

## Introduction

Diffusion coefficients of silicon ( $D_{Si}$ ) in mantle minerals provide the basic understanding of rheology. Jaoul et al. (1981) and Dohmen et al. (2002) measured  $D_{Si}$  at ambient  $P$  in forsterite (Fo) and in natural olivine (Ol), respectively, providing results of ~2-3 orders of magnitude lower than that estimated from dislocation climb rates (Kohlstedt, 2006). In this study, we measured  $D_{Si}$  in dry Fo at 1600 and 1800 K, 0-13 GPa, and obtained a much higher  $D_{Si}$ , which well explains the high dislocation climb rates.

## Experimental procedure

### Sample

- Fo single crystal

### Deposition

- $Mg_2^{29}SiO_4$  thin film (300-500 nm)
- $ZrO_2$  thin film (~100 nm)

### Annealing

- Multi-anvil & ambient  $P$  furnace
- 1600 & 1800 K
- 0 – 13 GPa
- 0 – 41 hours
- “Dry” condition ( $C_{H_2O} < 1$  ppm)

### Polishing

- Reduce surface roughness

### SIMS

- Cameca 6f with  $Cs^+$  primary beam
- Depth profiling mode

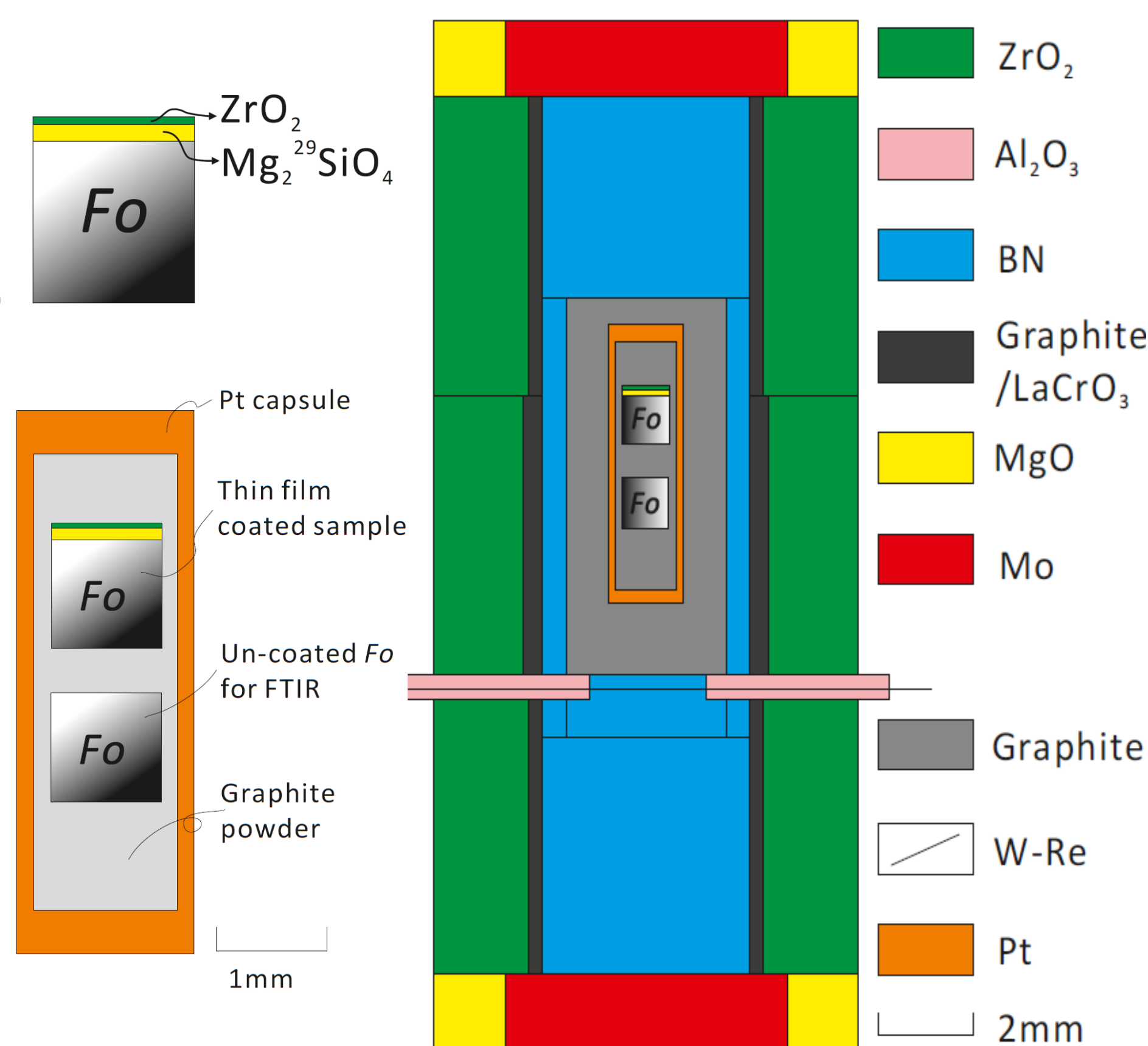


Fig. 1. coated samples and multi-anvil assembly

## Conclusions

- Negative  $P$  dependence of  $D_{Si}$  with  $\Delta V = 1.7 \pm 2.3$  cm<sup>3</sup>/mol.
- $D_{Si}$  in dry Fo at ambient  $P$  is much higher than previous studies and consistent with dislocation climb rates.
- Effect of iron, water, and structural difference of  $(Mg,Fe)_2SiO_4$  on  $D_{Si}$  is small.
- $D_{Si}$  slightly increases with depth in the upper mantle.
- $\eta$  slightly decreases or nearly constant with depth.

