Design of Energy Absorption Bases on Porous Materials Including Shape Memory Alloys

MURI–UW, Subcontract to UCSD

(Prof. Sia Nemat – Nasser, PI of MURI Project)

Subcontract Budget Period: 12/01/02 - 11/30/03

Prime Grant/ Contract # N00014 - 12 – 0666

(Dr. Roshy Barsoum, Program Manager, ONR)

Minoru Taya, Professor

Robert Y. Liang, Research Associate

Ying Zhao, Graduate Student

Center for Intelligent Materials and Systems

University of Washington

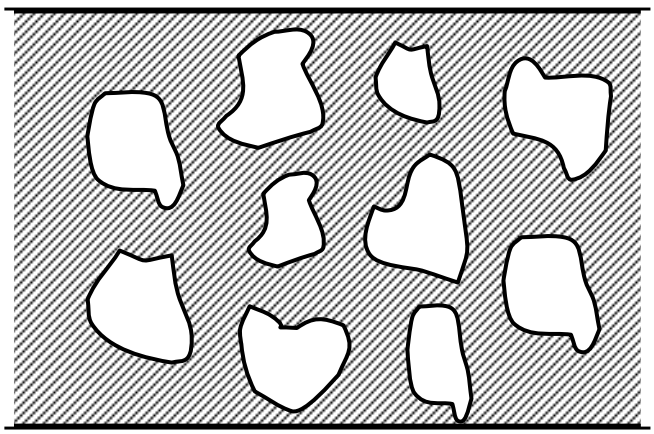
Introduction

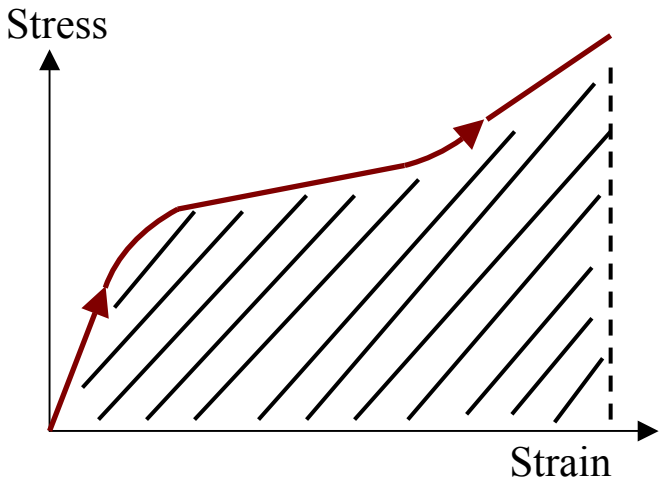
Goal:

To design and process porous NiTi with higher energy absorption capacity under compressive loading

Approach Method:

Inspired by our buckling test results of Al, Steel and NiTi, we plan to design porous NiTi with micro-pillar structure where the effect of side force is expected to increase the energy absorption, i.e. enforcing higher order buckling mode





Collaborators:

Profs. Watanabe, Kawasaki and Kang, Department of Materials Processing, Tohoku University. Japan.

illustrative figure of buckling

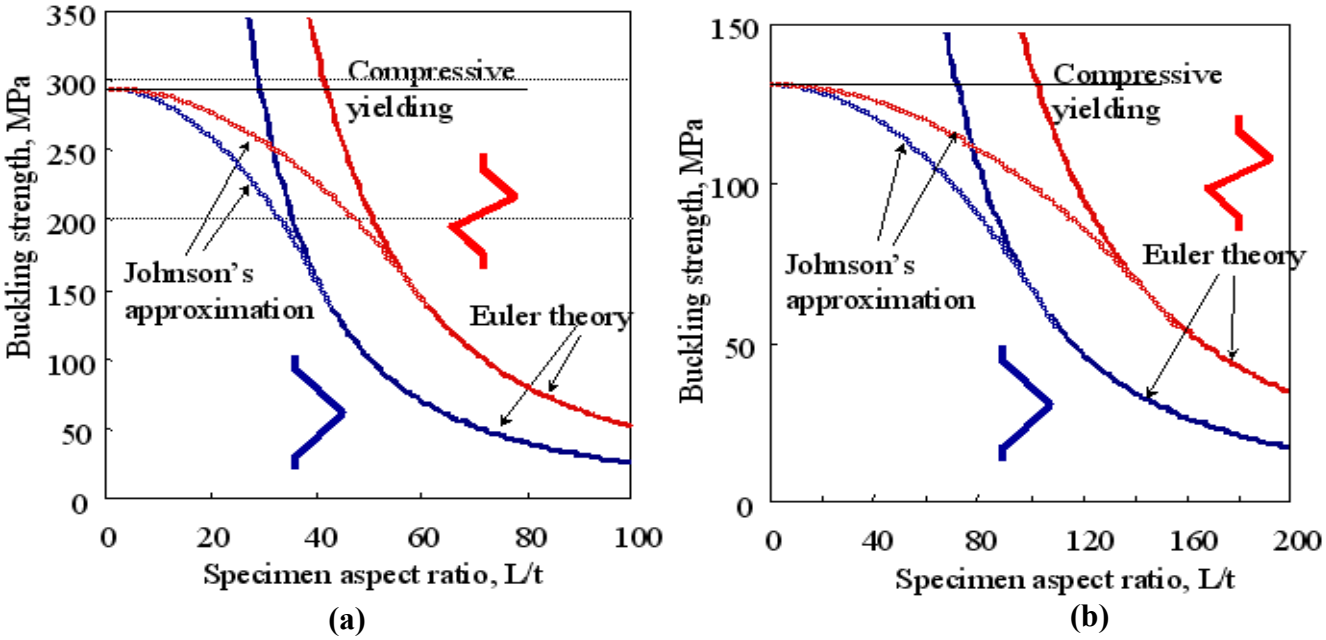
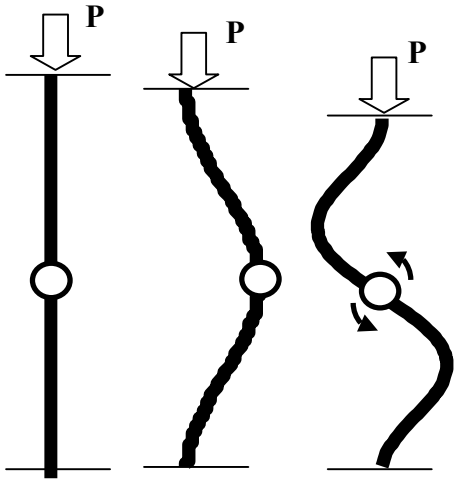


Fig. 1 The estimation of buckling behavior by using Euler and Johnson's methods: (a) Aluminum (A6061) (b) Steel.



