Development of Kawai-type MA with SD Anvils and its Application: Equation of State of $MgSiO_3$-perovskite

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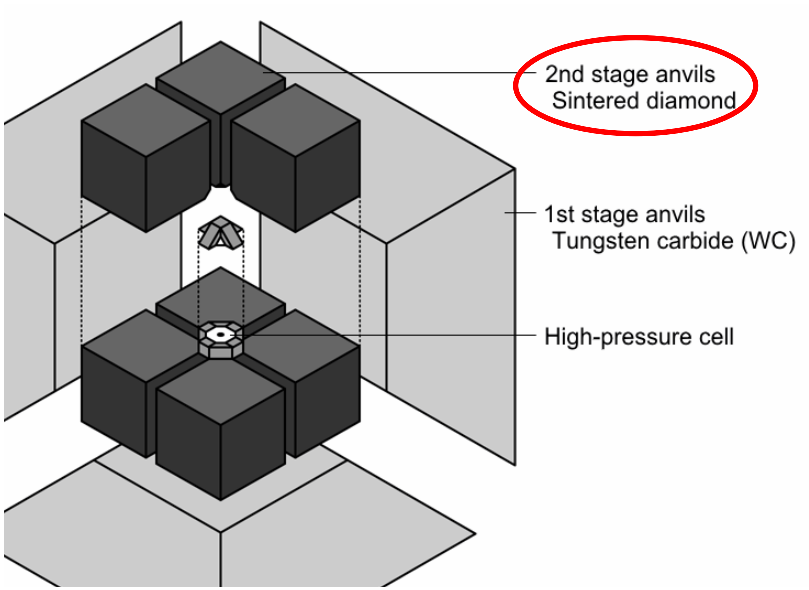
Introduction

Kawai-type (double-stage) Multi-Anvil Apparatus

Kawai and Endo (1970)



6-anvils (1st) > 8-anvils (2nd)

WC < 30 GPa

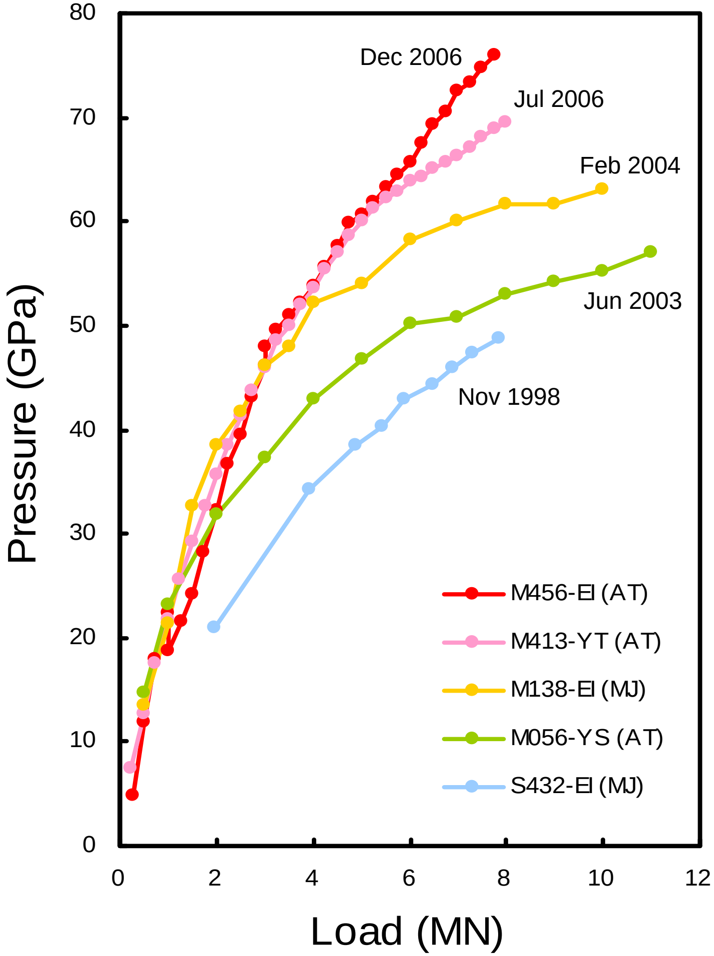
- Large sample volume
- Stabile *P*-*T* generation
  - Precise measurements
  - Sample synthesize

SPEED-Mk.II/ BL04B1, SPring-8

Katsura et al. (2004)