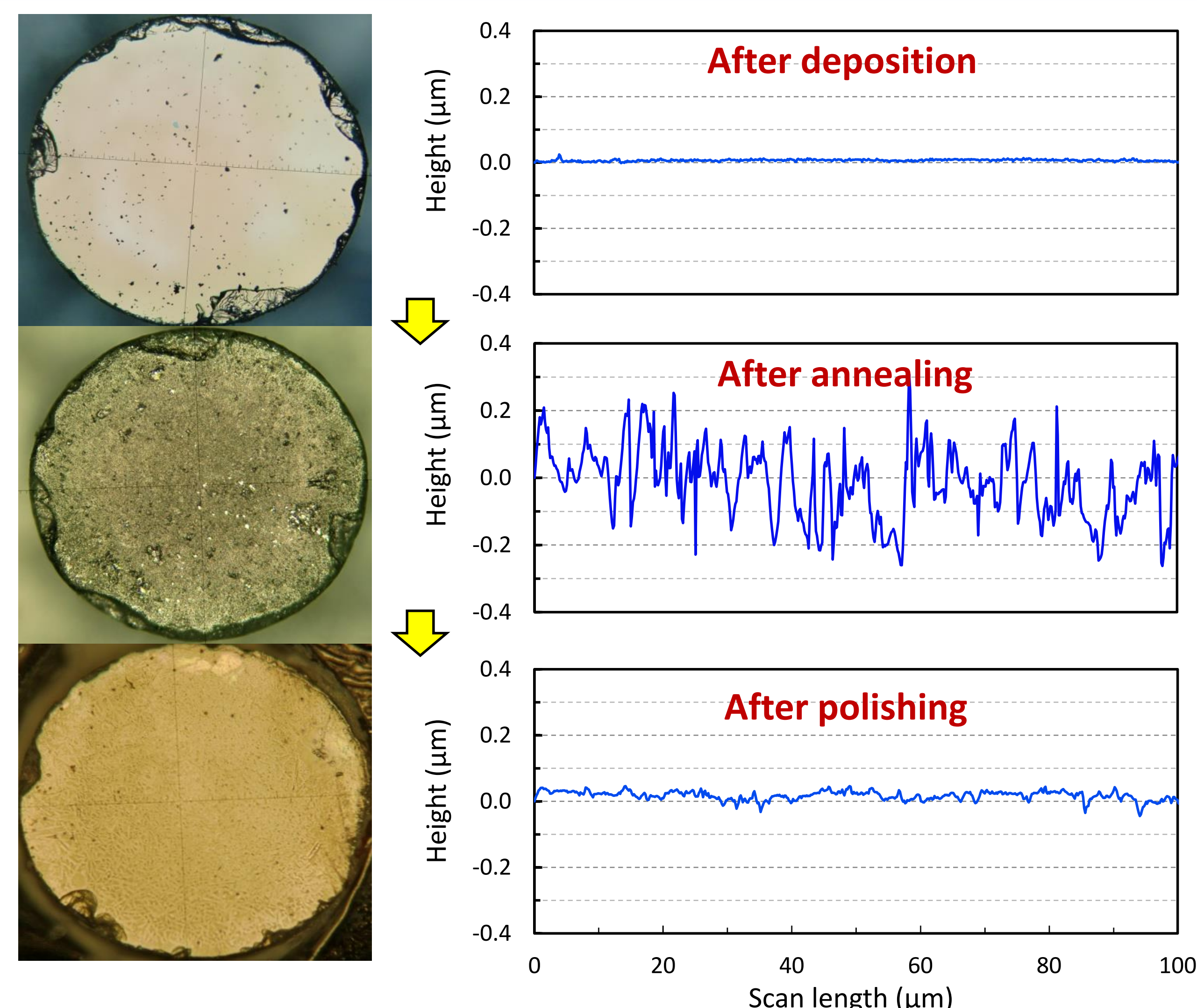


Fig. 2. surface roughness after each step

## Results

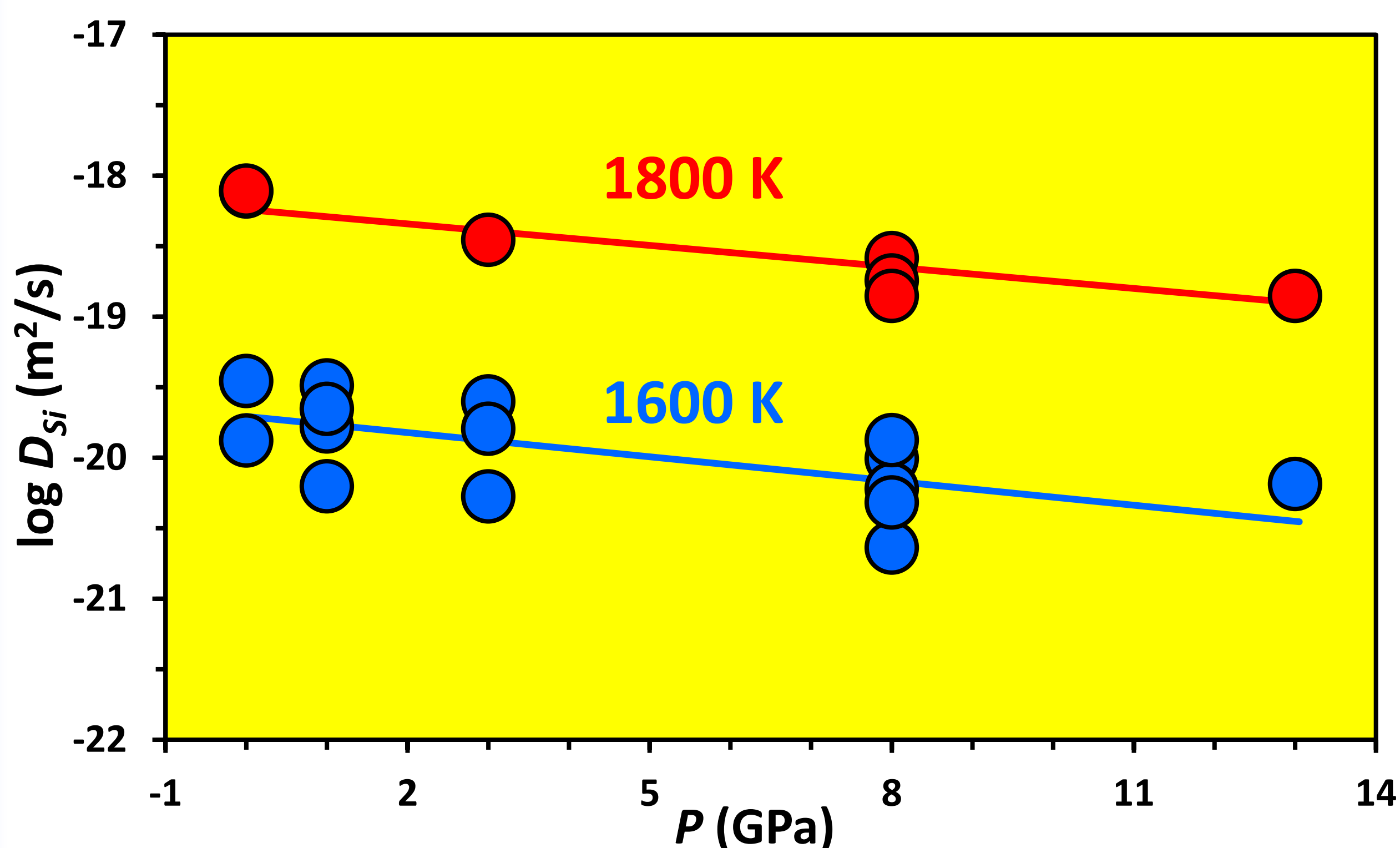


Fig. 4.  $\log D_{Si}$  with pressure

- Negative pressure dependence of  $D_{Si}$  in forsterite.
- $\Delta V = 1.7 \pm 2.3$  cm<sup>3</sup>/mol,  $\Delta E = 407 \pm 50$  kJ/mol.

