Tensile Behavior of Micro-Sized Specimen Fabricated from Nanocrystalline Nickel Film

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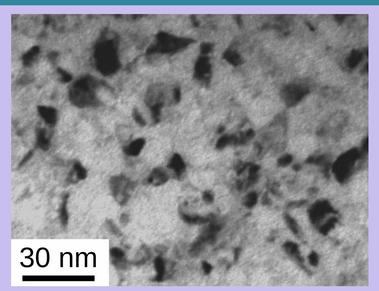
Introduction

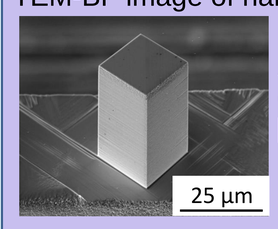
Micro-compression test of nanocrystalline Ni



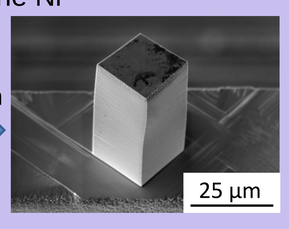
TEM-BF image of nanocrystalline Ni

Ni film fabricated by electroplating with supercritical CO_2(EP-SCE)

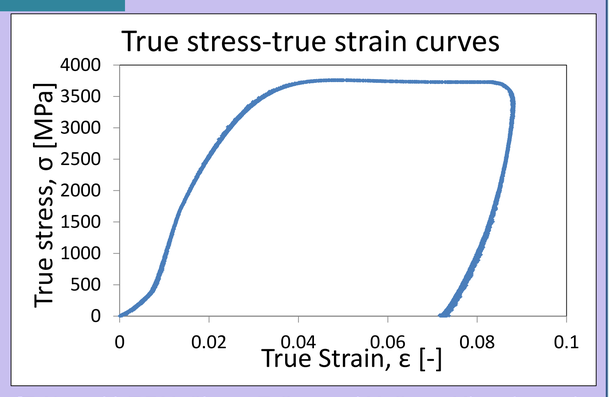
Average grain size: 8 nm



After deformation



SEM images of micro-pillar before and after compression



[T. Nagoshi, T.F.M. Chang, T. Sato and M. Sone, Microelectronic Engineering **110** (2013) 270-273]

Cannot provide
- Fractured strength
- Elongation

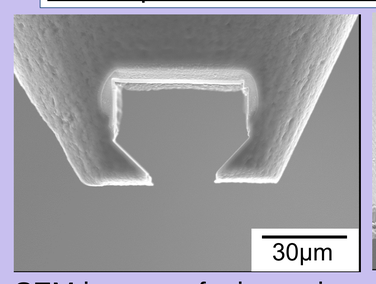
Micro-tensile test

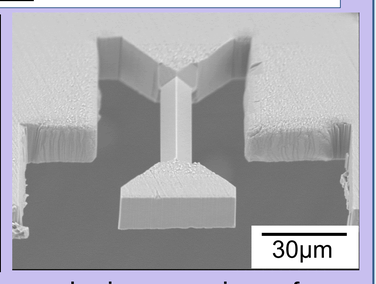
Application for MEMS

Micro-tensile test

Can obtain
- Fractured strength
- Elongation

Conduct micro-tensile test using micro-gripper and micro-specimen to evaluate





SEM images of micro-gripper and micro-specimen for micro-tensile test fabricated by focused ion beam.

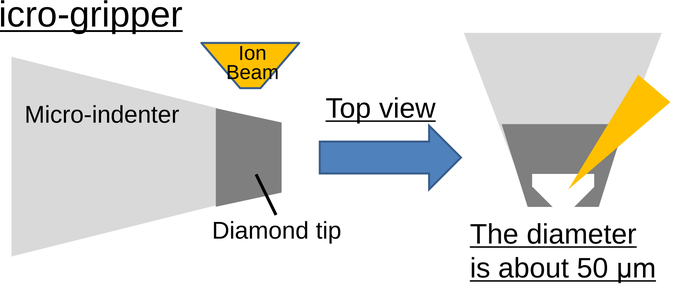
Objective

Evaluate fracture strength of micro-specimen composed of nanocrystalline Ni using micro-tensile testing.