Introduction

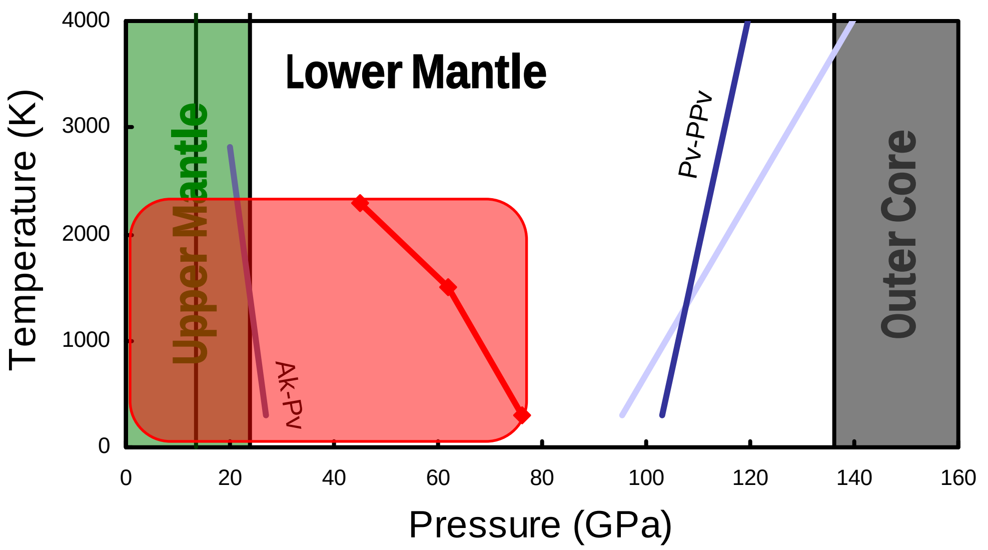
Development in High-Pressure Generation



<u>Room temperature</u>

SD anvil (14 mm cube)
TEL = 1.5 mm

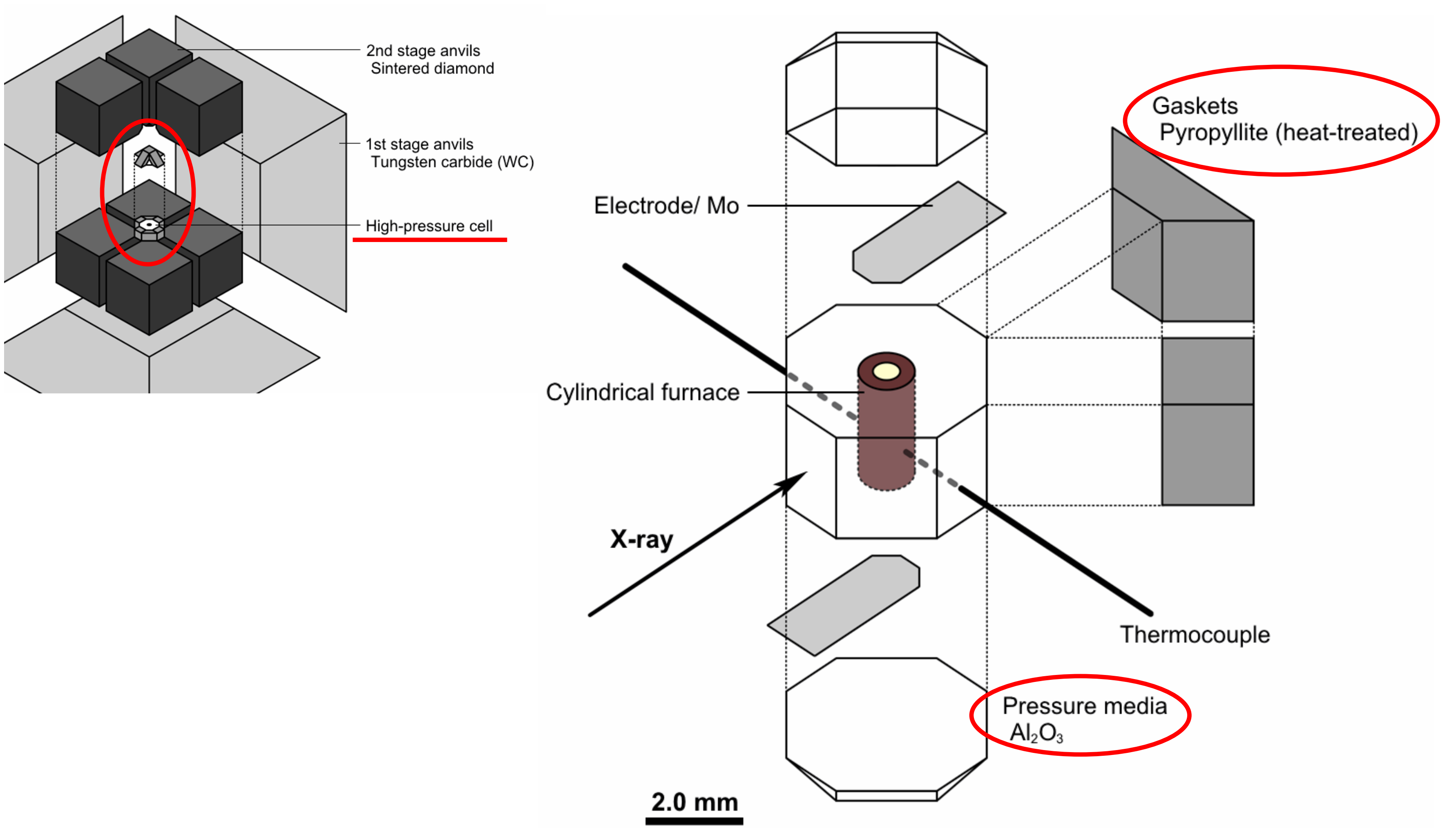
MJ: MgO/ Jamieson et al. (1998)
AT: Au/ Tsuchiya (2003)



Ak-Pv: Hirose et al. (2001)/ AT
Pv-PPv: Hirose et al. (2006), dark line/ AT; pale line, MgO/ Speziale et al. (2001)

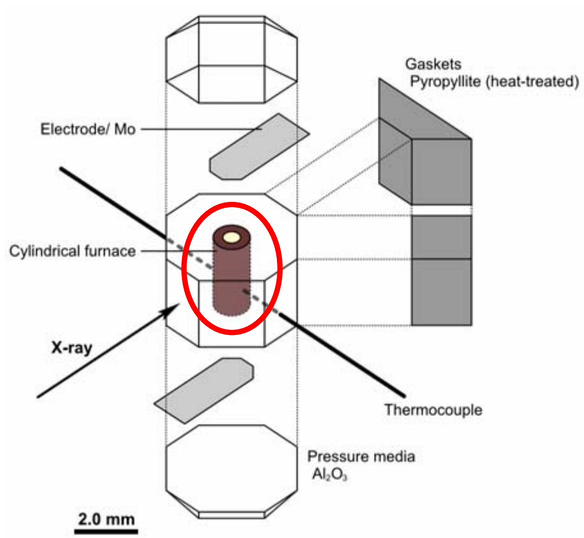
Experimental Detail

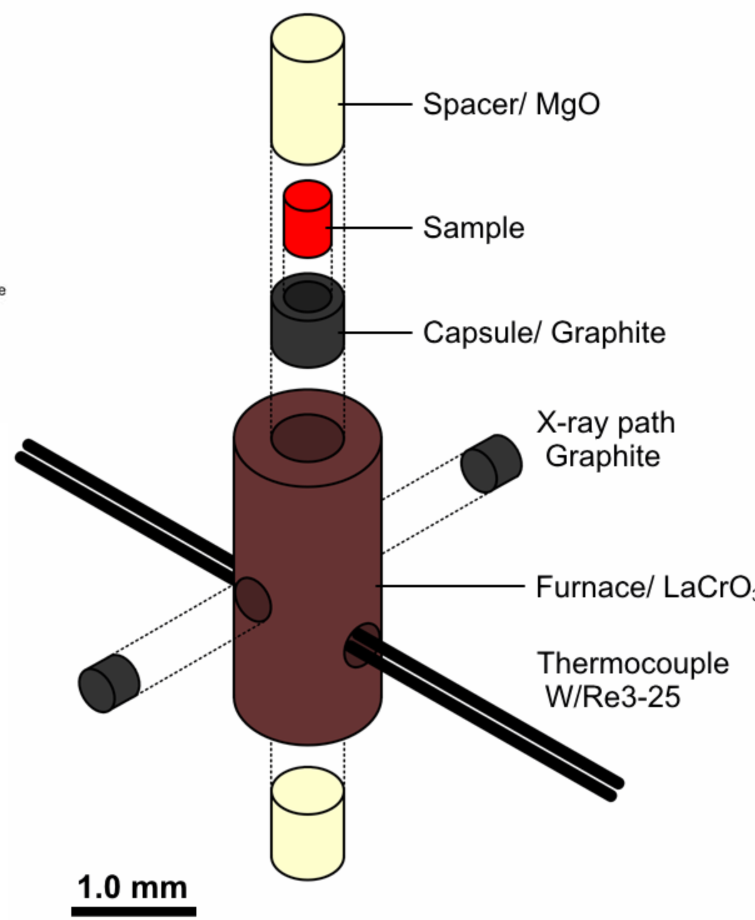
High-Pressure Cell Assembly (TEL = 1.5 mm)