## Discussion

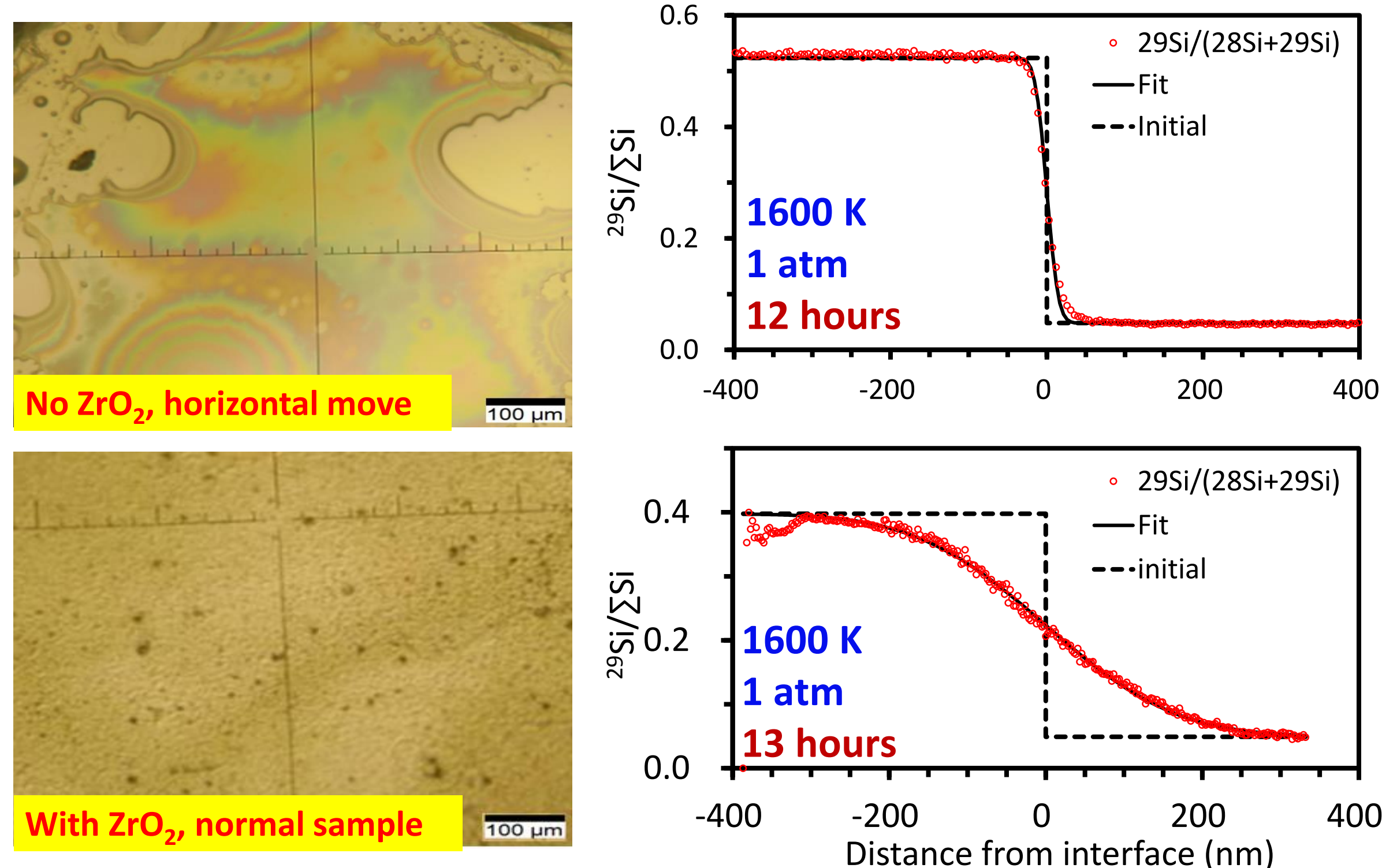


Fig. 5. Large difference of diffusion profiles none/with  $ZrO_2$

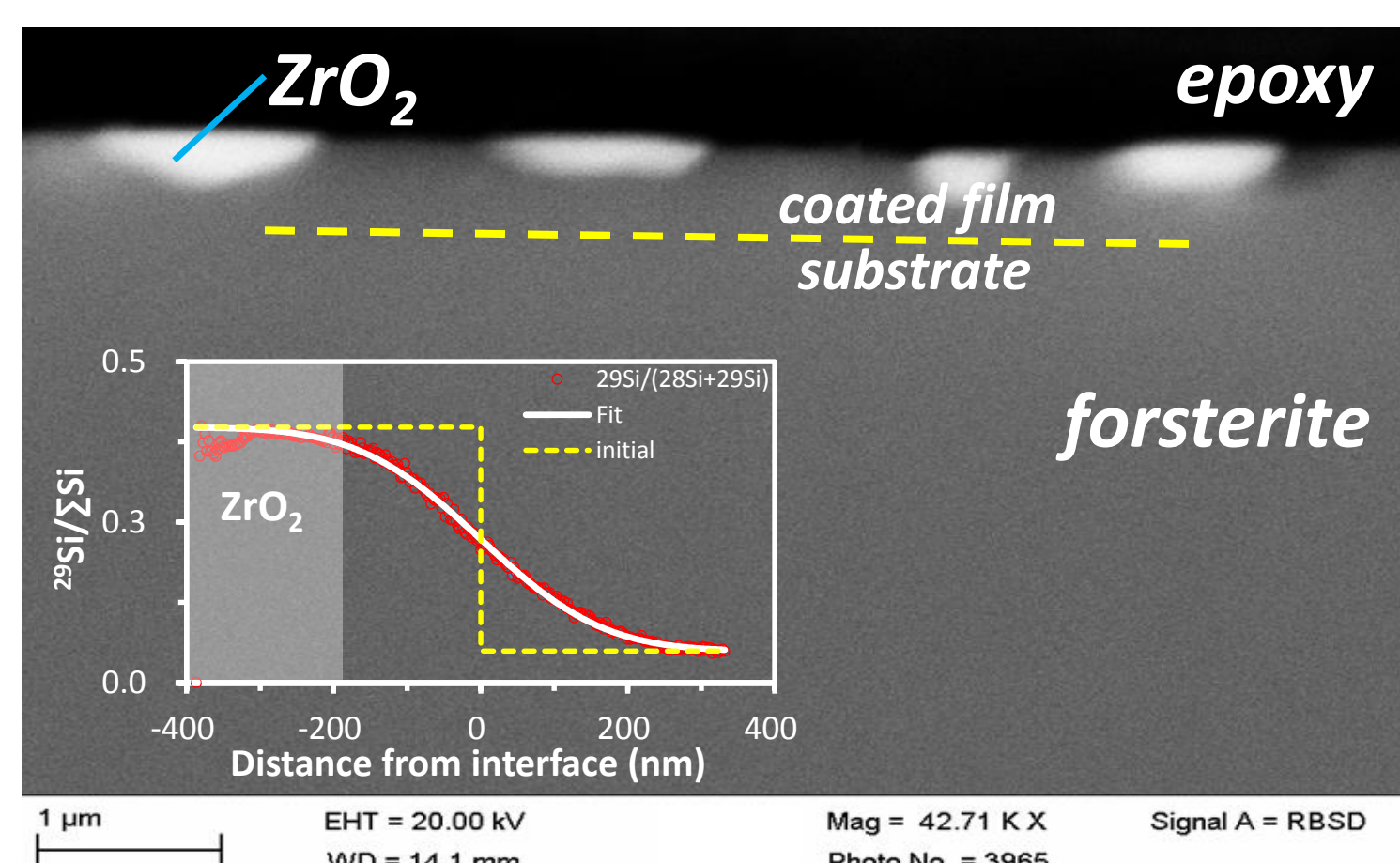


Fig. 6. SEM image of cross section

- Diffusion profile is much longer with  $ZrO_2$  than without  $ZrO_2$ .
- Without  $ZrO_2$ , large deformation of thin film caused bad contact with substrate.
- Presence of  $ZrO_2$  does not affect  $D_{Si}$  directly (Fig. 6).
- Perhaps large deformation of thin films occurred in previous studies at ambient  $P$ .

