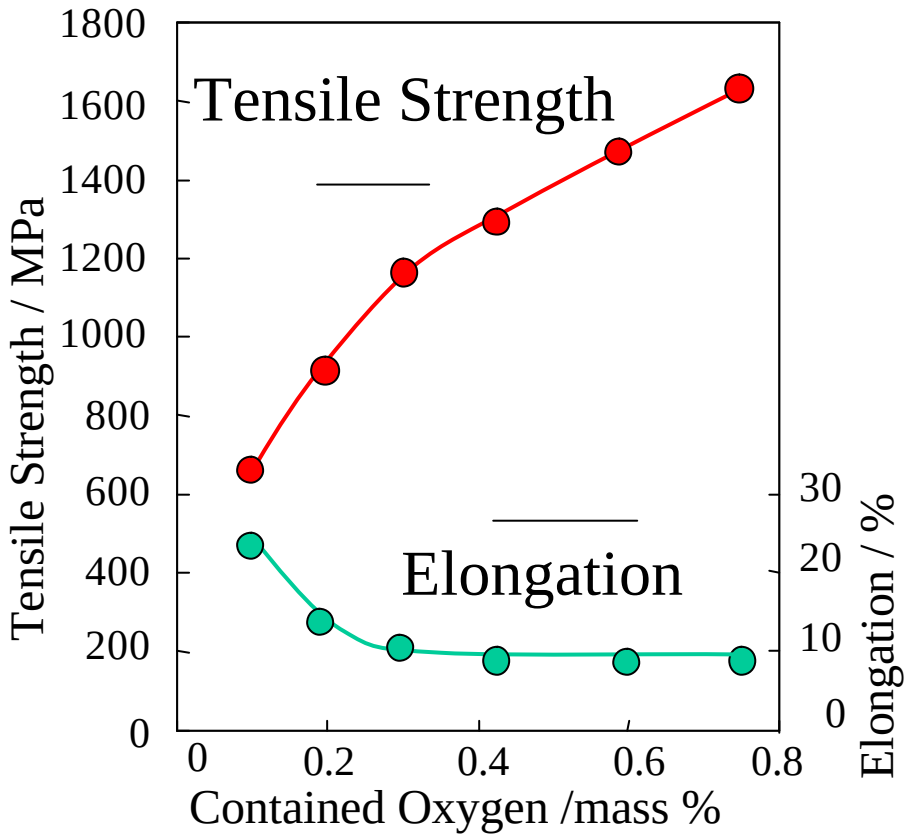
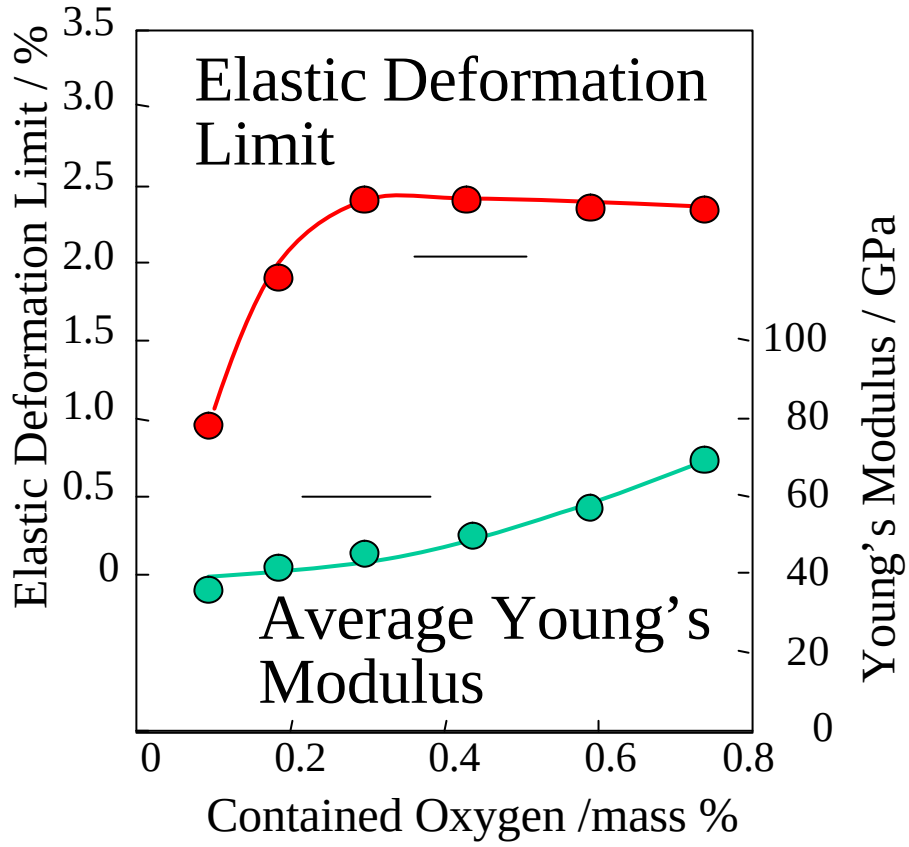
Effects of Oxygen contained in Gum Metal





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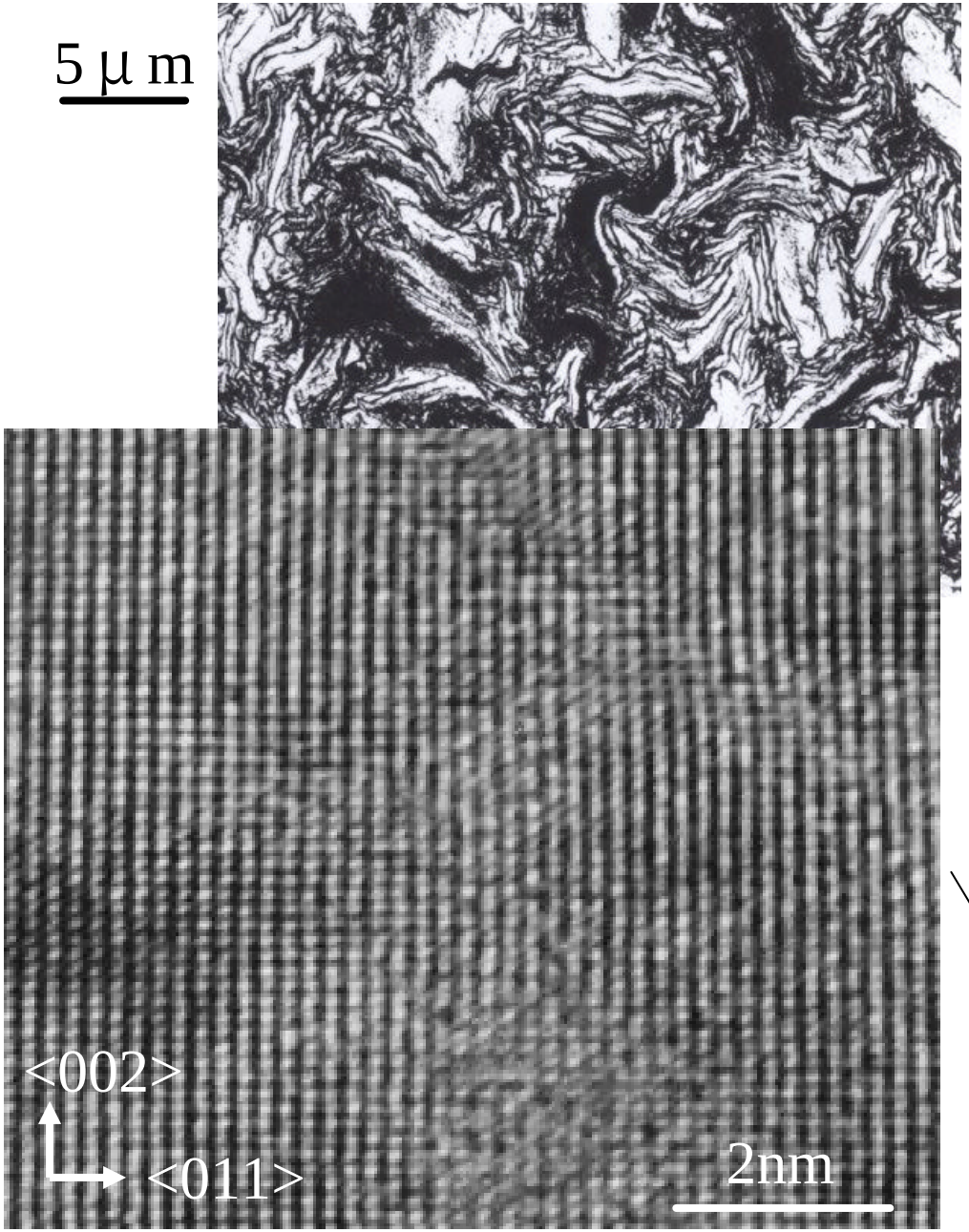
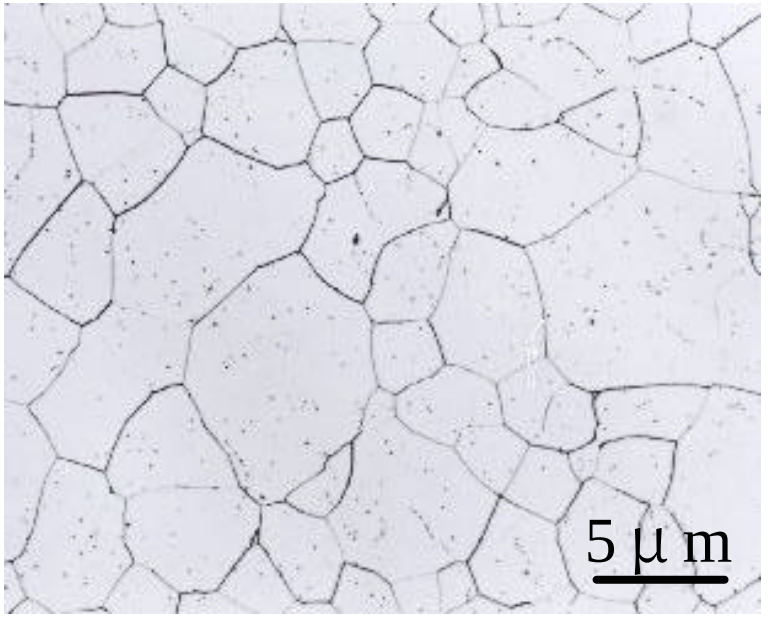
After Cold Working (90%)