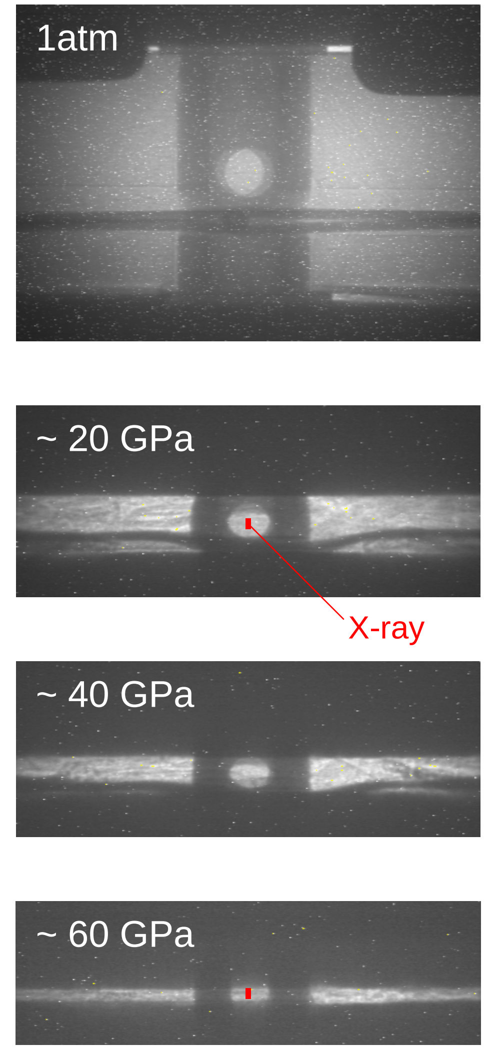


Experimental Detail

High-Pressure Cell Assembly

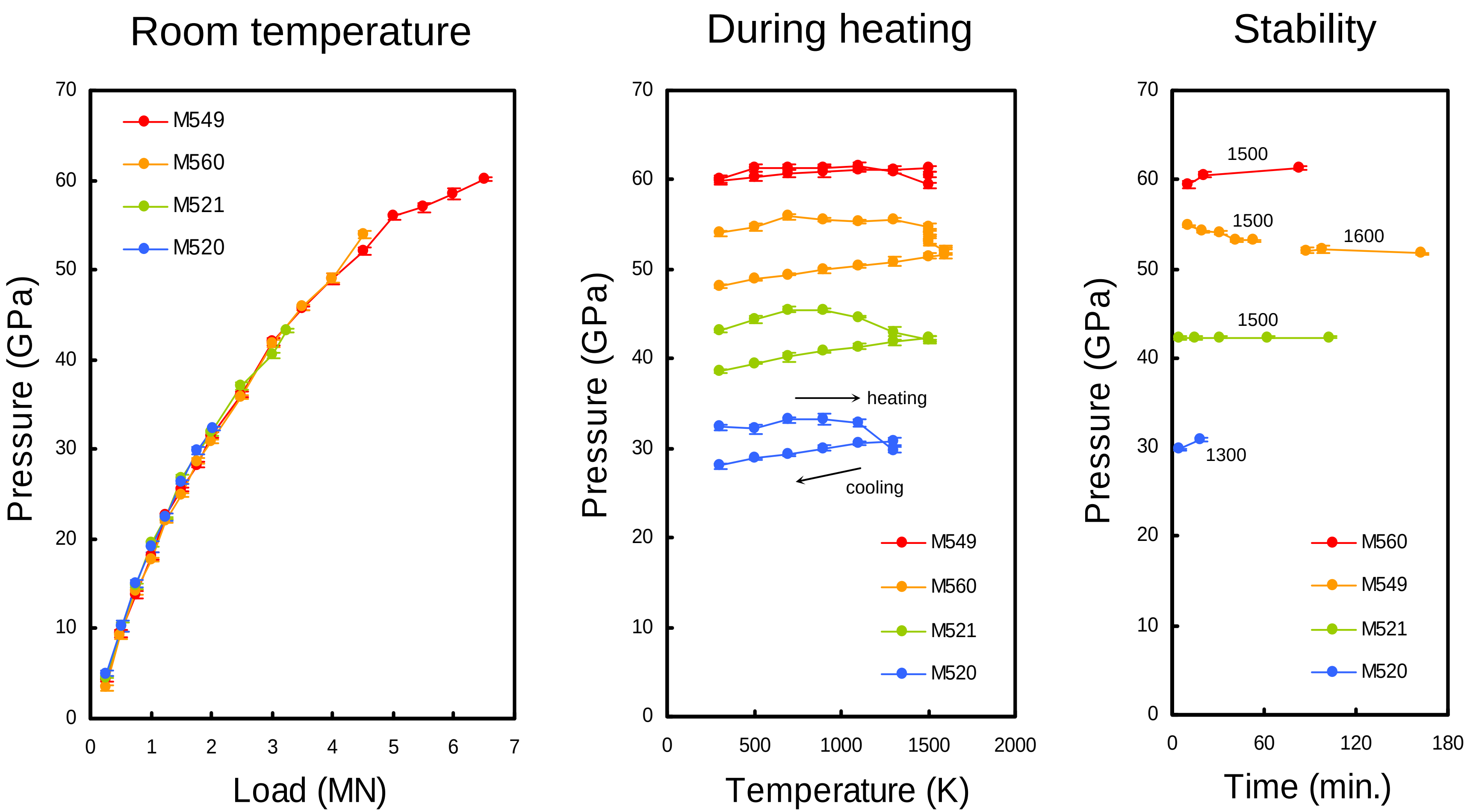






Experimental Detail

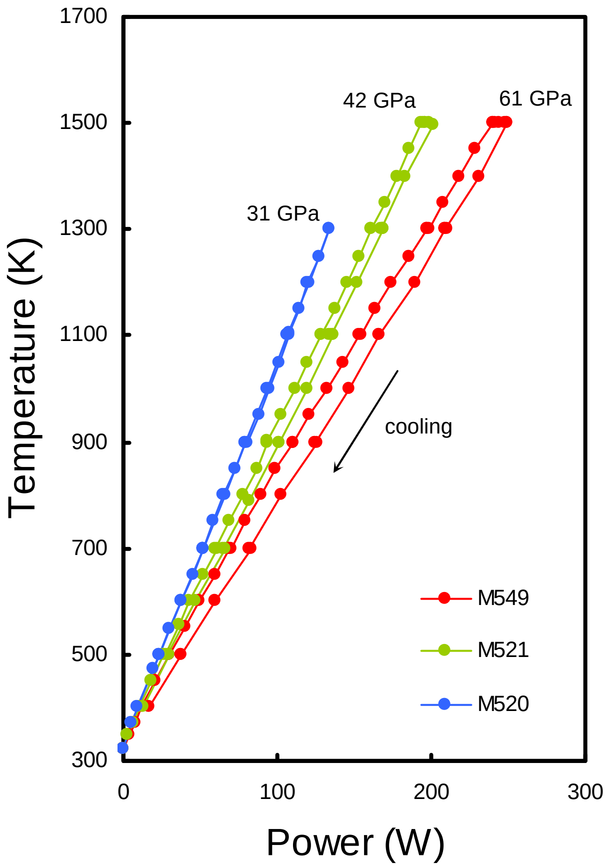
High-Pressure Generation



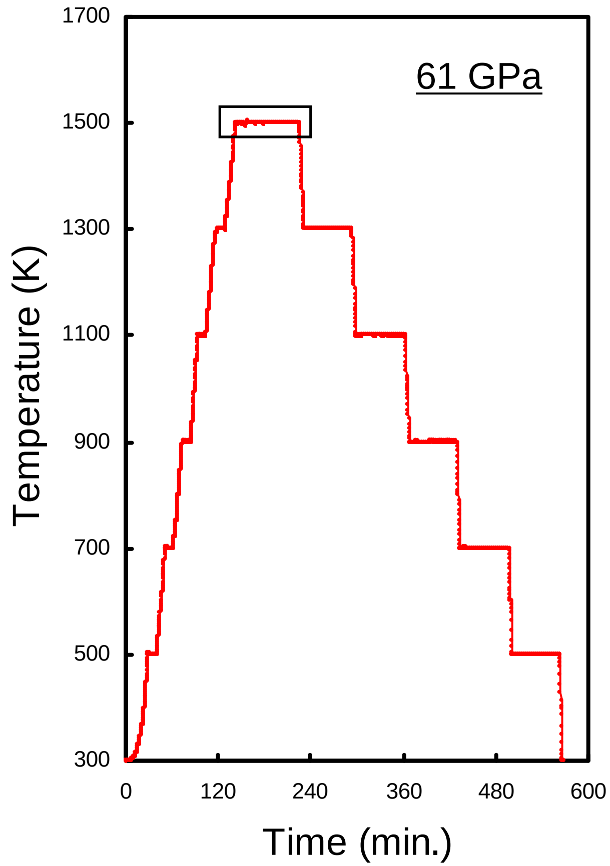
Experimental Detail

High-Temperature Generation

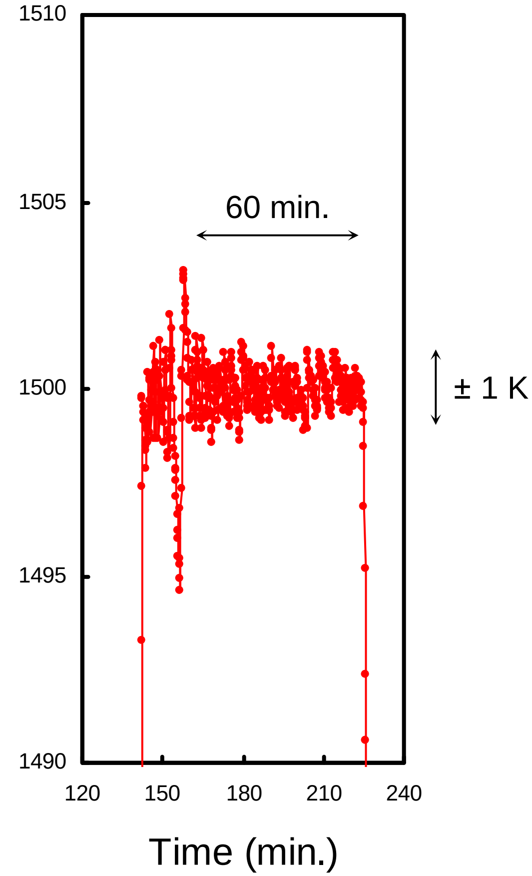
Efficiency