Initial state mode 1 mode 2

Fig. 2(a) Buckling mode

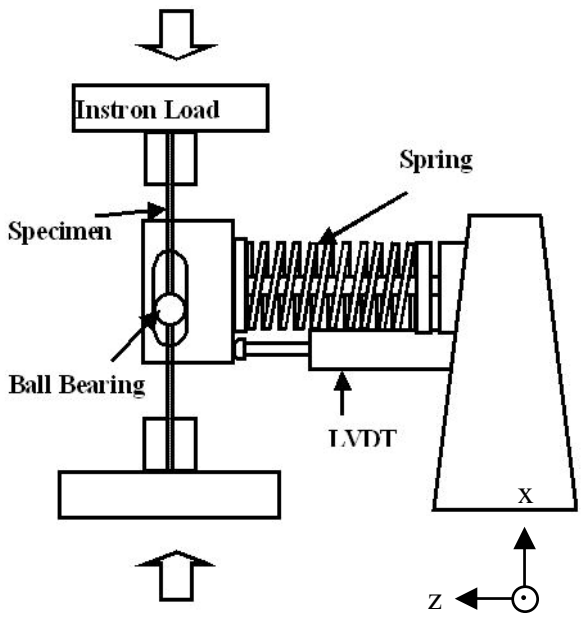


Fig. 2(b) Buckling Setup

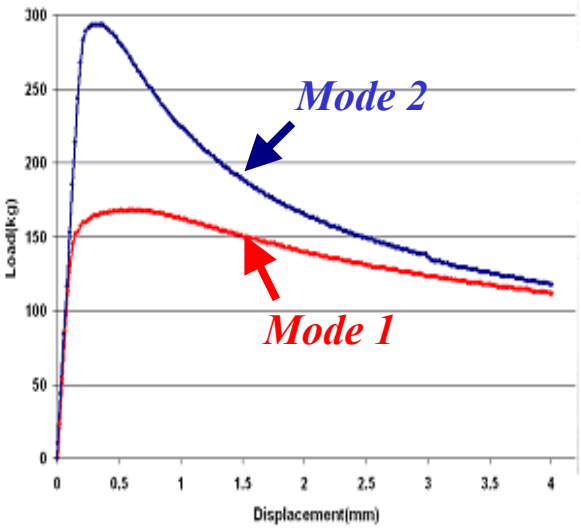


Fig. 3(a), Buckling Result for Al6061

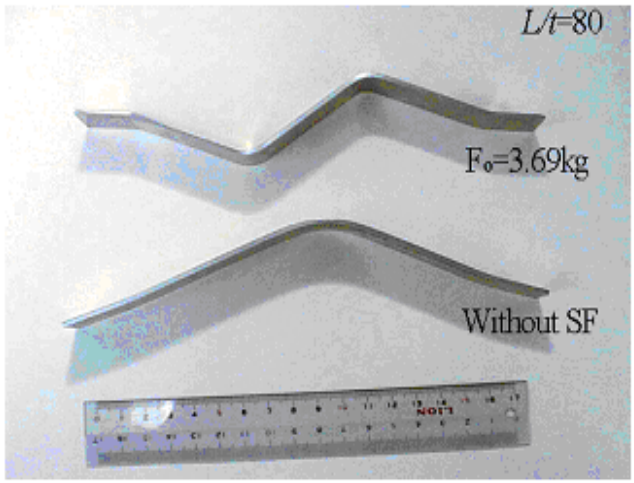


Fig. 3(b), Buckling Result for Al6061

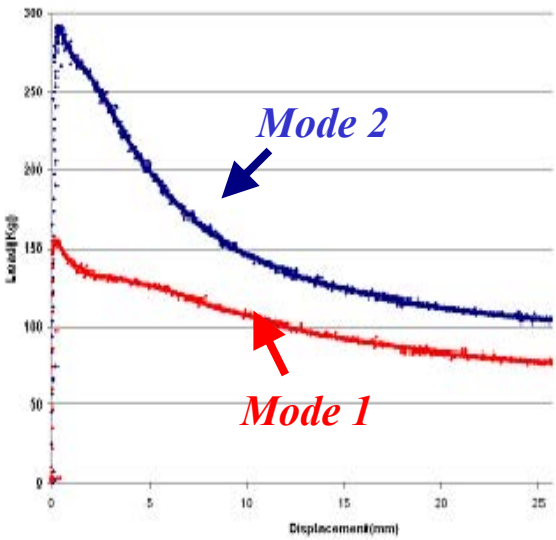


Fig. 8(a) Buckling result for TiNi (Superelastic)

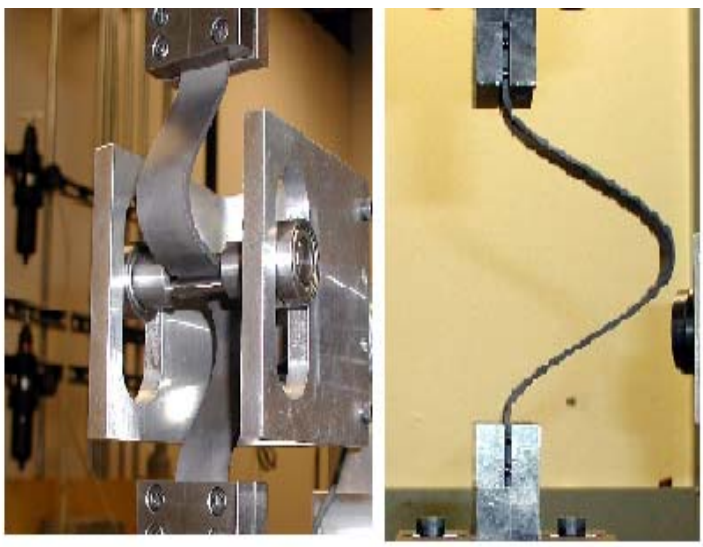
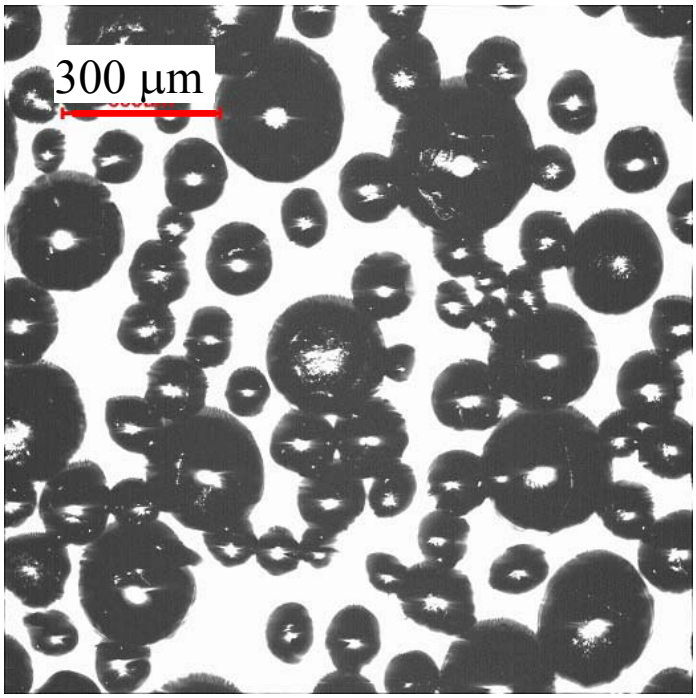