Before Cold Working



Lattice Distortion

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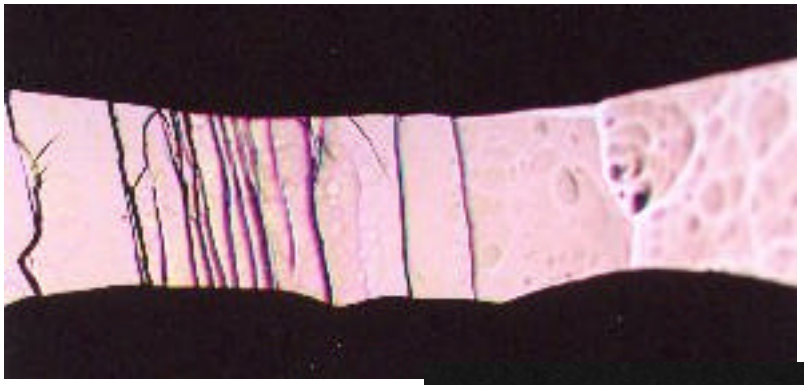
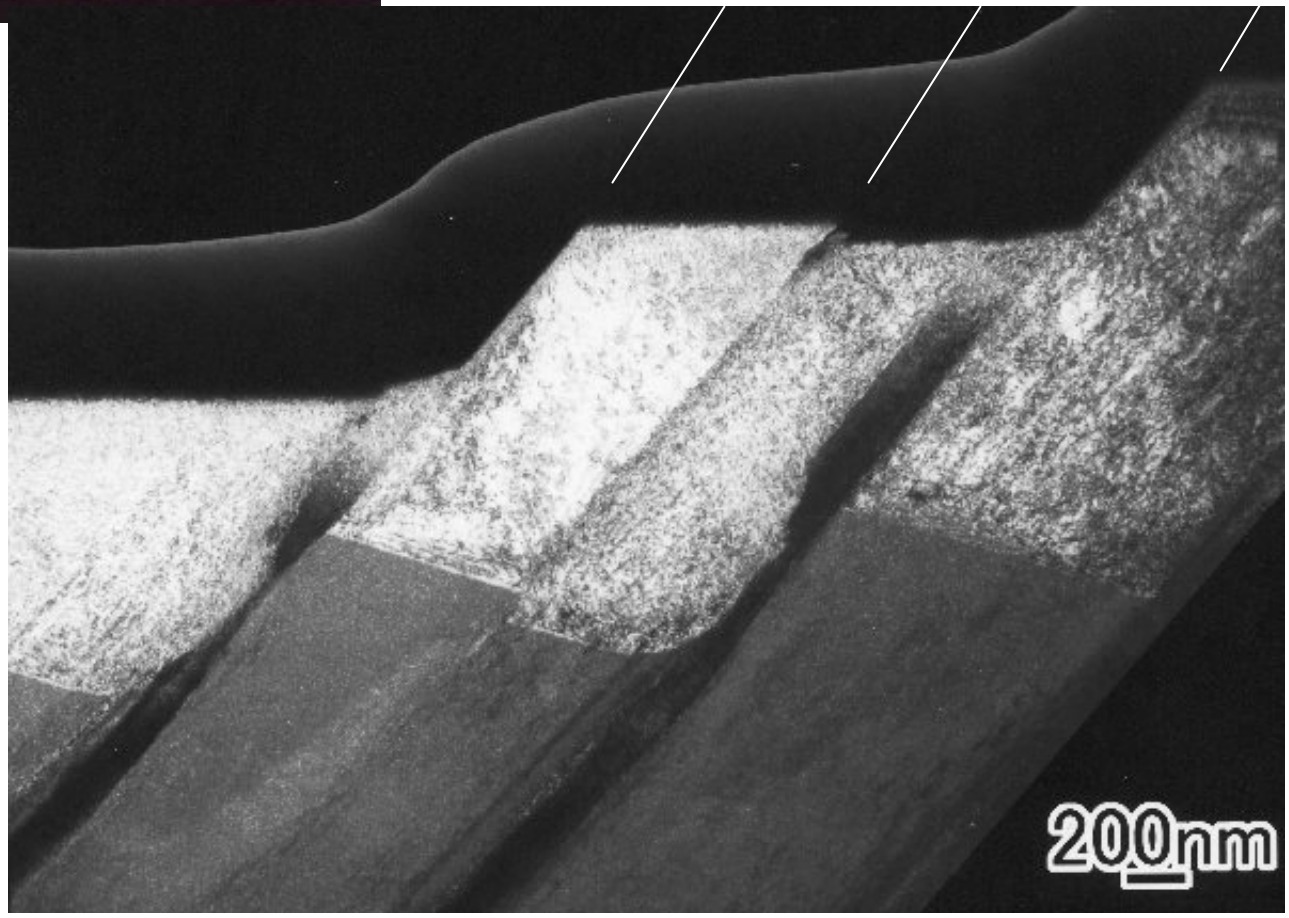


20 μ m

After 10.6% Deformation

Tensile Test

Giant Fault



Deformation of Gum Metal

Another Manner than the Usual Dislocation Mechanism

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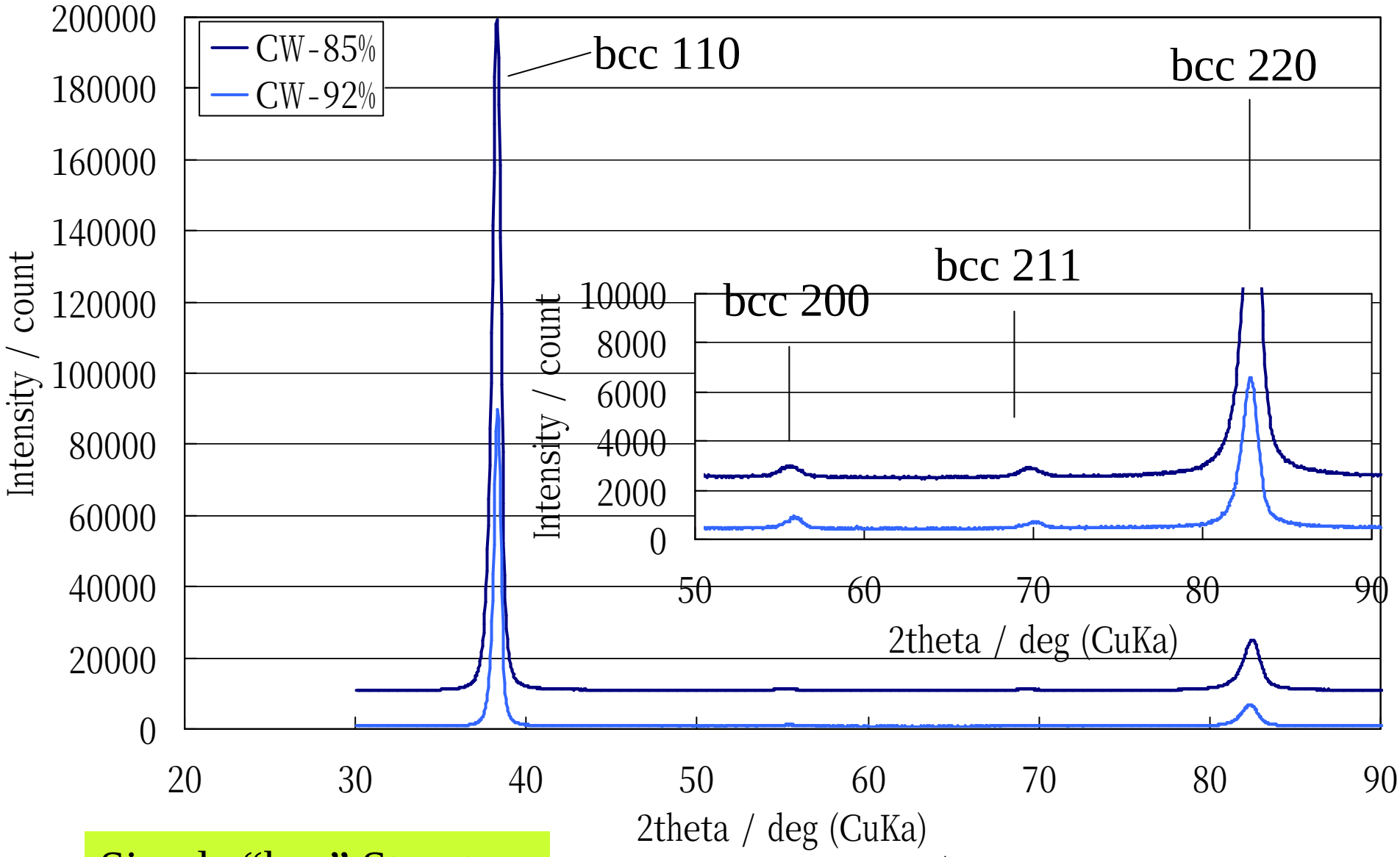
X-ray Diffraction Pattern