Heating cycle



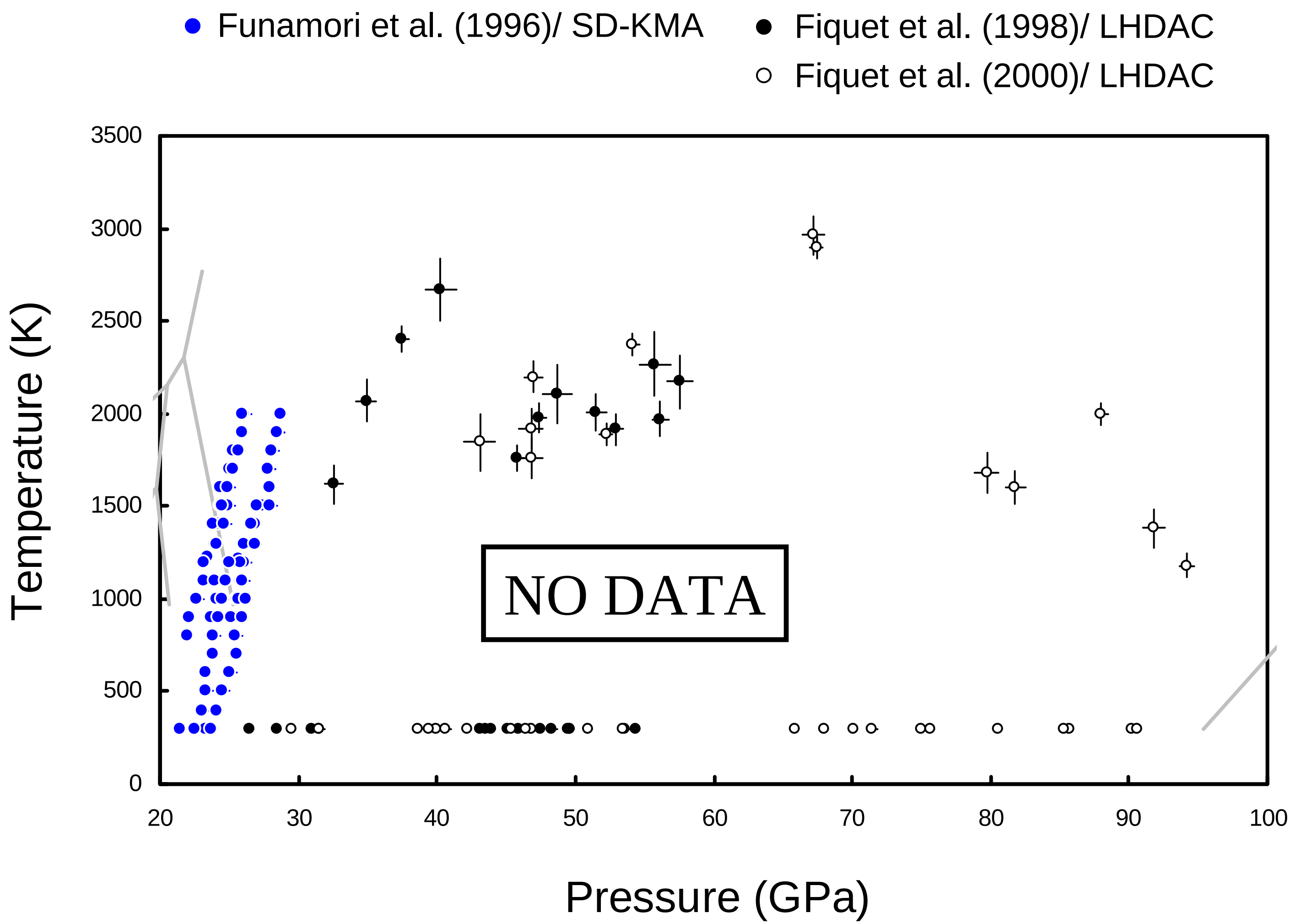
Stability



Equation of State of $MgSiO_3$-perovskite

Introduction

Previous *P*-*V*-*T* Measurements (in the stability field)



Experimental Procedure

<u>Starting material</u>

Mg_2SiO_4-Forsterite

> ($MgSiO_3$-Pv + MgO) at high *P*-*T*

<u>Apparatus</u>

Kawai-type multi-anvil apparatus with SD (TEL=1.5)