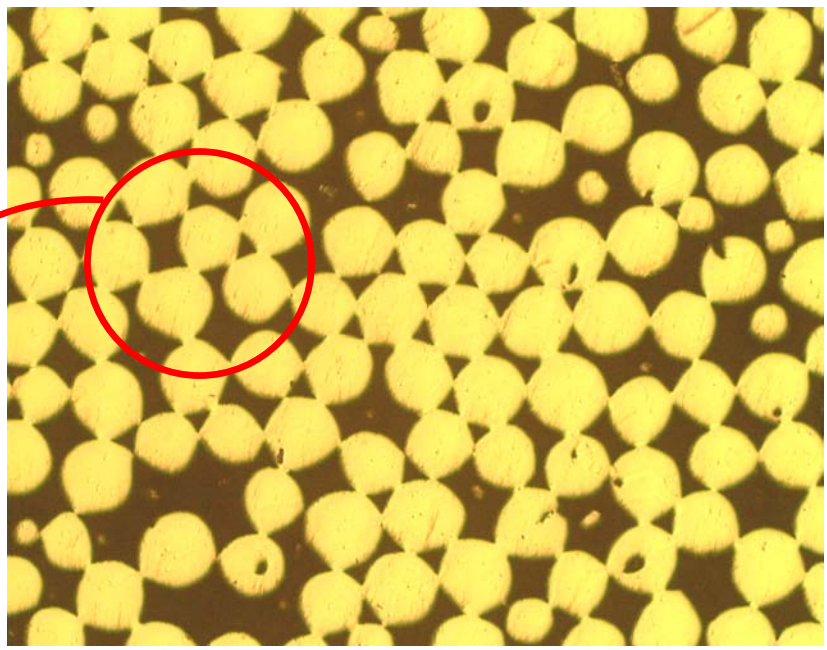
Fig. 8(b) TiNi (Superelastic) specimens after buckling test

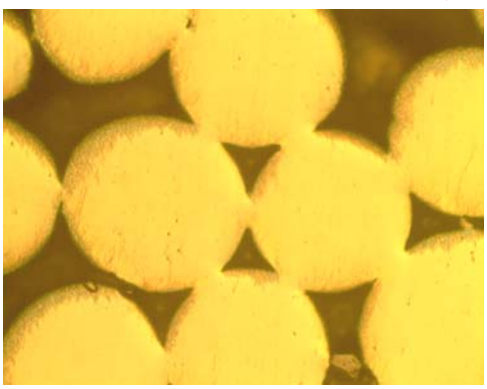
NiTi Powder and Sintered Porous Structure

Powder of
Ni-49.1%at.Ti



Sintered porous structure





Provided by collaborator in Tohoku University. Japan.

Material Processing and Testing

NiTi Alloy Powder

Spark Plasma Sintering (SPS)

Porous NiTi Alloy Disk

EDM Cutting
(Electro-Discharge Machining)

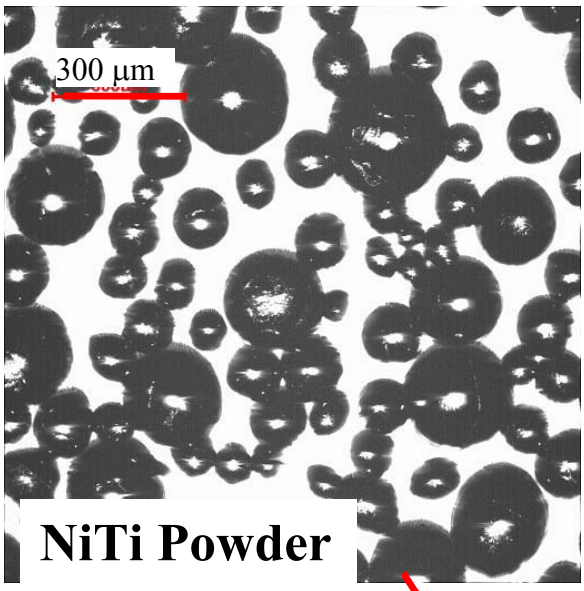
Porous NiTi Alloy Cylindrical Specimen

Heat Treatment

Superelasticity

- **Microscopic Observations**
- **Compression Tests**
- **Impact Tests**

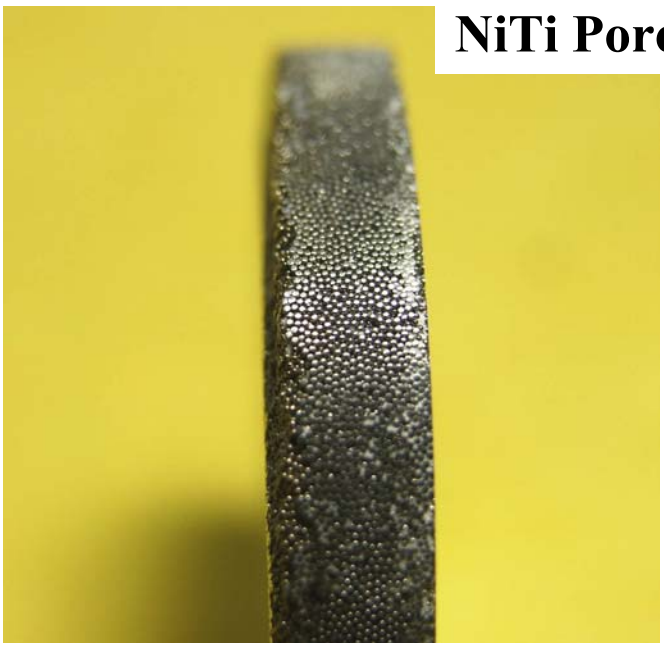
SPS Sintered NiTi Porous Disc

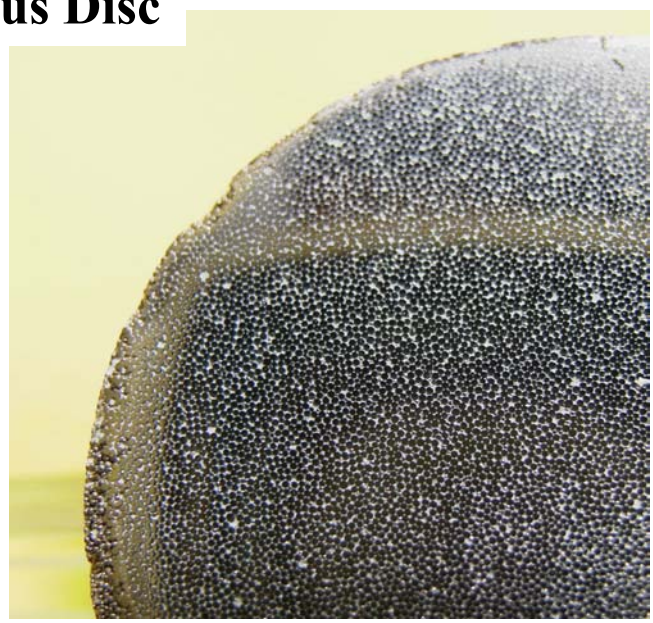


NiTi Powder

Spark Plasma Sintering
(SPS)