Simple “bcc” Structure

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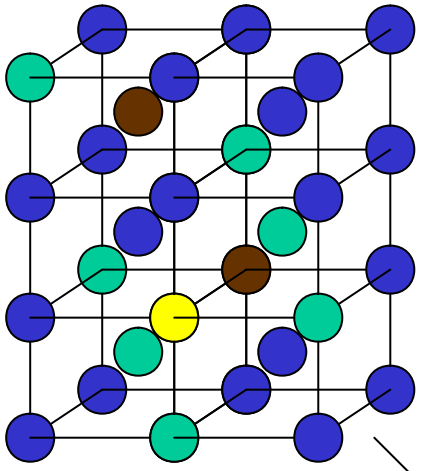
Crystal Structure of Gum Metal ⇒ Disordered “bcc” Lattice



for Local Structure Study using XAFS Analysis

- Ti
- Nb
- Ta
- Zr

× —— Very Difficult

○

△ —— Difficult

○

Local Structure around Nb and Zr Atoms

⇓

Information about the Crystal and the Deformation Mechanism

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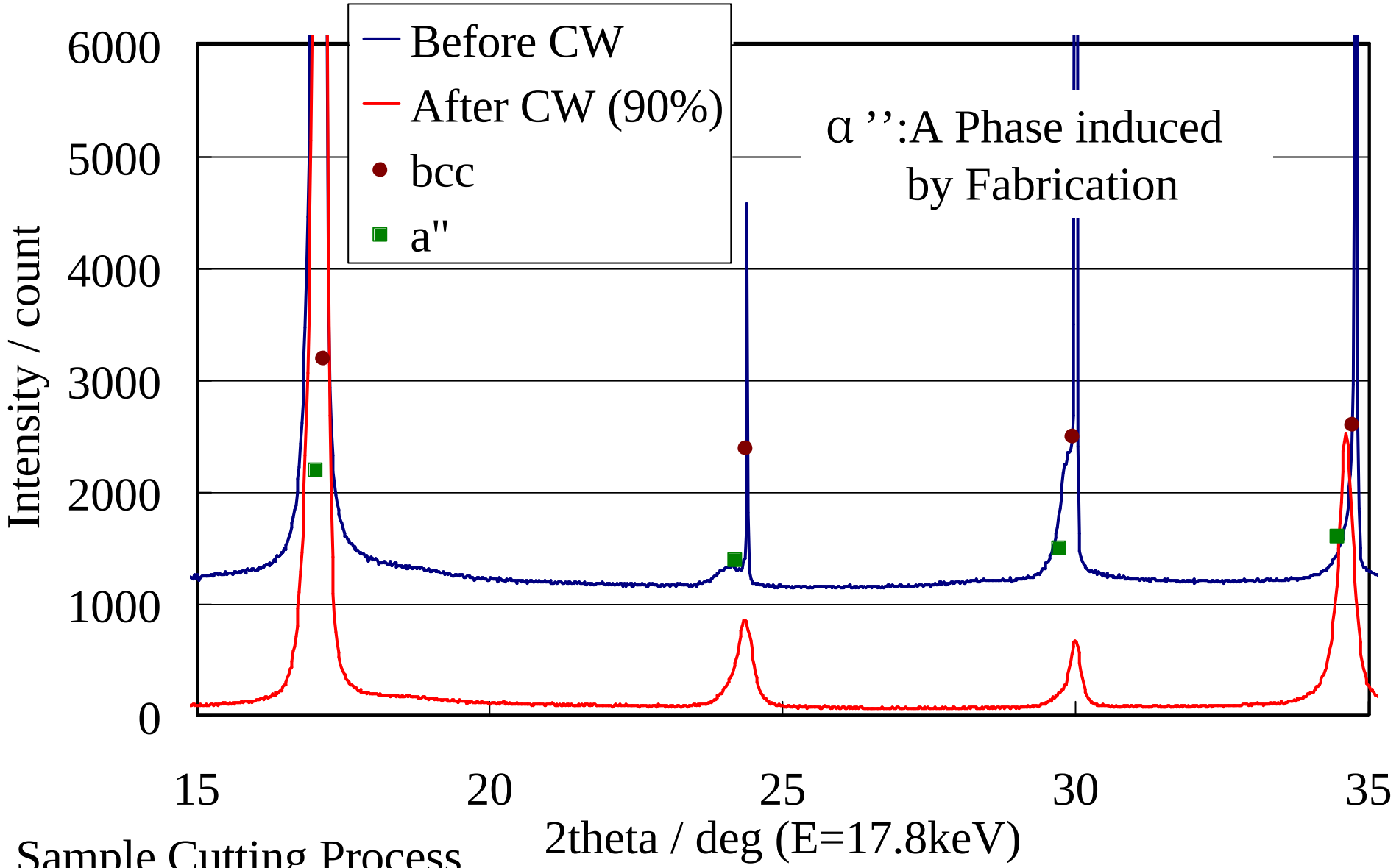
Samples for this XAFS Analysis



Sample Cutting Process
makes α ’’ Phase.

