Nitinol With Improved Ductility

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Ductility – Heat Treated at 575°C  Ni$_{50.8}$Ti
Ductility – Heat Treated at 575°C
Ductility – Heat Treated at 540°C

![Graph showing the relationship between engineering stress and engineering strain for samples heat treated at 540°C for 15 and 30 minutes.](image)
Ductility – Heat Treated at 540°C

![Graph showing the relationship between time and elongation or UTS.]

- **Elongation at UTS (%)**
  - Time (min.)
  - UTS (MPa)

**Legend:**
- **Blue Squares:** Elongation
- **Red Circles:** UTS
TEM study- aged at 575 °C for 3 min. before deformation

Conventional bright field micrograph

- Showing the <111> B2 zone axis and existence of 1/7<321> super reflections as indication of Ni₄Ti₃ precipitates.
Precipitates are formed in a sequence due to formation of each one in the strain field of the other one which after deformation can form grain boundary.
High resolution TEM technique

Nano $\text{Ni}_4\text{Ti}_3$ precipitates are indicated by arrows
High resolution TEM technique: most of the precipitates are coherent or semi-coherent.

Filtered HRTEM image

Inverse fast Fourier transform

Local g-map

Formation of two misfit dislocation in the interface matrix/precipitate
TEM study: After deformation 9%

Formation of low angle grain boundaries, residual martensite and existence of the morphology of martensite plates

Formation of low angle twist boundary was also confirmed by observation of screw dislocations network inside grains.
Diffraction study: No reflections related to precipitates were detected

- Smaller, coherent precipitates are not only sheared, but are actually dissolved by the passage of dislocations due to increase of the surface energy of sheared particles.
Residual larger precipitates but became incoherent with higher number of dislocations around them.

Larger precipitates appear to accumulate dislocations during Orowan looping. After forming Orowan loop, it shrinks onto the precipitate-matrix interface.
Rotary Bending Fatigue - Results

Test Temperature: 37°C

Number of Cycles to Failure ($N_f$)

Strain Amplitude (%)
An unusually sudden and dramatic increase in ductility is observed during ageing of cold worked Ni-rich NiTi at 575 °C-3min or 540 °C-30min.

During deformation smaller, coherent precipitates are sheared and then dissolved by the passage of dislocations.

Larger precipitates appear to accumulate dislocations, indicative of Orowan looping.

Proposed mechanism:

Smaller coherent precipitates provide initial hardening (by shearing precipitates) till precipitates dissolve and their hardening effect is lost and fracture occurs (575/2min). However, in the presence of coherent and semi-coherent precipitates, semi-coherent larger precipitates are able to survive deformation and thus ductility is increased.
Thank You
Ductility – Heat Treated at 575°C
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The graph illustrates the changes in elongation and Ultimate Tensile Strength (UTS) over time after heat treatment at 575°C. The elongation percentage decreases significantly with time, while the UTS increases. The error bars indicate the variability in measurements.