NiTi Porous Disc

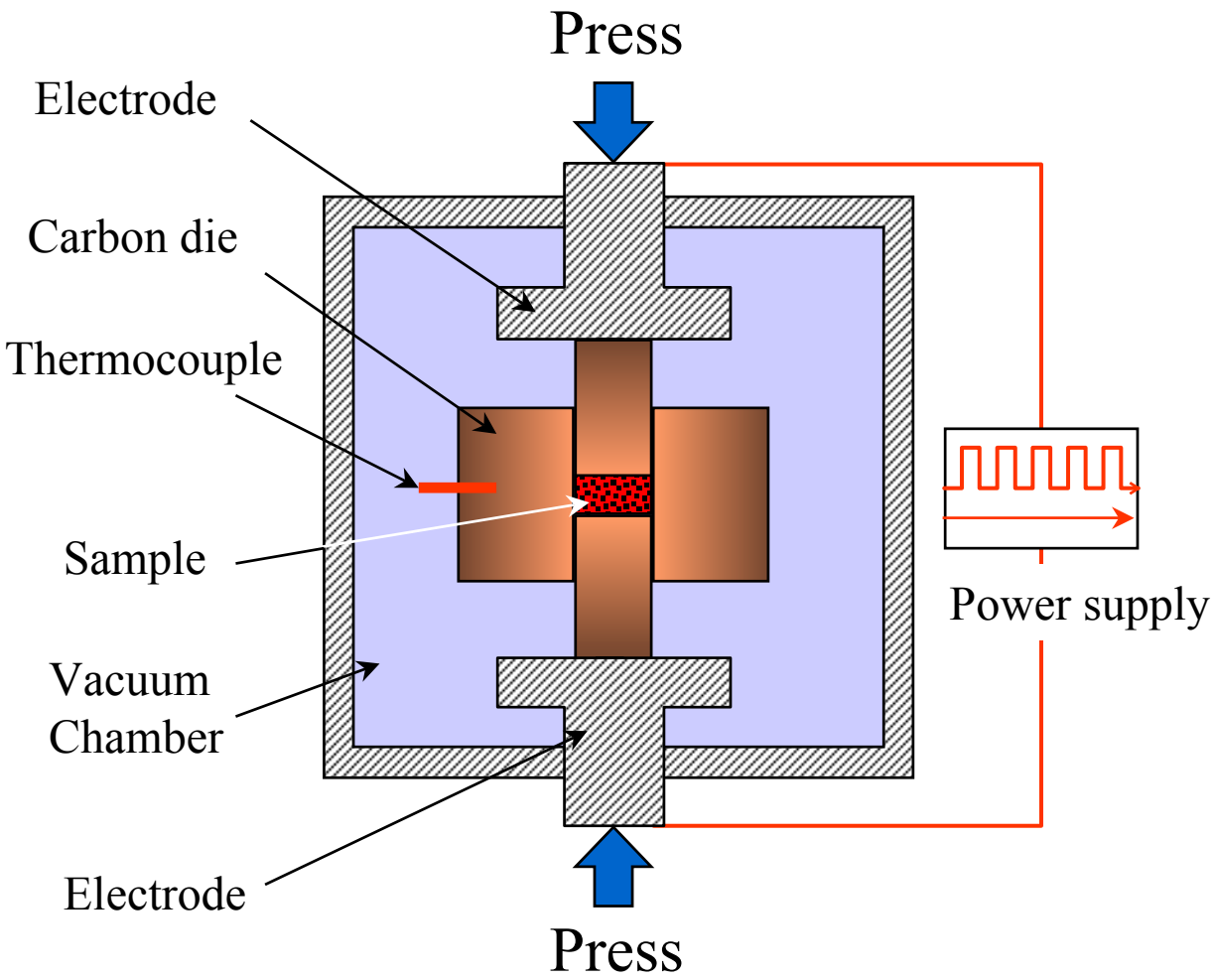




Schematic Sketch of Spark Plasma Sintering

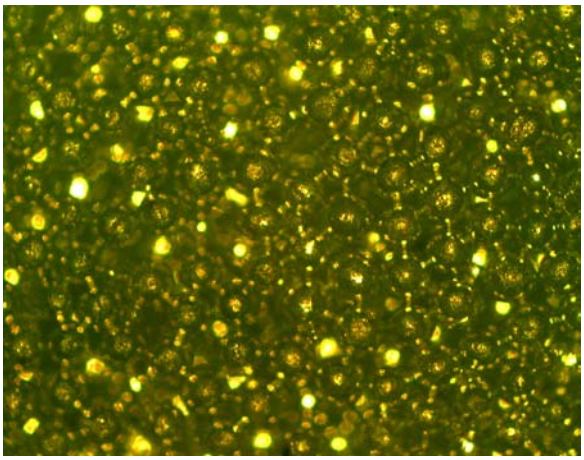
Process in Tohoku University, Japan

- Porosity is mainly controlled by pressure
- Higher pressure, lower porosity

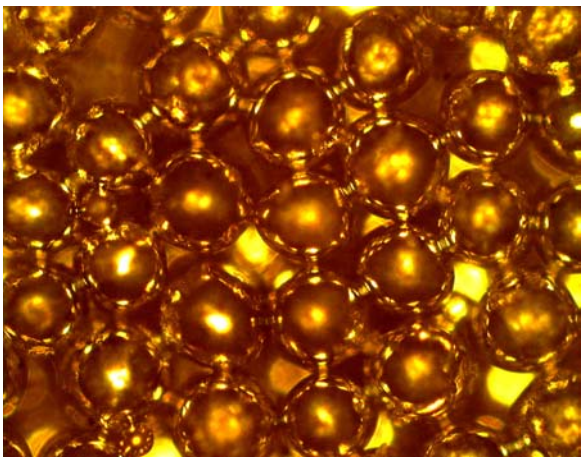


Example of Sintered Sample Surface

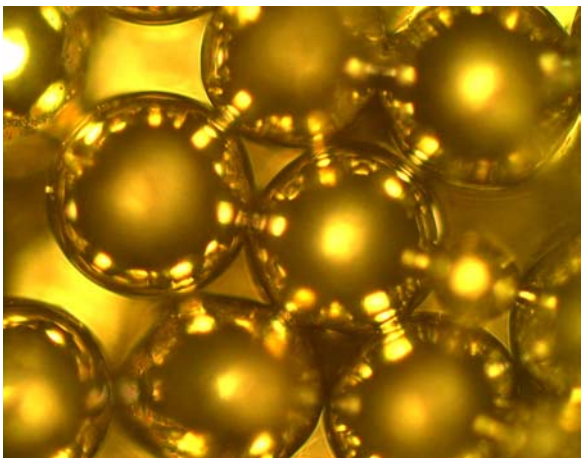
(750℃ for 5 Min.)