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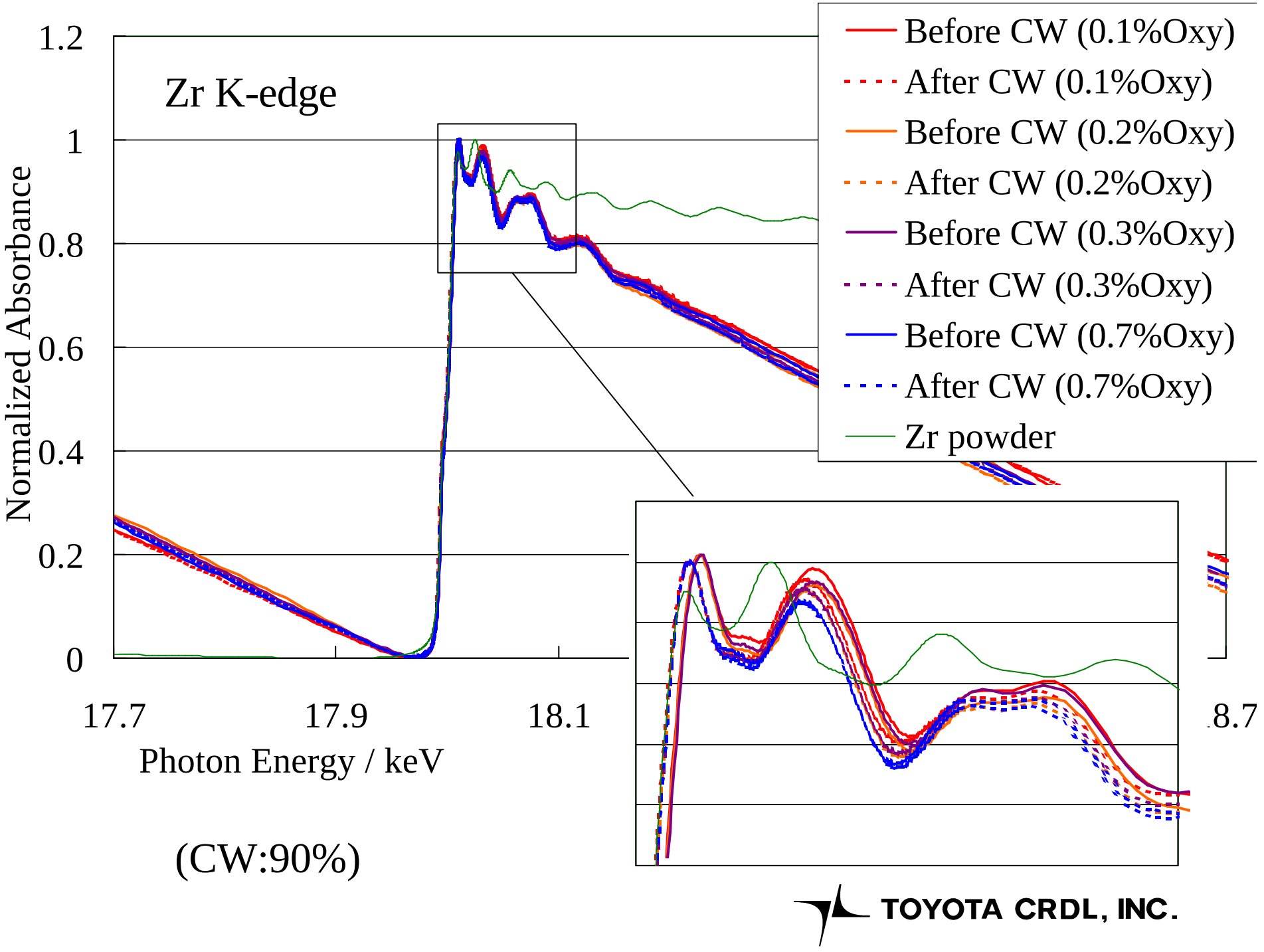
Zr K-edge
Normalized Absorbance
1.2
1
0.8
0.6
0.4
0.2
0
17.7
17.9
18.1
8.7
Photon Energy / keV
Before CW (0.1%Oxy)
After CW (0.1%Oxy)
Before CW (0.2%Oxy)
After CW (0.2%Oxy)
Before CW (0.3%Oxy)
After CW (0.3%Oxy)
Before CW (0.7%Oxy)
After CW (0.7%Oxy)
Zr powder
(CW:90%)
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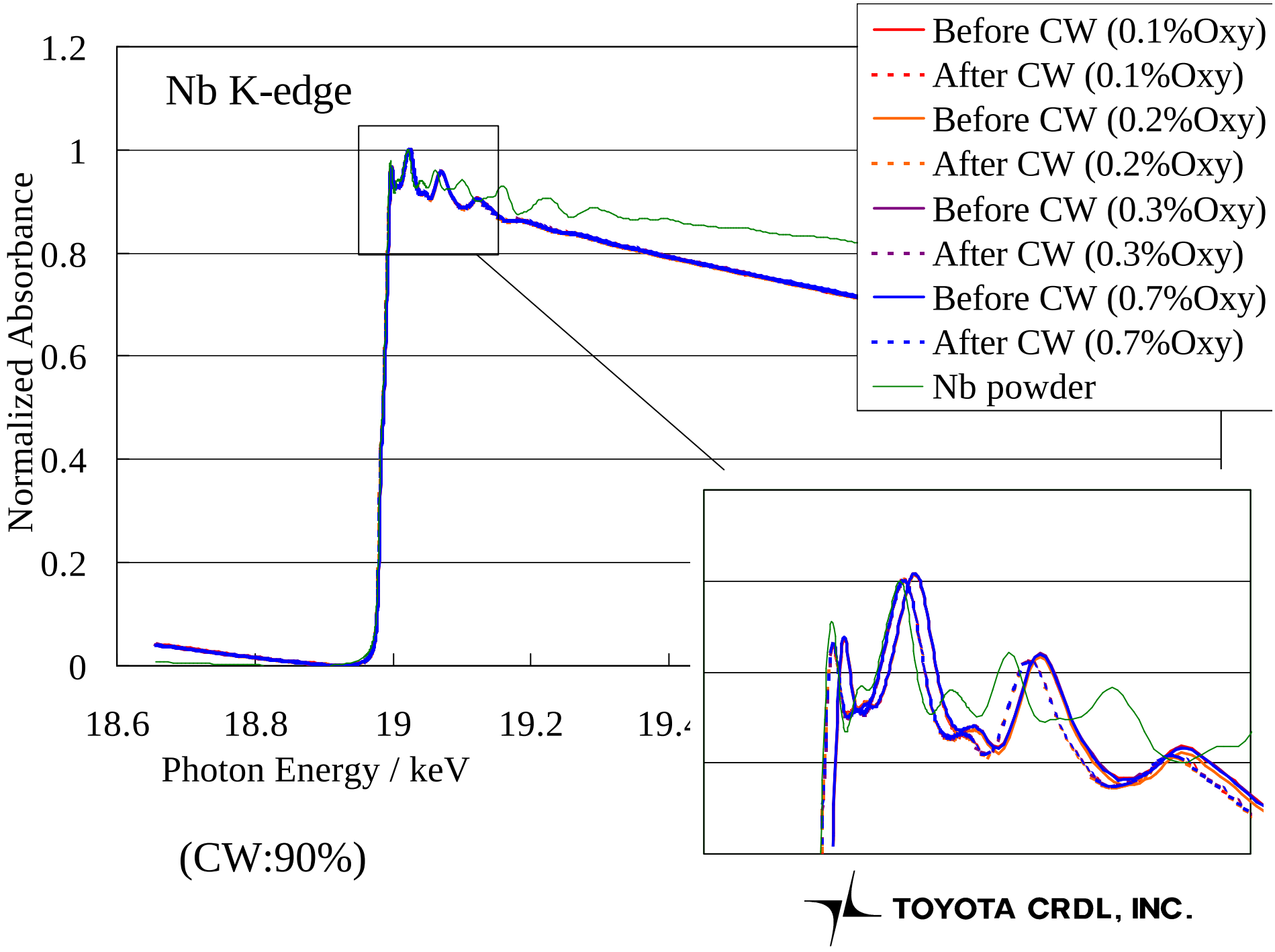
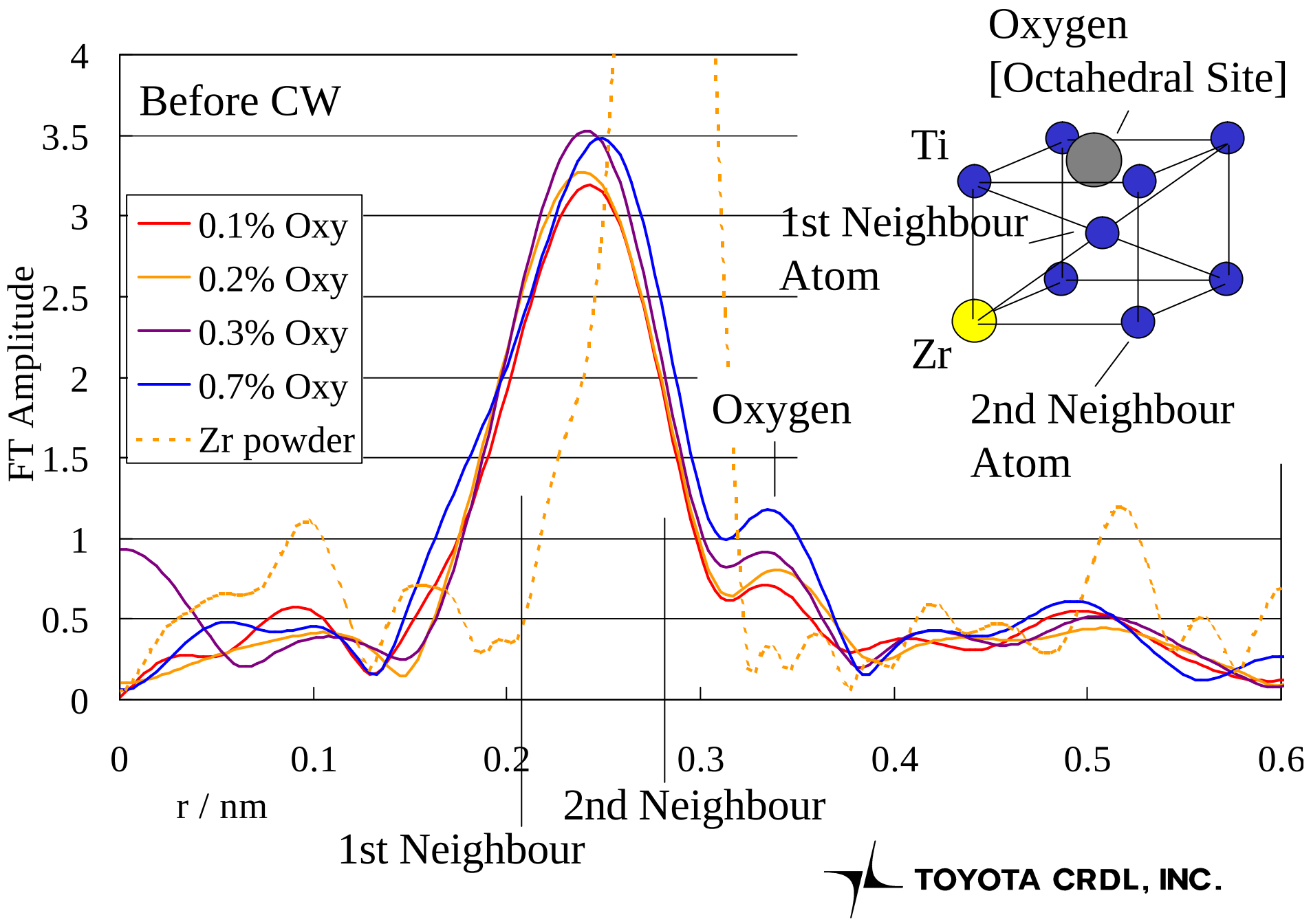

Nb K-edge
Normalized Absorbance
1.2
1
0.8
0.6
0.4
0.2
0
18.6
18.8
19
19.2
19.4
Photon Energy / keV
Before CW (0.1%Oxy)
After CW (0.1%Oxy)
Before CW (0.2%Oxy)
After CW (0.2%Oxy)
Before CW (0.3%Oxy)
After CW (0.3%Oxy)
Before CW (0.7%Oxy)
After CW (0.7%Oxy)
Nb powder
(CW:90%)
TOYOTA CRDL, INC.