Experimental Procedure

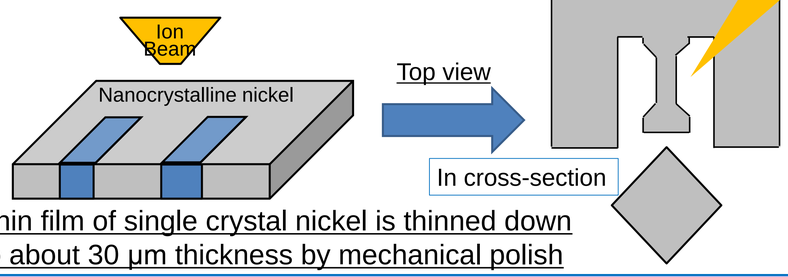
Fabrication method

Micro-gripper



Gripped part of the specimen is similar to diamond gripper

Micro-specimen

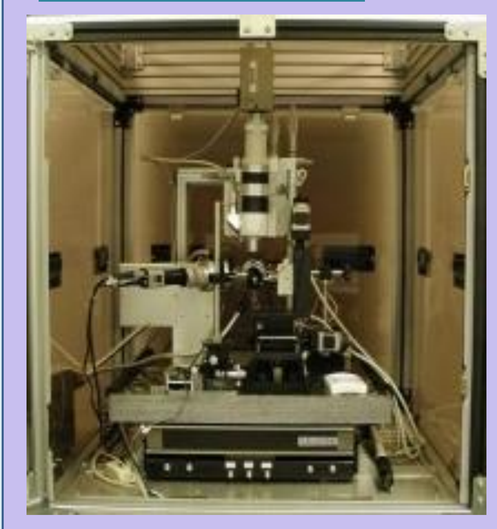


Thin film of single crystal nickel is thinned down to about 30 μm thickness by mechanical polish

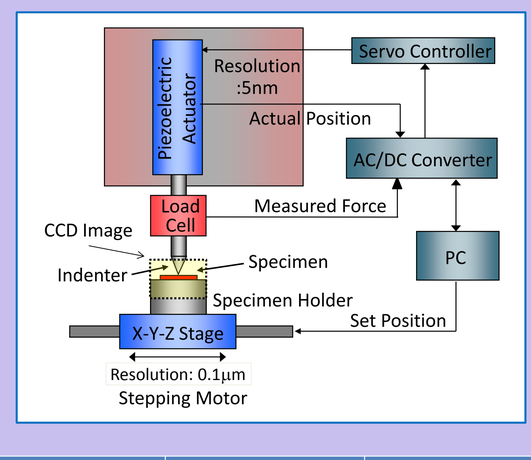
Gauge part of the specimen has a square cross-section

Material of specimens	Dimension of the gauge part [μm]
Nanocrystalline nickel	10 × 10 × 40

Testing condition



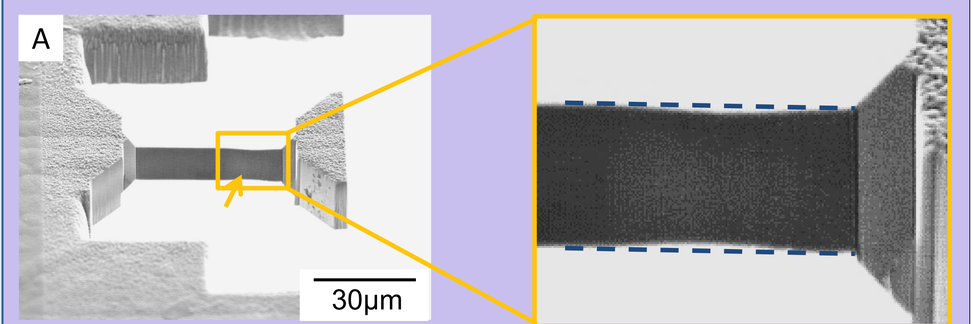
Test machine designed for micro-sized specimens



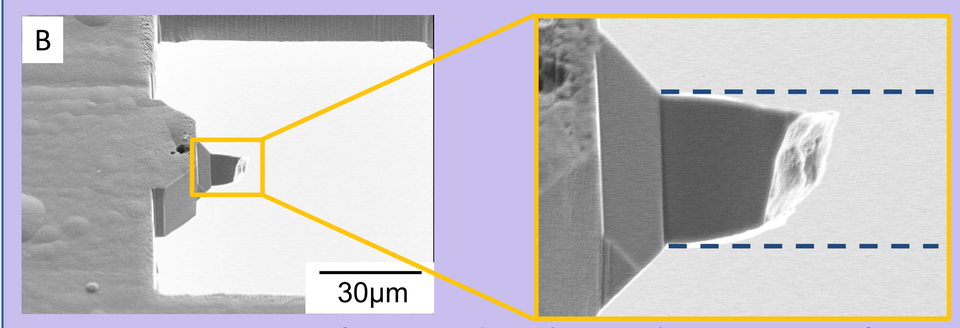
Control	Displacement rate	Load resolution
Displacement control	0.1 [μm/s]	10 [mN]