5X



10X



20X

Provided by collaborator in Tohoku University, Japan.

Material Processing and Testing

NiTi Alloy Powder

Spark Plasma Sintering

NiTi Alloy Porous Disc

EDM Cutting
(Electro-Discharge Machining)

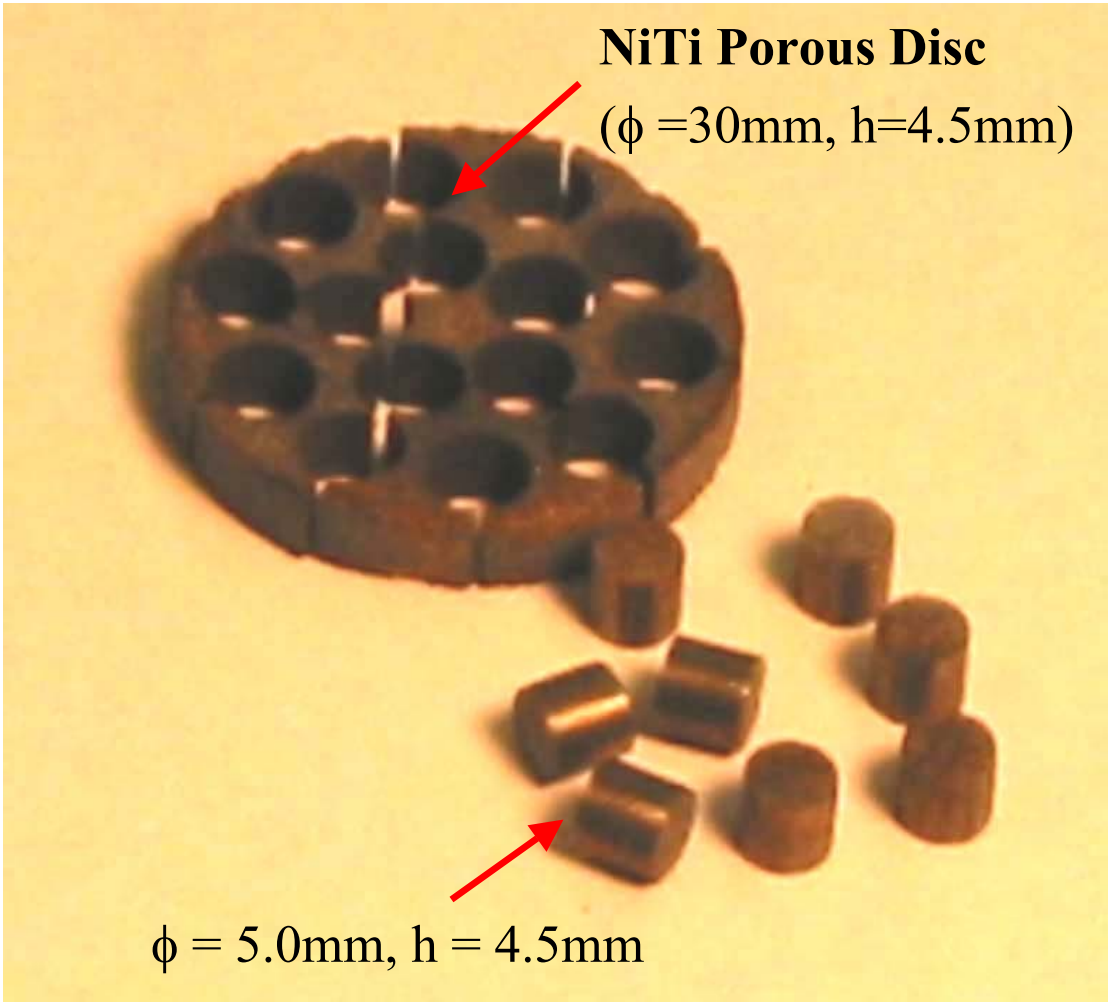
Porous NiTi Alloy Cylindrical Specimen

Heat Treatment

Superelasticity

- Microscopic Observations
- Compression Tests
- Impact Tests

EDM Cutting and Heat Treatment



Heat treatment for superelasticity:

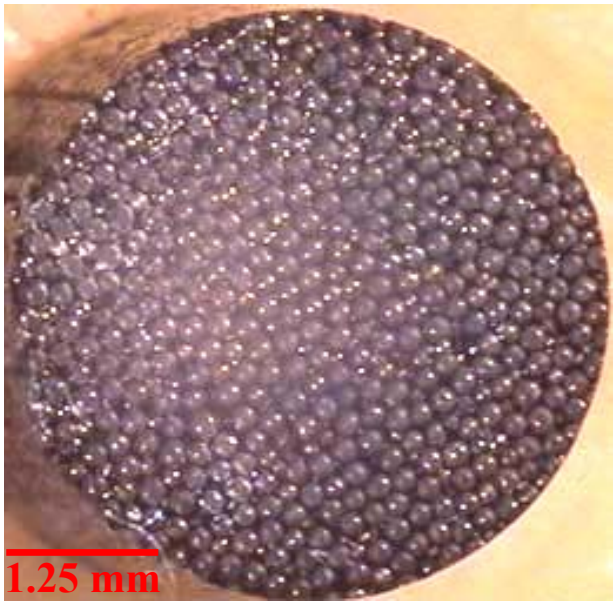
- 300°C in air for 30 Min.
- Iced water quench

Microscopy of Different Porosity Specimens

Spark Plasma Sintered at

750°C for 5 Min.