Fourier Transferred Spectra from Zr K-edge



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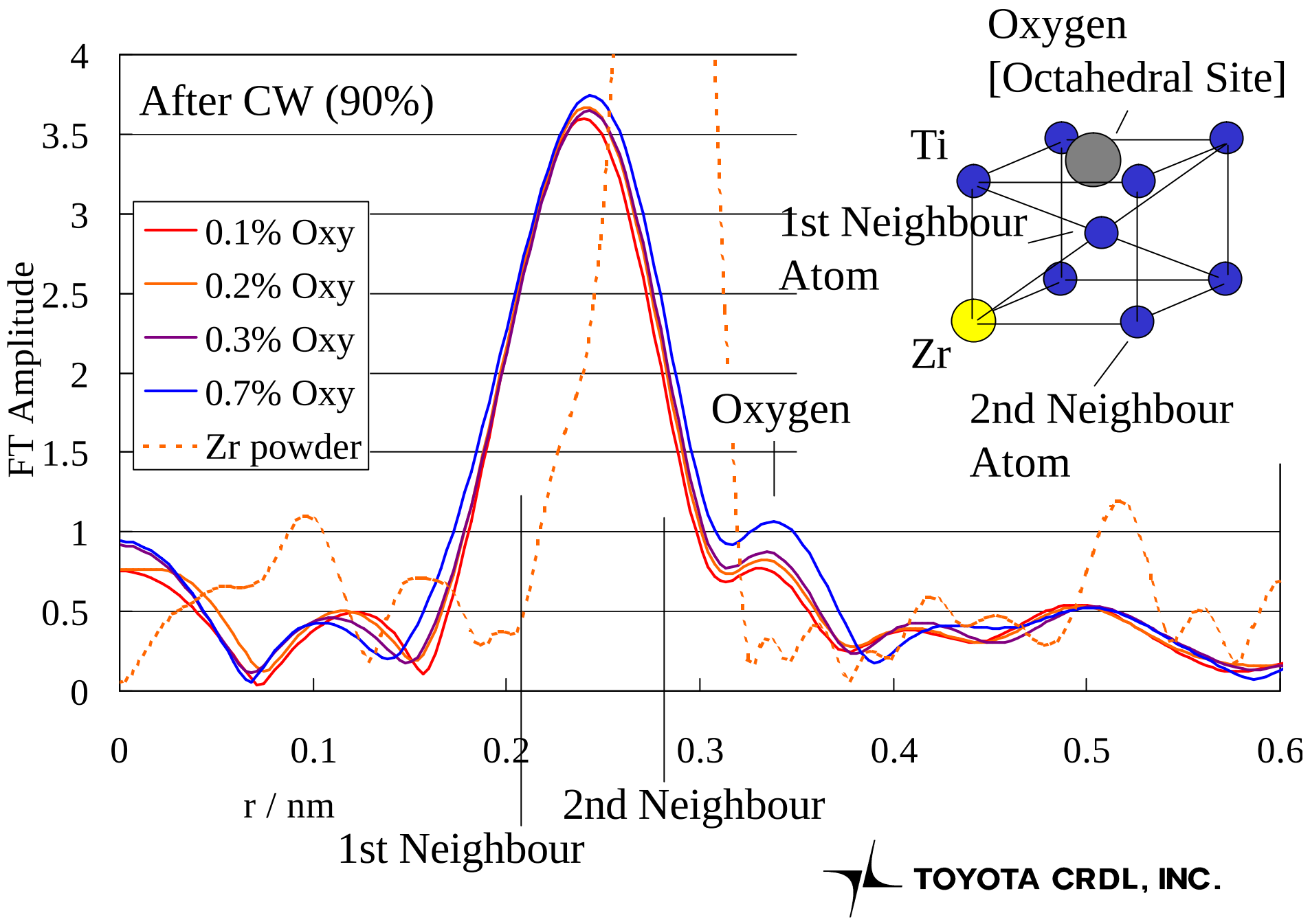
Fourier Transferred Spectra from Zr K-edge



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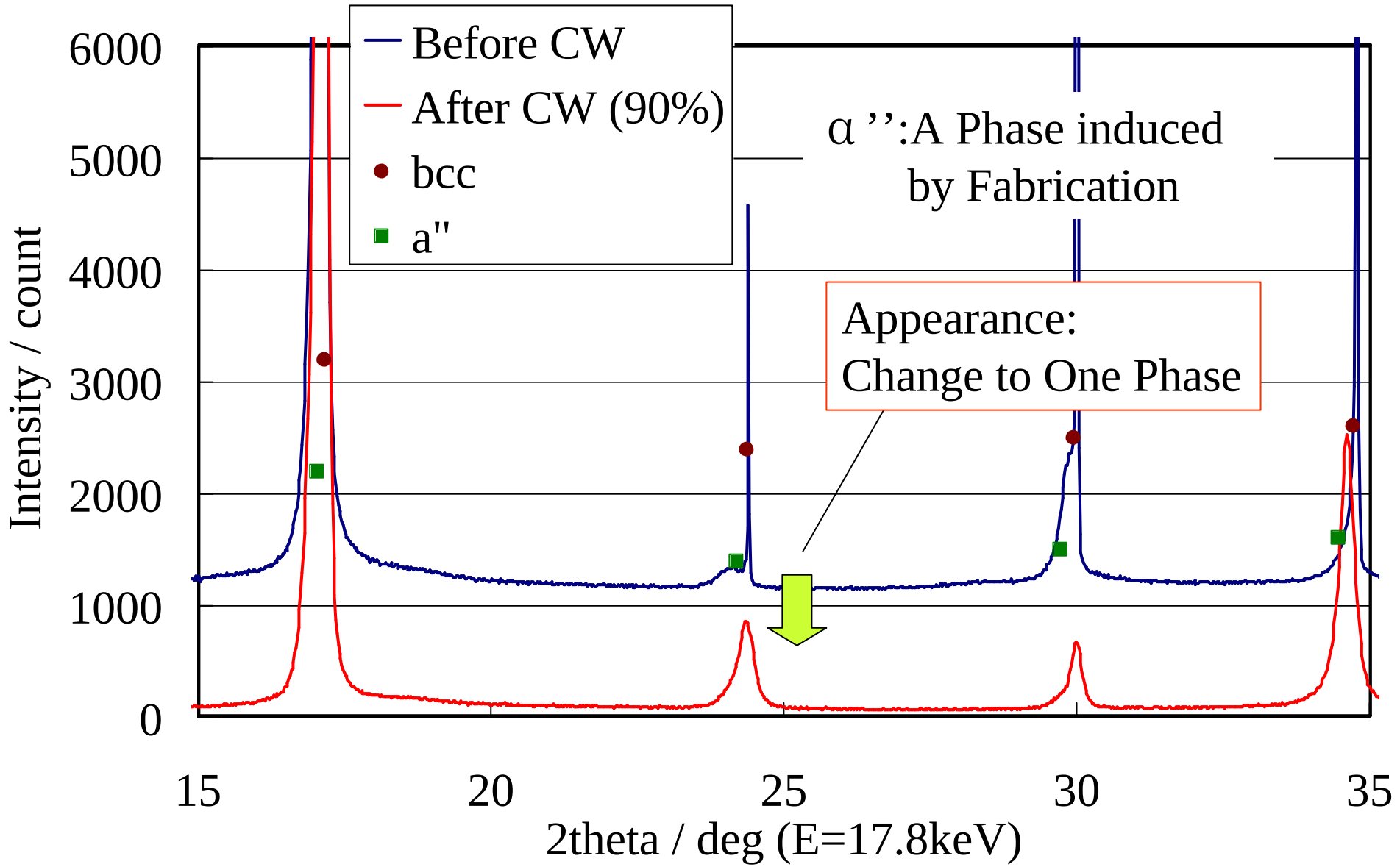
Samples for this XAFS Analysis