P: EOS of Au, MgO

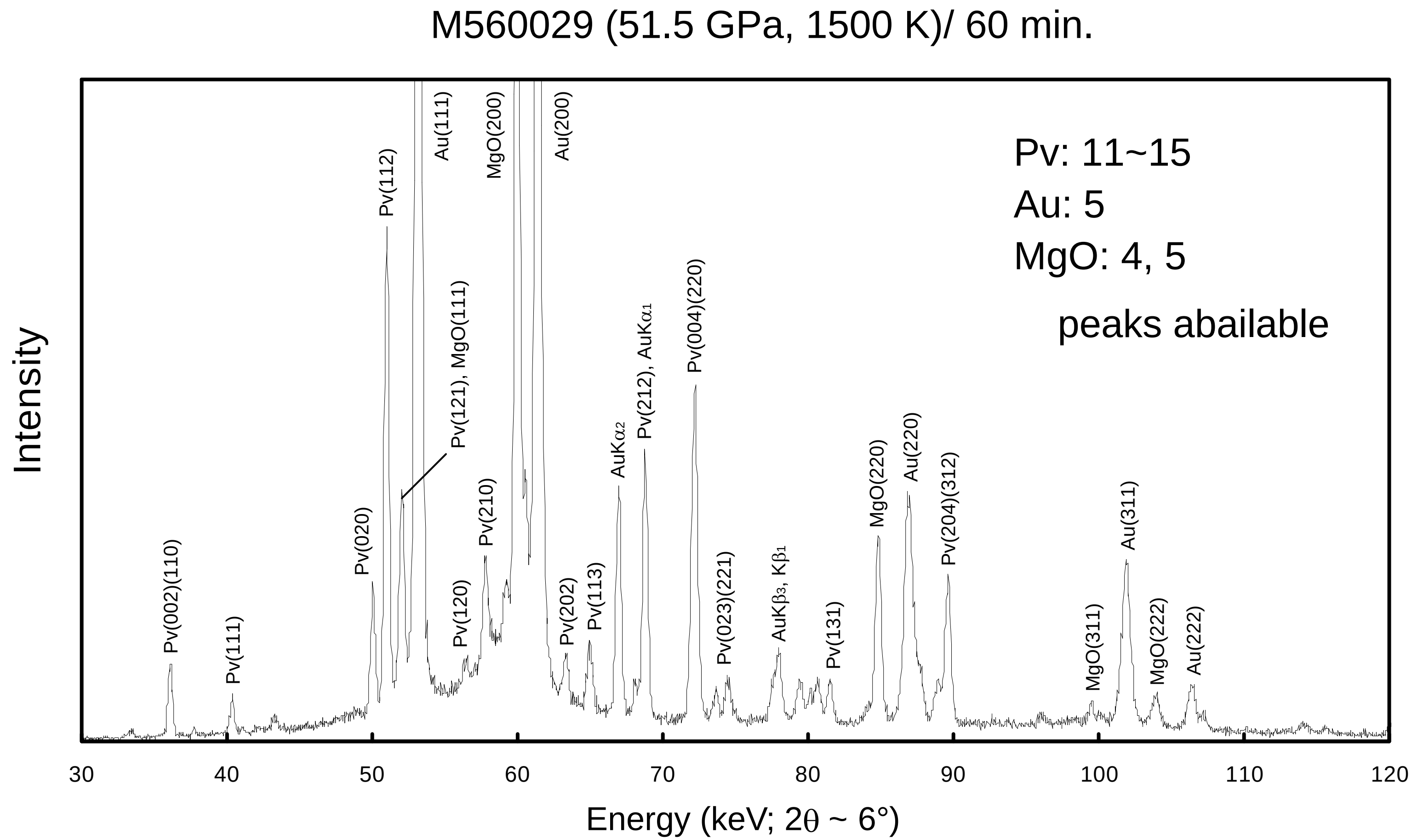
T: W/Re3-25 thermocouple

<u>In-situ X-ray diffraction measurements</u>

Energy dispersive system (BL04B1, SPring-8)

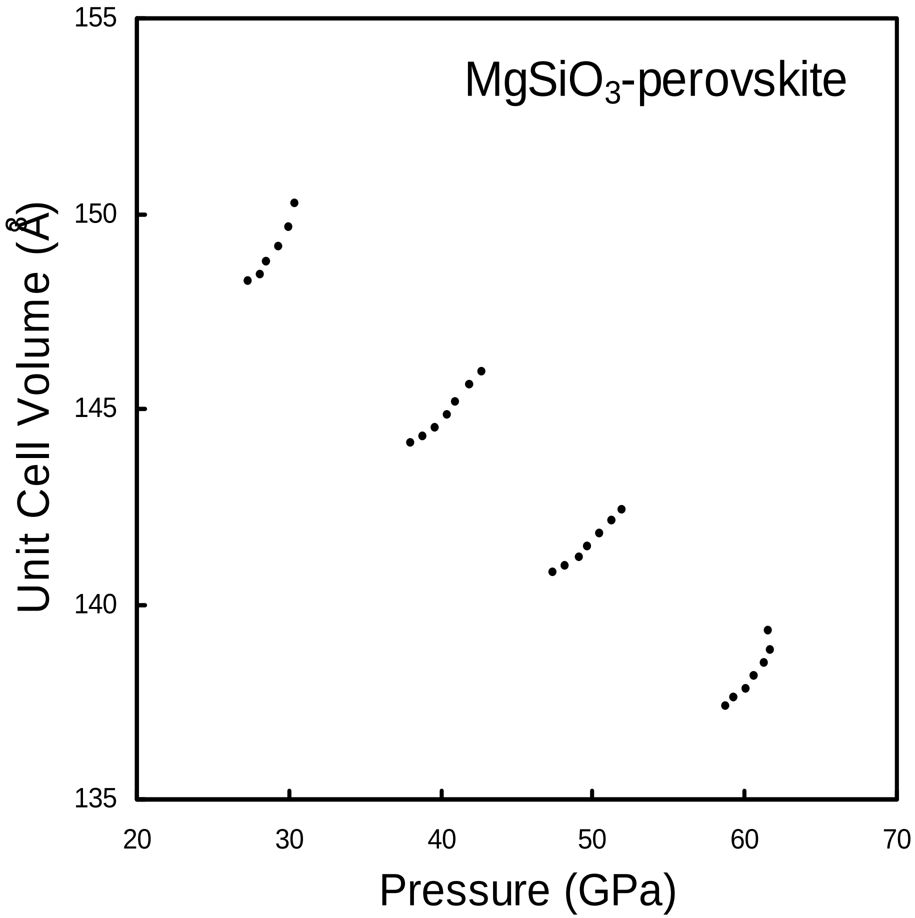
Result

Typical XRD Profile



Result

P-*V*-*T* measurements



P : 27-62 GPa

T : 300-1500 K

Errors (1σ)

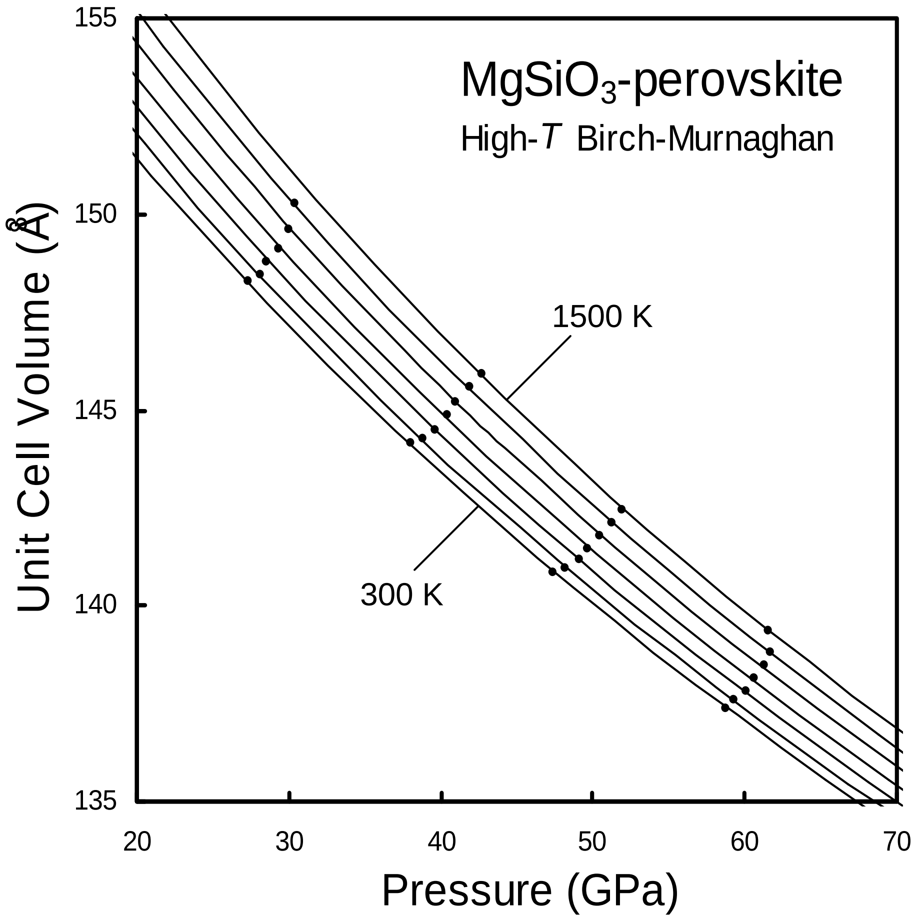
- *P* < 0.3 GPa
- *V* < 0.1 Å^3
- *T* < 1 K