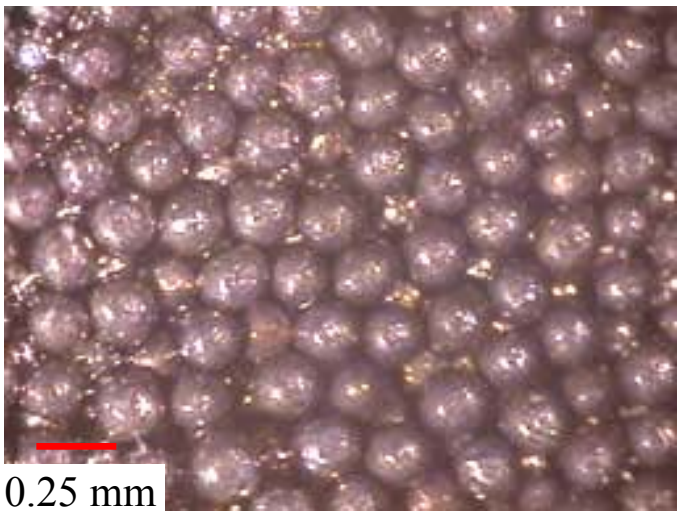
Pressure: 5.1 MPa

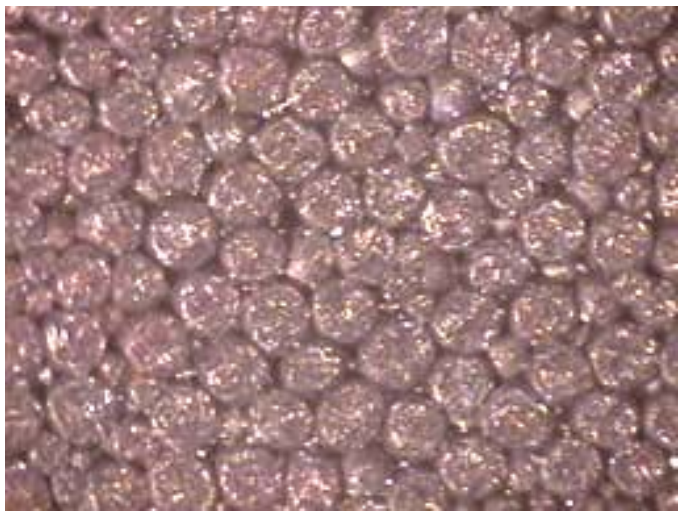


Spark Plasma Sintered at

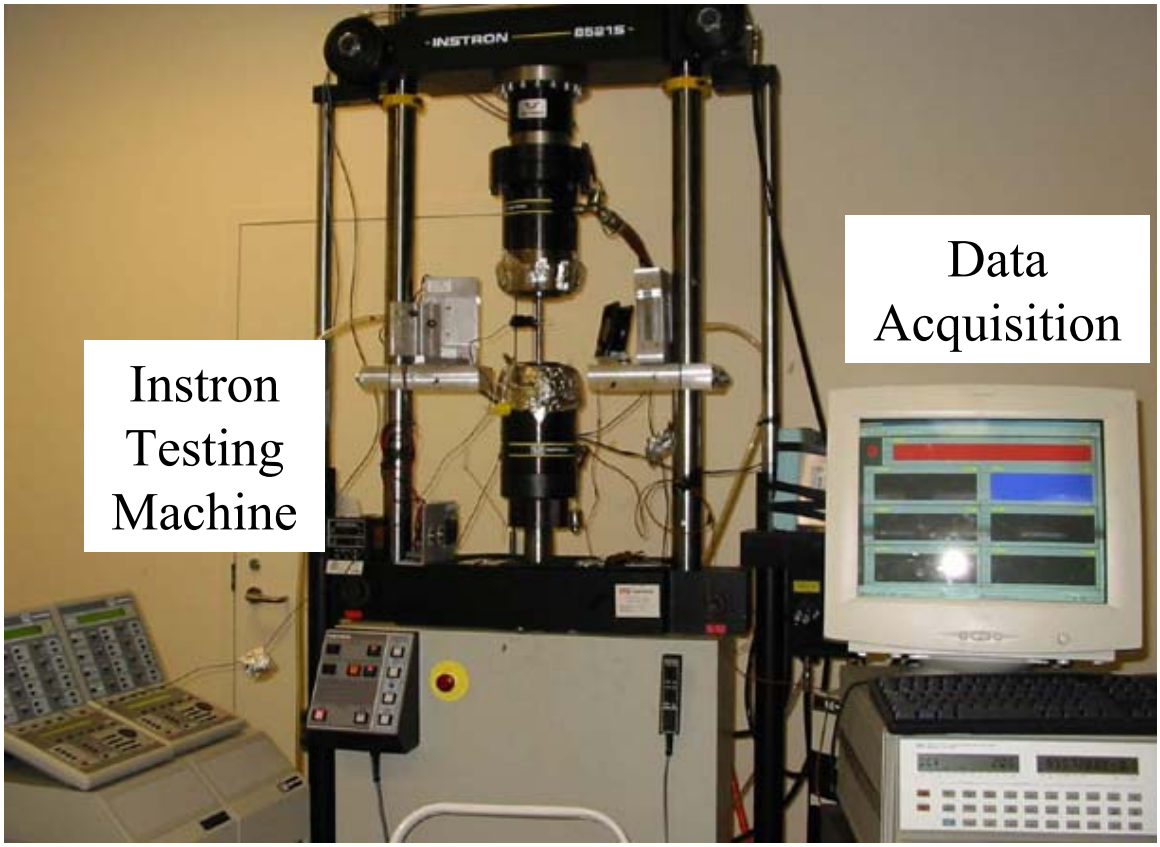
800°C for 5 Min.