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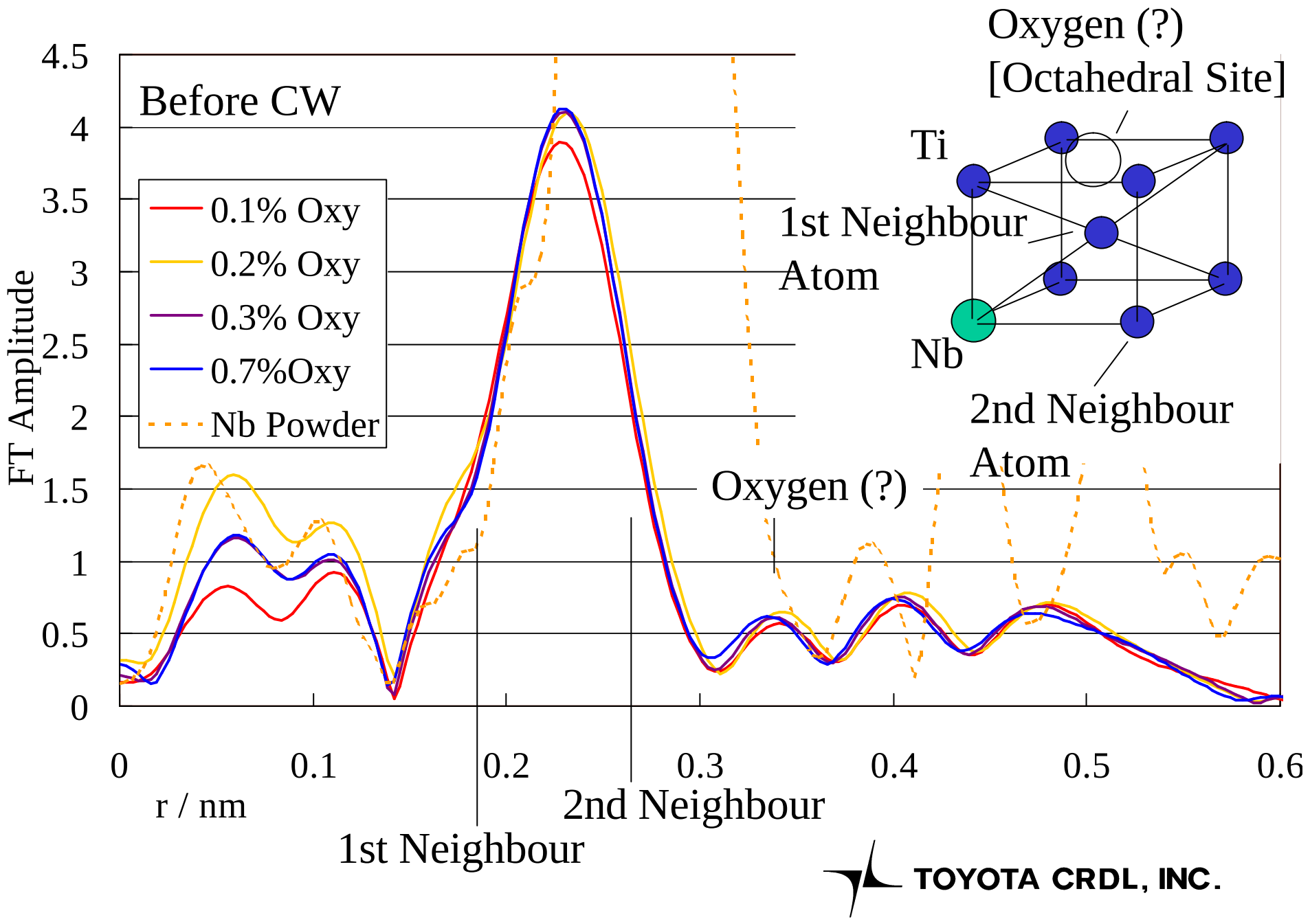
Fourier Transferred Spectra from Nb K-edge



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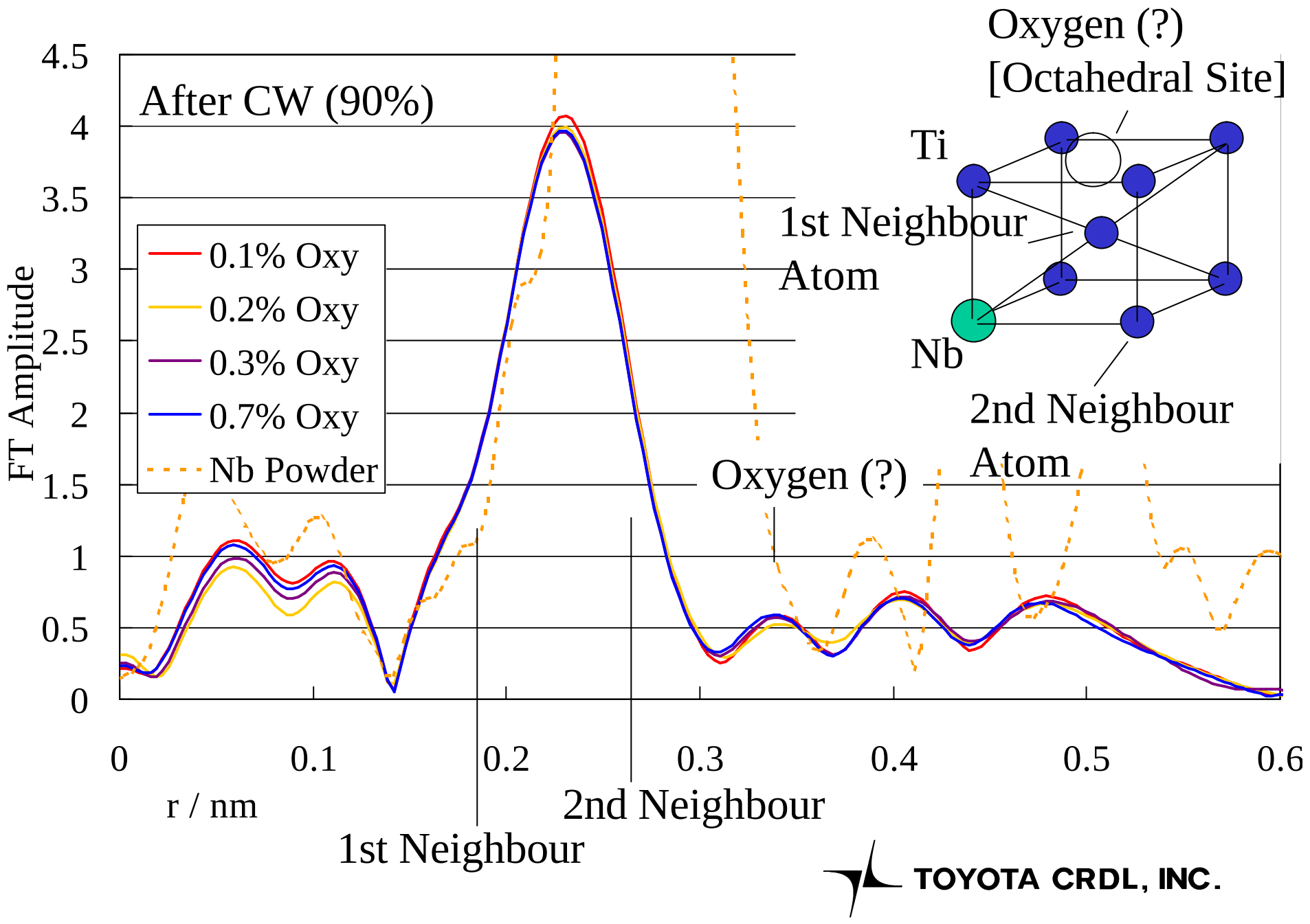
Fourier Transferred Spectra from Nb K-edge



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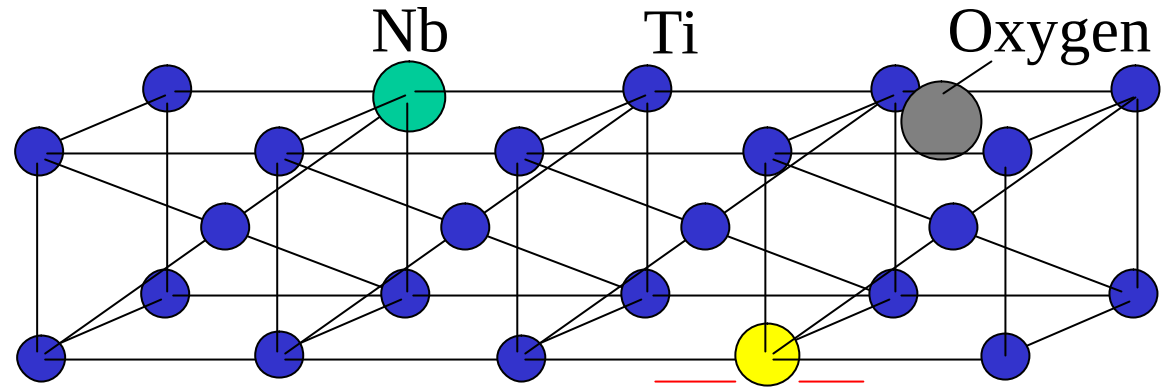
Comparing of Surroundings between Zr and Nb atoms



(1) Atomic displacements are piled up.

(2) Oxygen atoms are in octahedral sites.