## Surface problem:

- Surface roughness largely increased after diffusion annealing (Fig.2).
- Solved by:
  - Careful polishing (in colloidal silica solution)
  - Roughness calibration with linear relationship between nominal diffusion length and roughness (Fig. 3).

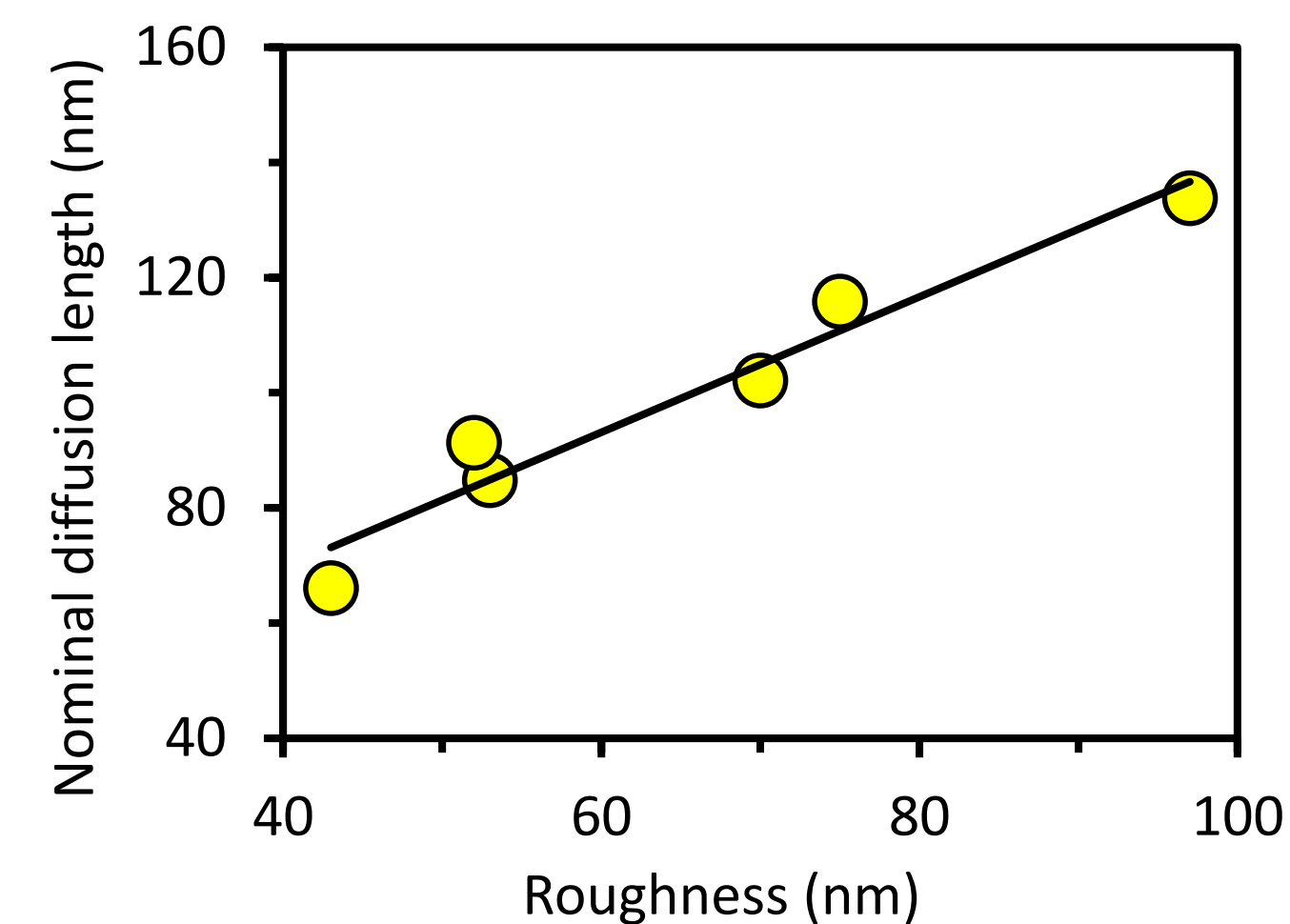