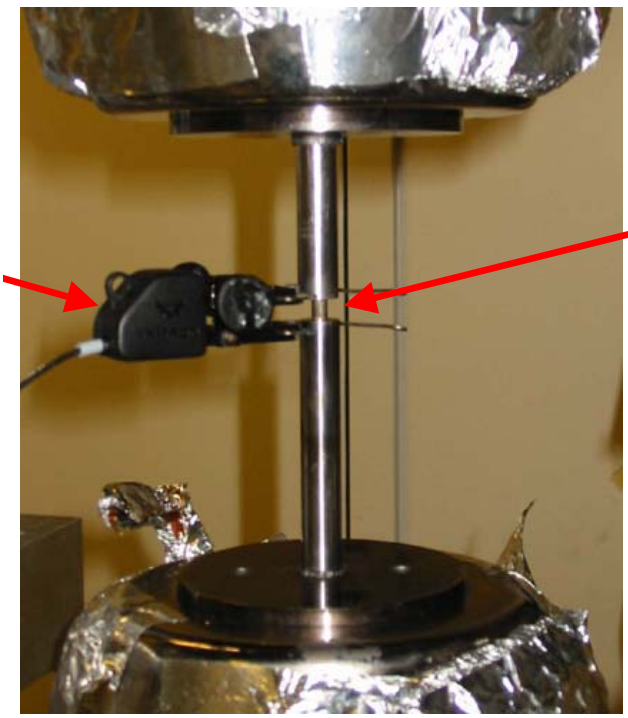
Pressure: 25 MPa

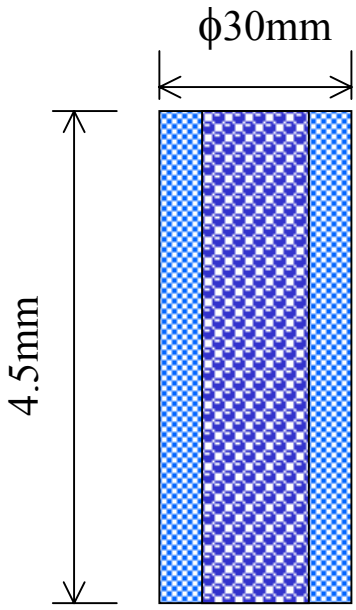




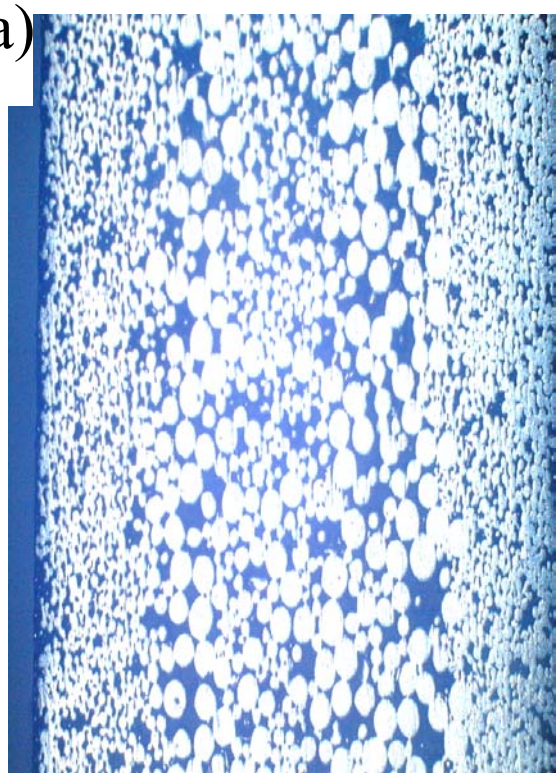
Compression Testing Apparatus



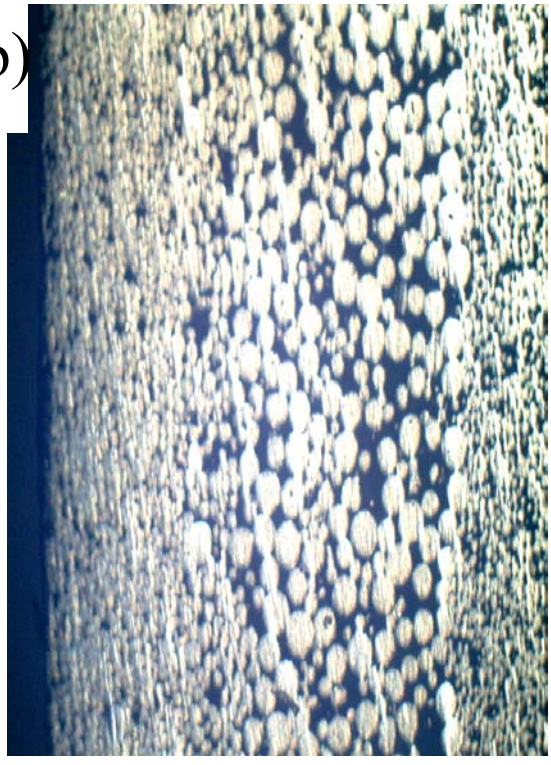




a)



b)



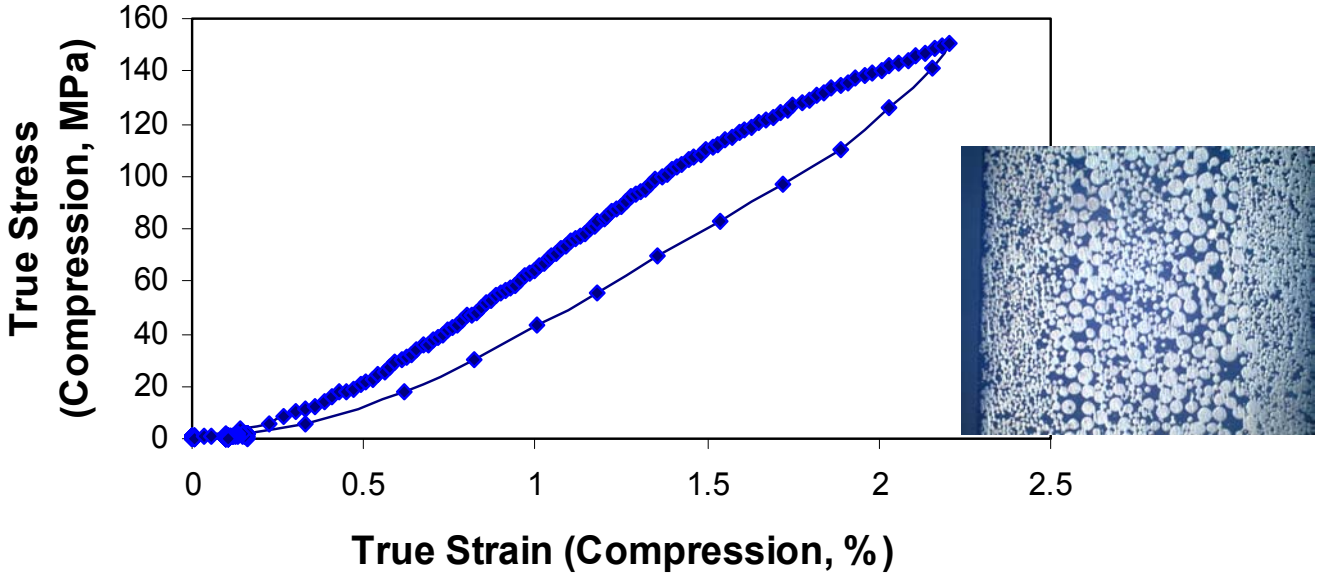
c)