P : EOS of MgO/ Speziale et al. (2001)

T : W/Re3-25 thermocouple

Result

Thermal Equation of State



Parameters	This study (MS)
V_0 (Å^3)	162.35 (fixed)
K_{T0} (GPa)	247.3(18)
K'_T	4.20(10)
$(\partial K_T/\partial T)_P$ (GPaK^{-1})	-0.030(3)
a (10^{-5}K^{-1})	2.46(14)
b (10^{-8}K^{-2})	1.05(15)
c (K)	0 (fixed)

Successfully determined 5 parameters at once

Discussion

Comparison with Previous Experiments

Parameters	This study (MS)	Fiquet et al. (2000)	Funamori et al. (1996)
V_0 (Å^3)	162.35 (fixed)	162.3 (fixed)	-
K_{T0} (GPa)	247.3(18)	259.5(9)	261 (fixed)
K'_T	4.20(10)	3.69(4)	4 (fixed)
$(\partial K_T/\partial T)_P$ (GPaK^{-1})	-0.030(3)	-0.017(2)	-0.028(3)
a (10^{-5}K^{-1})	2.46(14)	2.18(12)	1.982
b (10^{-8}K^{-2})	1.05(15)	0.11(8)	0.8(3)
c (K)	0 (fixed)	0 (fixed)	0.5 (1)

Consistent with Funamori et al. (1996)/ SD-KMA in temperature coefficients

Discussion

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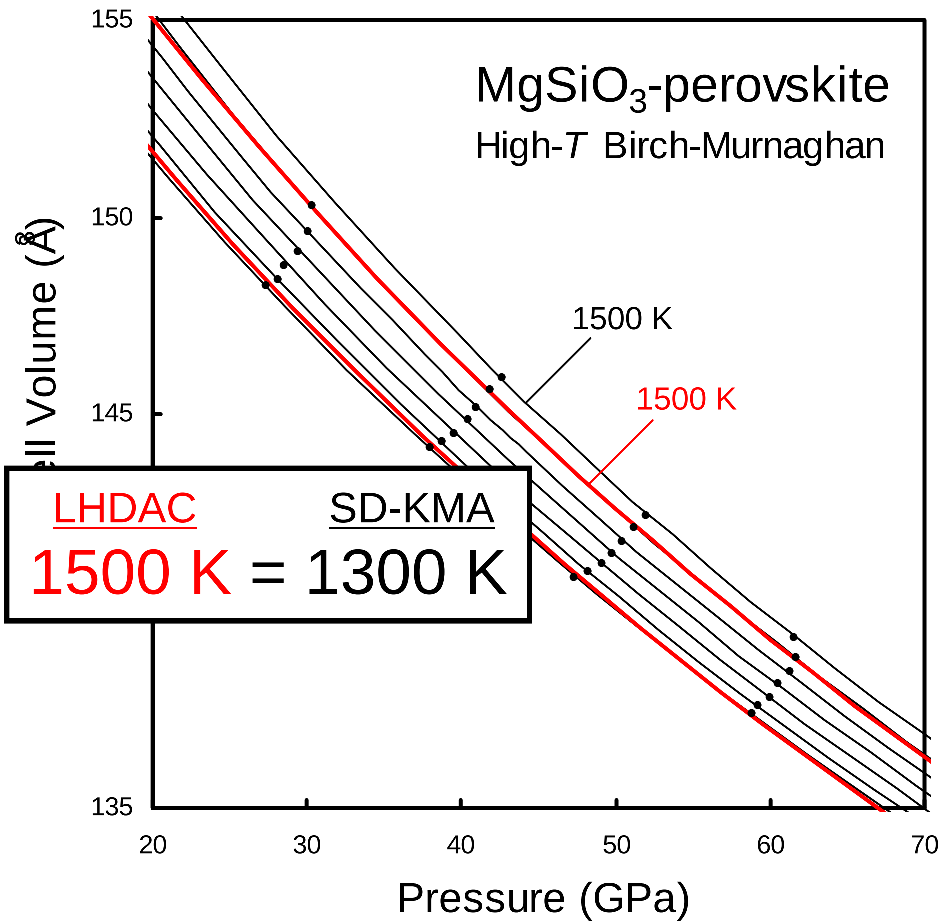
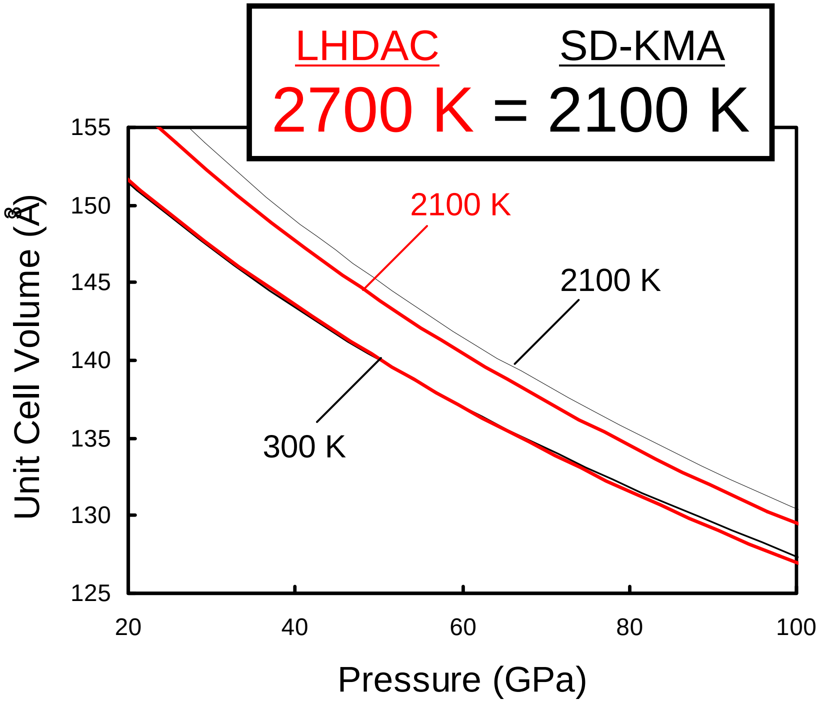
Difference in T-coefficients in K_T and α_0 between SD-KMA and LHDAC

Discussion

Comparison with Previous Experiments



Fiquet et al. (2000)
LHDAC up to 95 GPa, >2500 K
Pt/ Jamieson et al. (1984)