Fig. 3. nominal diffusion length in 0-time runs

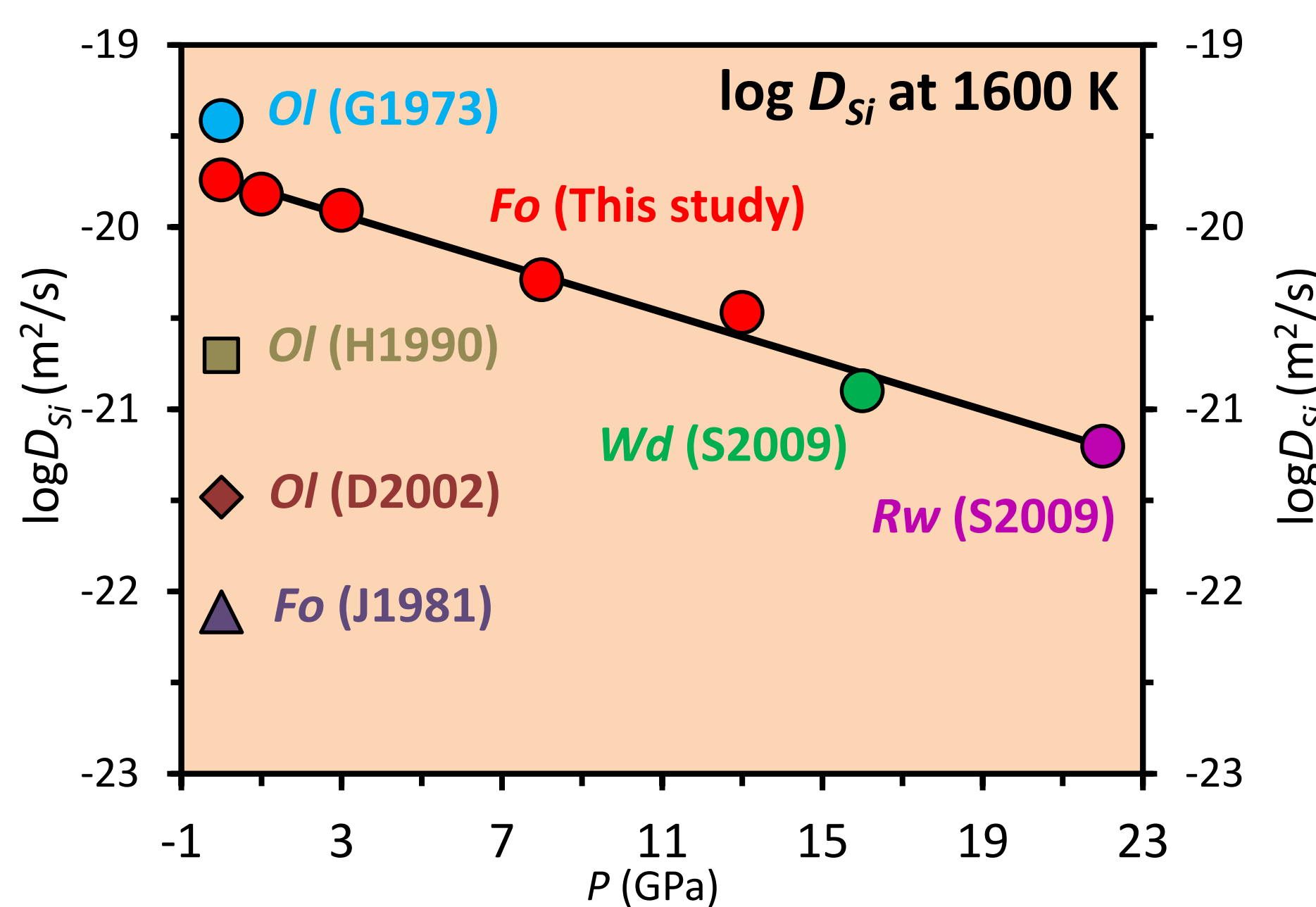


Fig. 7.  $D_{Si}$  in Fo, Ol, Wd & Rw

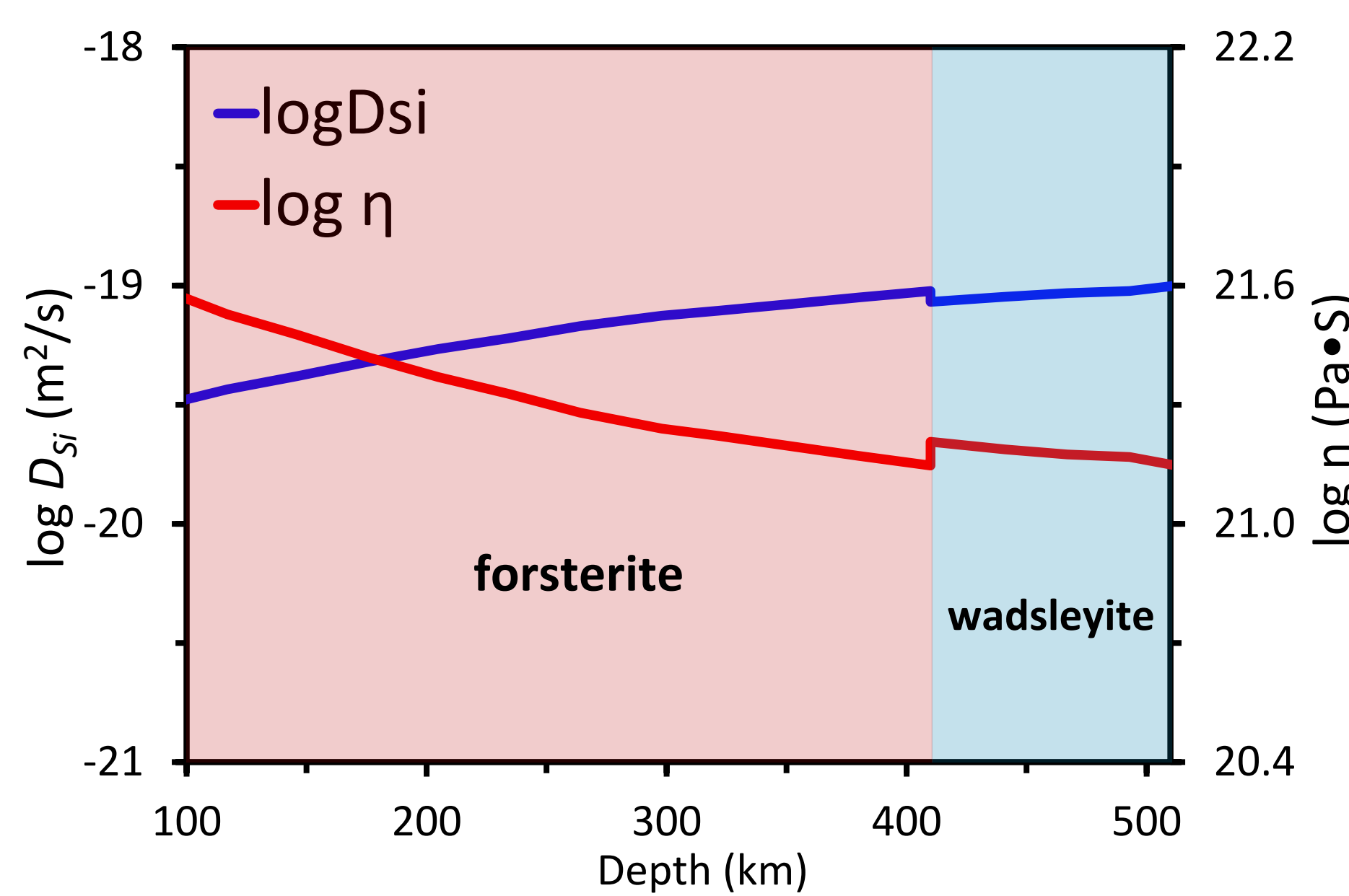


Fig. 8.  $D_{Si}$  &  $\eta$  in the upper mantle

- $D_{Si}$  in this study is much higher than previous studies at ambient  $P$ .
- Consistent with dislocation climb rate (G1973).
- Linear relationship of  $D_{Si}$  in dry Fo, iron and water bearing Wd and Rw.
- Effect of iron, water, and structural difference of  $(Mg,Fe)_2SiO_4$  on  $D_{Si}$  is small.
- $D_{Si}$  slightly increases with depth in the upper mantle.
- $\eta$  slightly decreases or nearly constant (assuming inversely proportional to  $D_{Si}$ ).