Change of Distance between Nearest Neighbour Atoms caused by Cold Working

↓

Very Large (Detectable on the FT Spectra)

↓

Existence of Oxygen

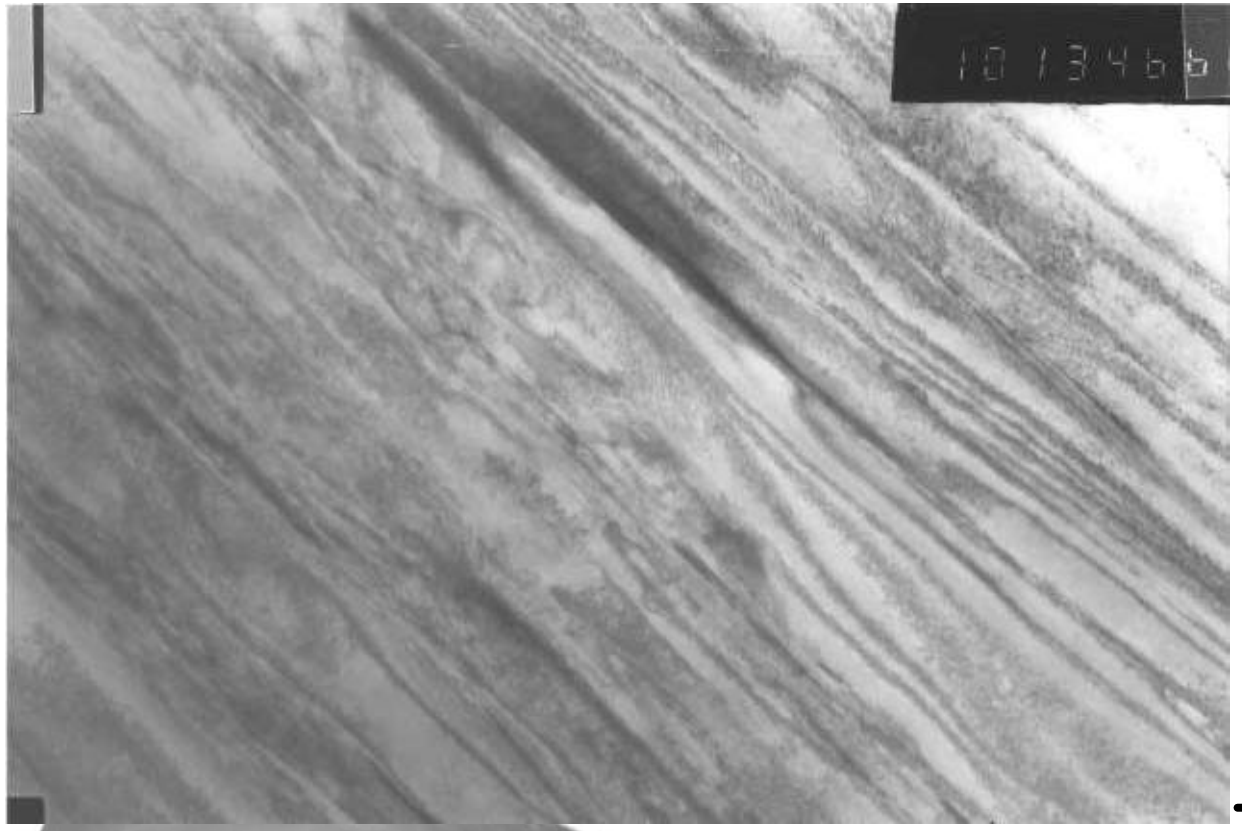
(A Probable Important Factor for the Atomic Displacement)

Conclusions

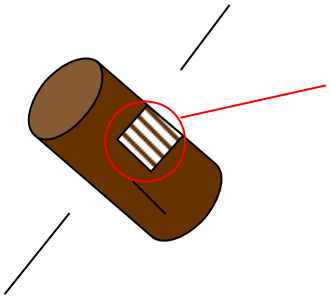
(1) Large crystal lattice distortion caused by cold working is one of the most important factors of the plastic deformation in Gum Metal.

(2) Comparing of surroundings between Nb and Zr atoms, atomic displacements are piled up around Zr atoms. Oxygen has tendency to be in the octahedral sites near Zr atoms, which is a probable important factor for large atomic displacement around them.

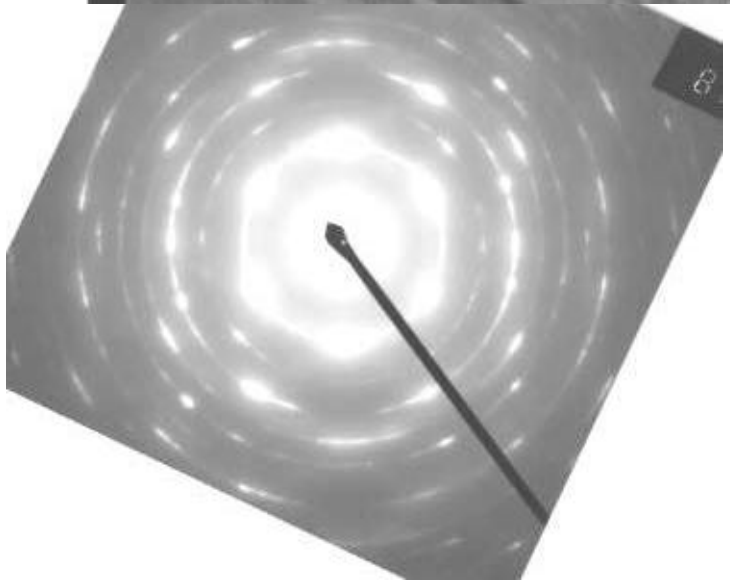
TEM observation



Rod



Cold Swaging
(90%)



Ti-30Nb-10Ta-5Zr (+ O)
CW-90%

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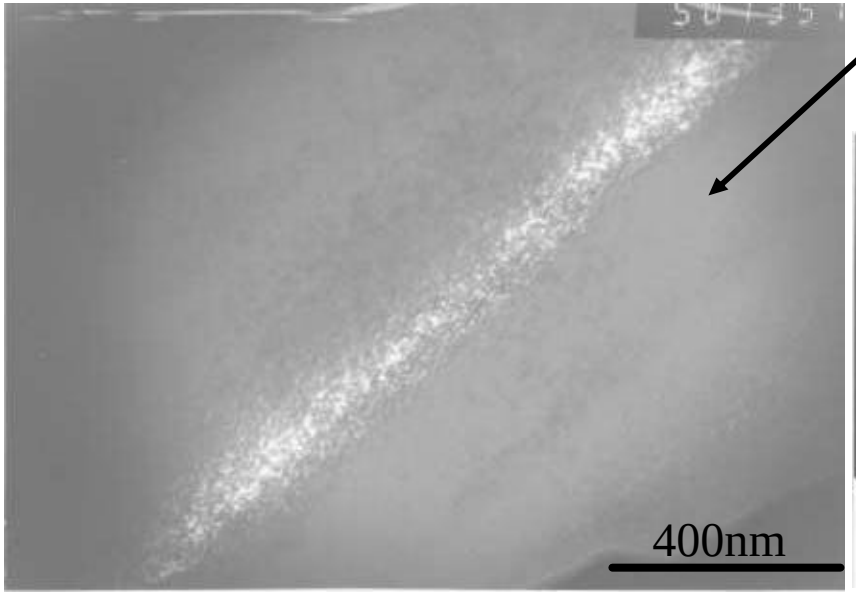
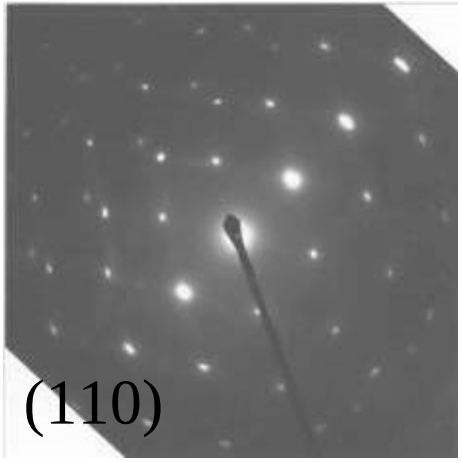
Dark Field Images