Summary

- SD-KMA can generate >75 GPa

  with its <u>original advantages</u>

  High stability in *P*-*T* generation

  ➢ Precise measurements

- *P*-*V*-*T* EOS of lower mantle phases

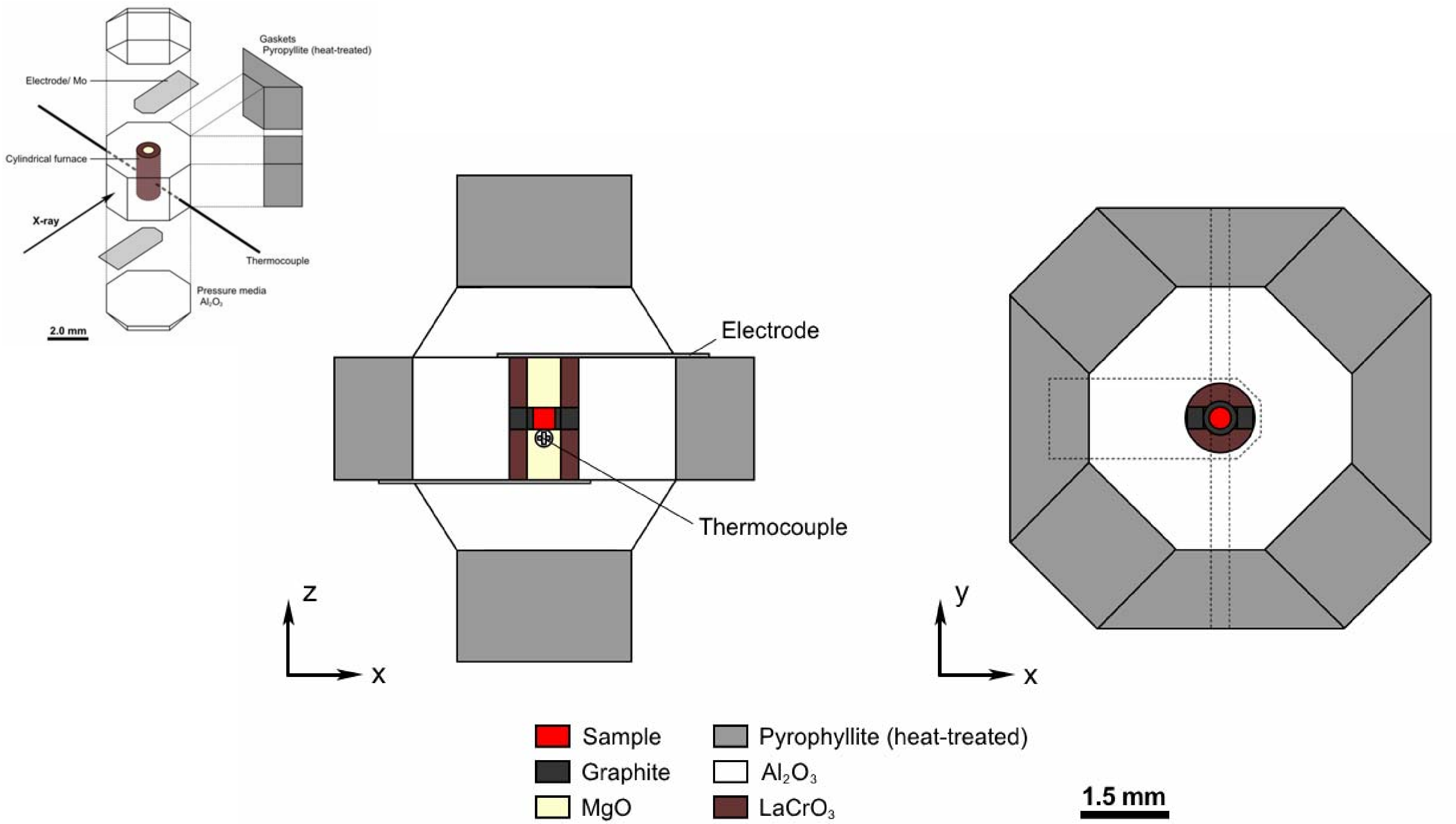
  can be determined by SD-KMA

  $MgSiO_3$-Pv has large thermal expansion

  ➢ Accelerates the thermal convection in the lower mantle

Experimental Detail

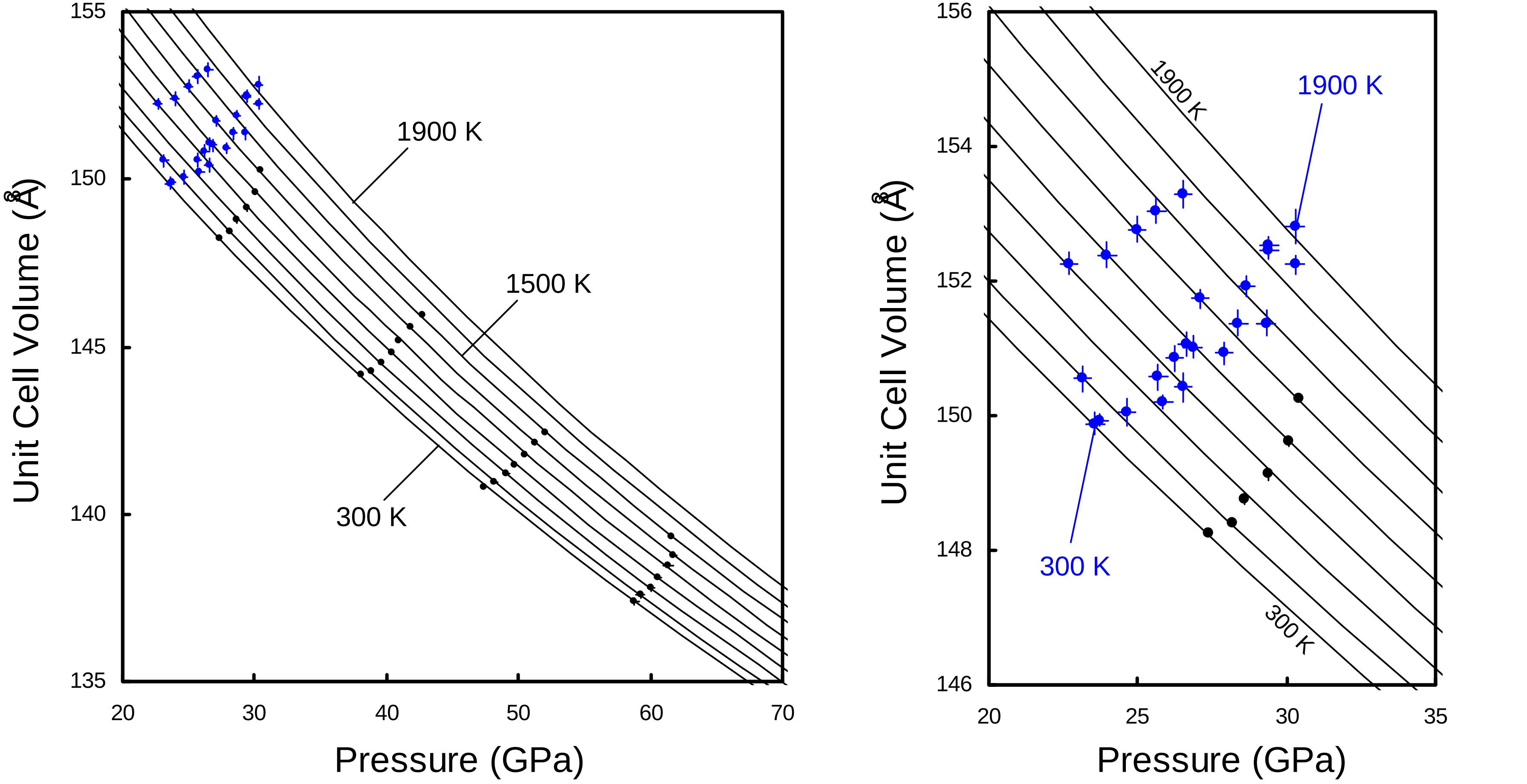
High-Pressure Cell Assembly



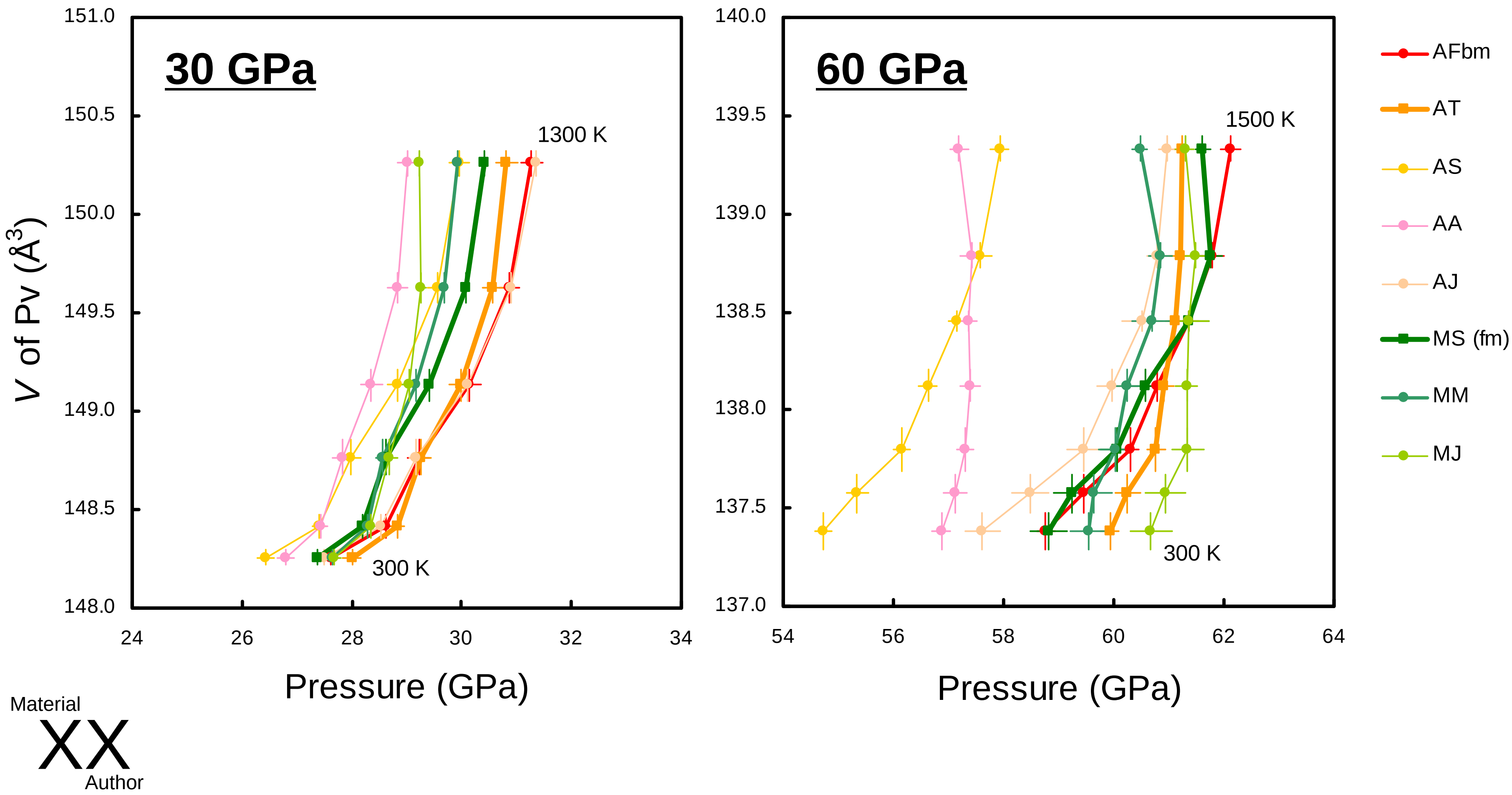
Discussion

Comparison with Previous Studies

- Funamori et al. (1996)/ KMA up to 30 GPa, 2000 K



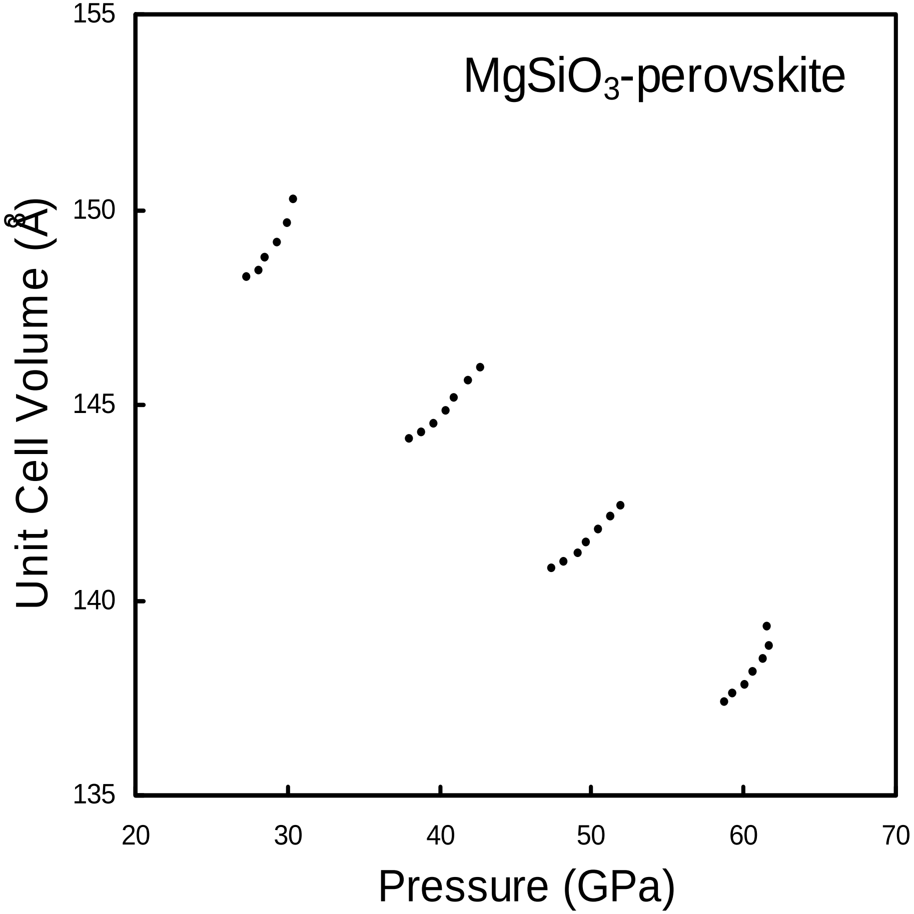
P-scale Comparison



AFbm/ Fei et al. (2007) -Birch-Murnaghan; AT/ Tsuchiya (2003); AS/ Shim et al. (2002);
AA/ Anderson et al. (1989); AJ/ Au of Jamieson et al. (1982); MS (fm)/ Speziale et al. (2001) -Fei's method;
MM/ Matsui (2000); MJ/ MgO of Jamieson et al. (1982).

Result

P-*V*-*T* measurements



High-*T* Birch-Murnaghan EOS

$$P(V,T_0)=\frac{3}{2}K_T\left[\left(\frac{V}{V_{0T}}\right)^{-7/3}-\left(\frac{V}{V_{0T}}\right)^{-5/3}\right]\left\{1-\frac{3}{4}(4-K_T')\left[\left(\frac{V}{V_{0T}}\right)^{-2/3}-1\right]\right\}$$

$$\underline{K_T'}=\left(\frac{\partial K_T}{\partial P}\right)_T$$

$$K_T=\underline{K_{T0}}+\underline{\left(\frac{\partial K_T}{\partial T}\right)_P}(T-T_0)$$

$$V_{0T}=\underline{V_0}\int_{T_0}^{T}\alpha(P_0,T)\,dT$$

$$\alpha(P_0,T)=\underline{a}+\underline{b}T-\underline{c}T^{-2}$$

Introduction

Previous *P*-*V*-*T* Measurement (in the stability field)