Results & Discussion

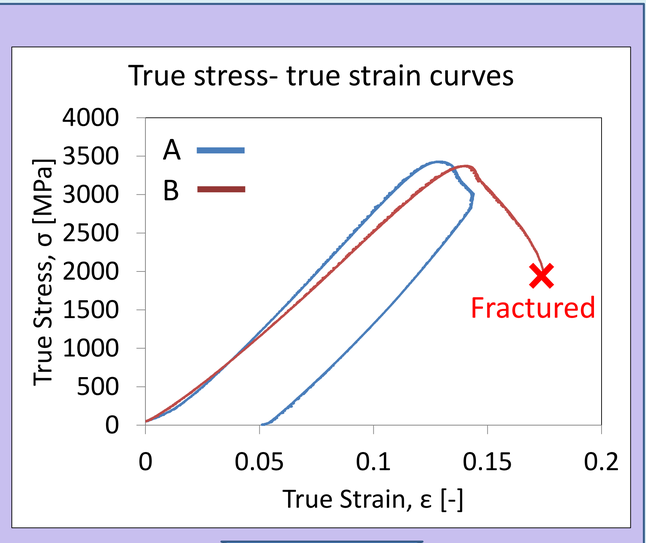
Deformation behavior and mechanical properties



Necking phenomena(marked by orange arrow) was observed in the gauge part before fracture.



Specimen was fractured without observation of any shear bands.



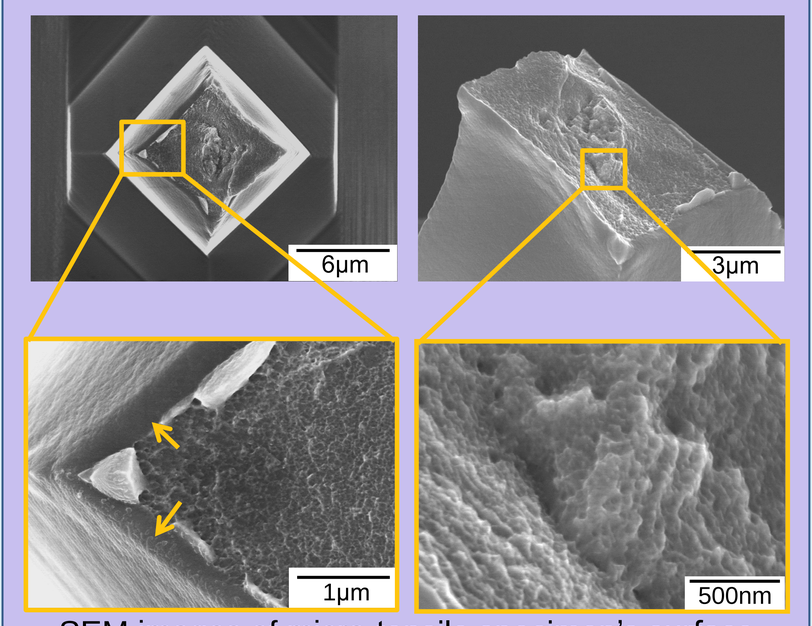
High strength

Both specimens showed high strength about 3.5 GPa.

A few plastic strain

After yield stress, about 3-5 % plastic strain were observed.

Fracture behavior



SEM images of micro-tensile specimen's surface after fracture

In fractured surfaces
- Shear lip(red arrows)
- Dimple pattern

→ Cup and corn fracture → Ductile material

Conclusions

- Nanocrystalline Ni showed a high strength(about 3.5 GPa) and a few plastic strain(3-5 %).
- Deformation and fracture behavior were similar to the fracture mode of ductile materials.
- Nanocrystalline Ni film fabricated by EP-SCE is suitable material to be applied in MEMS.
- The results in this study shows a more inherent deformation and fracture behavior of nanocrystalline Ni than the micro-compression test.

Acknowledgement

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