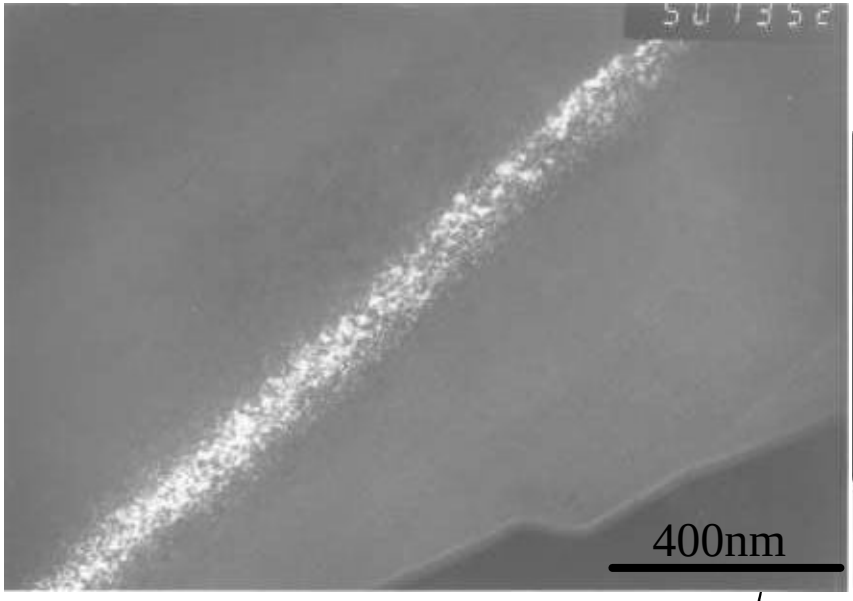
Rotation Axis of the Sample

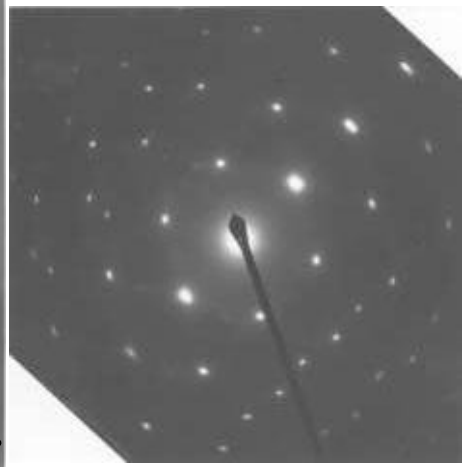
Gonio Tilt: -16.3 °





Gonio Tilt: -9.4 °





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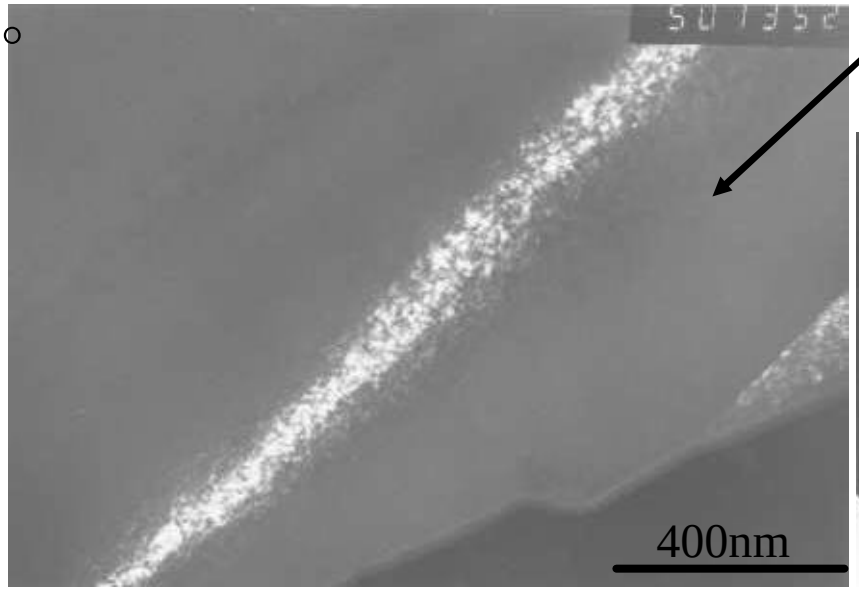
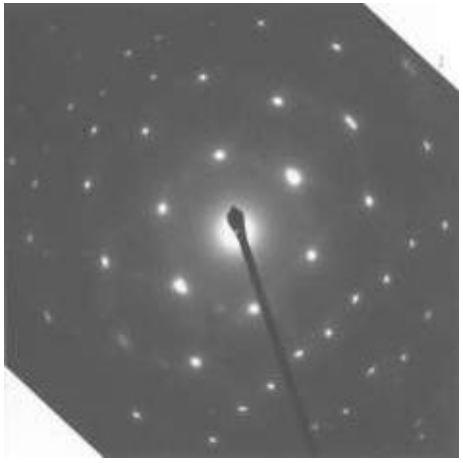
Dark Field Images

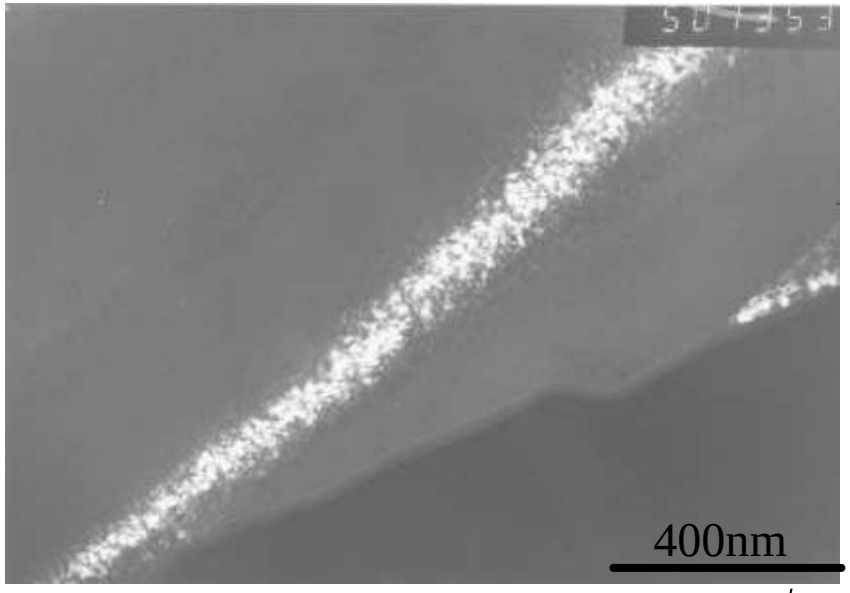
Rotation Axis of the Sample

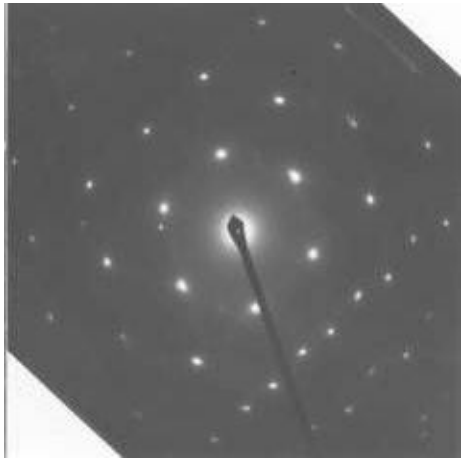
Gonio Tilt: -1.7 °





Gonio Tilt +6.1 °





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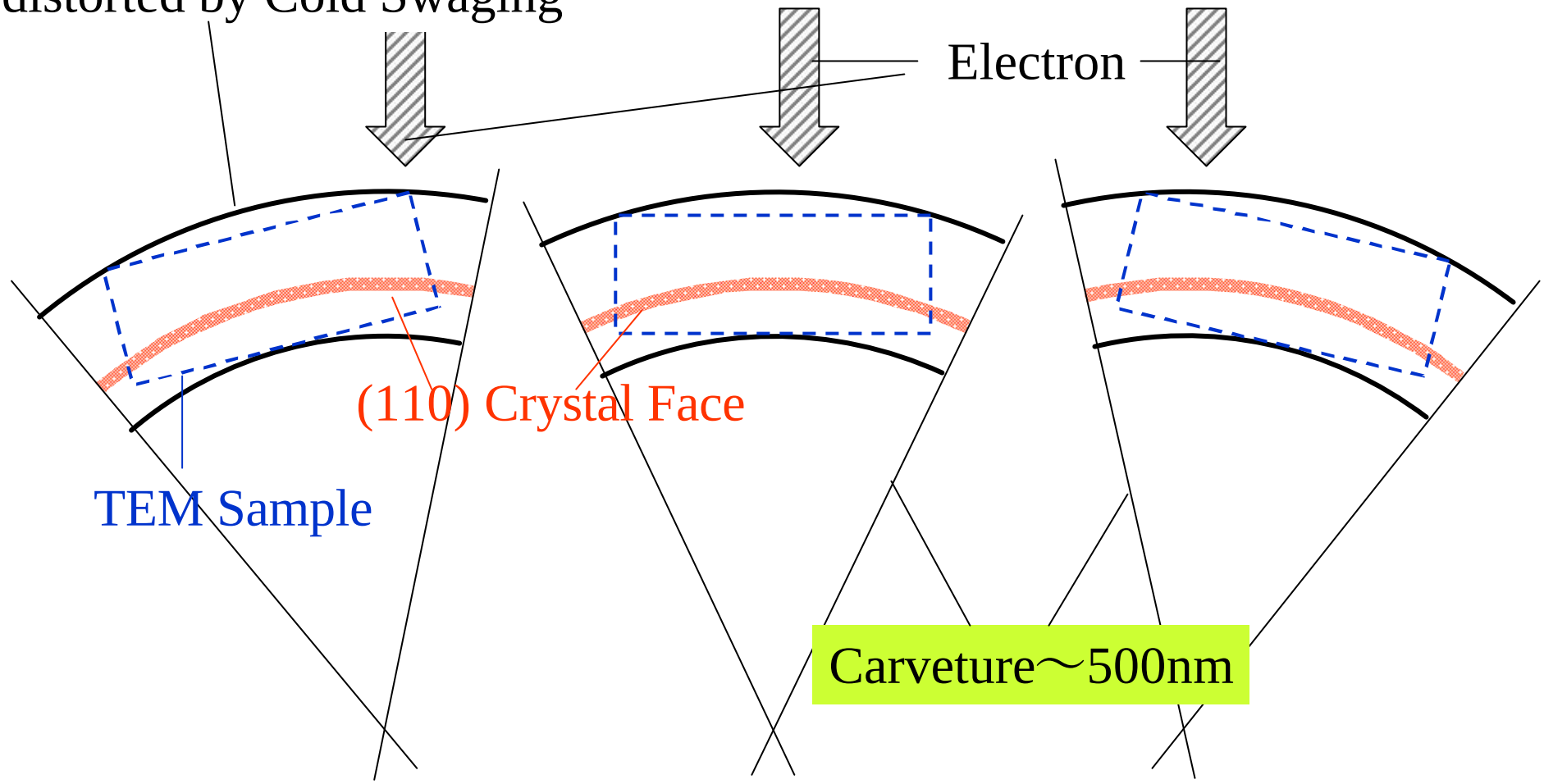
Gum Metal Crystal
distorted by Cold Swaging



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