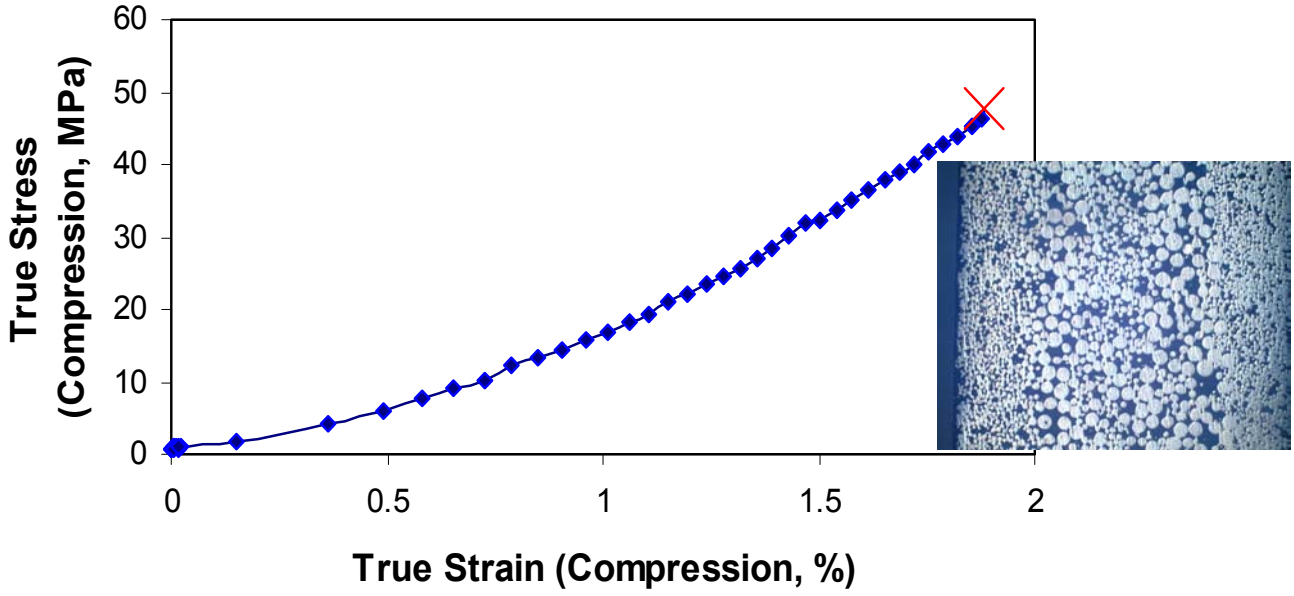
Porous graded porous structure of NiTi

a)750 °C **b)850** °C **c)950** °C

Compression Test Result of NiTi Porous Specimens of Type I

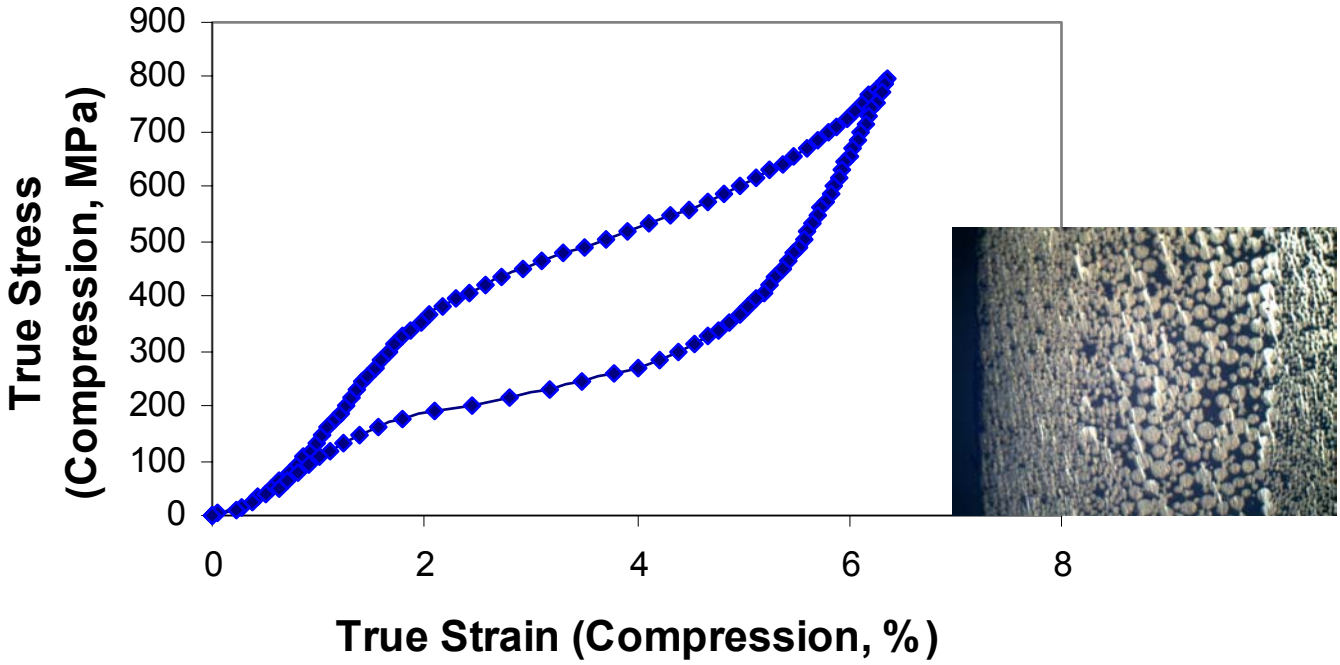
Type I: Spark plasma sintered at 750 °C *for 5 minutes with pressure of 5.1 MPa*

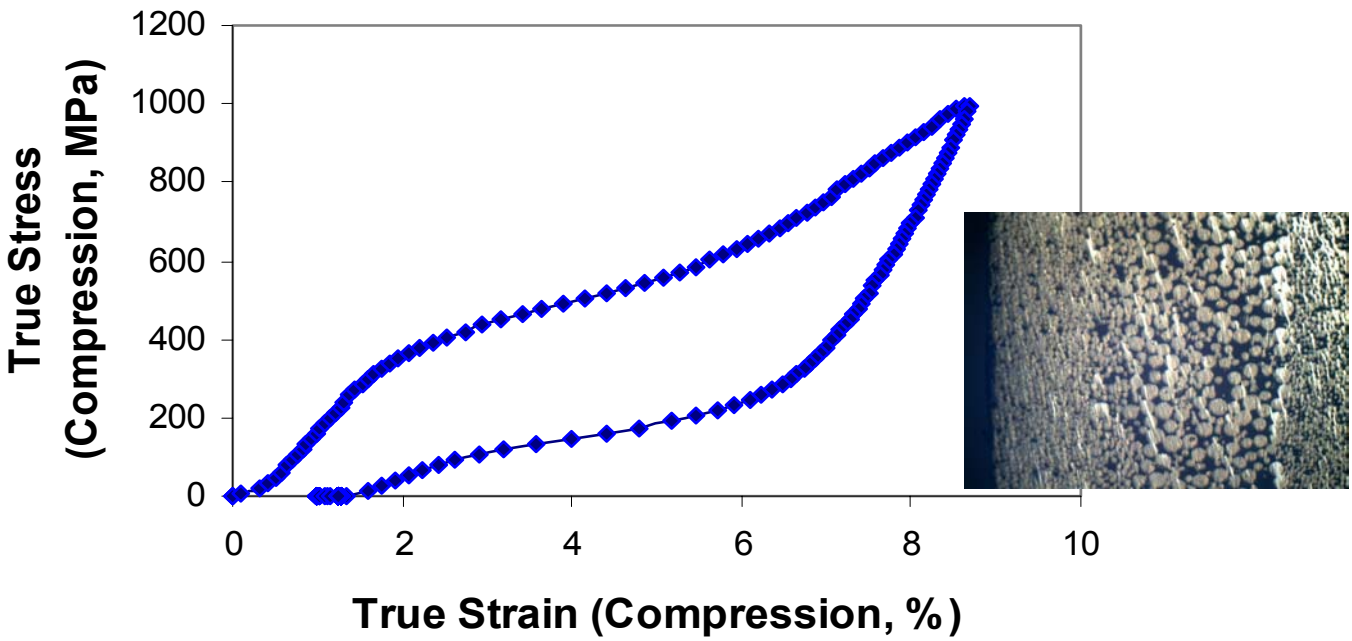




Compression Test Results of Porous NiTi Specimens of Type II

Type I: Spark plasma sintered at 800°C *for 5 minutes with pressure of 25MPa*





Summary

• Different porosity of NiTi specimens have been successfully produced by spark plasma sintering.

•Porous NiTi specimens exhibit superelasticity in compression test after EDM cutting and proper heat treatment

•The porous NiTi specimens sintered at 750 °C for five minutes with pressure of 5.1MPa shows nice superclasticity around 150MPa and 2.2% except one specimen crashed around 50MPa.

•The porous specimen sintered at 800°C for five minutes with pressure of 25MPa shows nice superelasicity up to 800MPa and lower than 1000MPa and 6.42%.