NSP1-104

Development of UHV scanning probe microscope with external stress and strain application

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Introduction

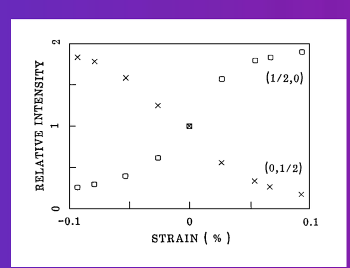
Surface stress and strain play important roles in surface reconstruction and nanostructure growth. If we can control the surface stress and strain, it may be one of the key technologies for fabrication of novel functional nanostructures. In order to understand the effect of stress/strain on the surface nanostructures, we have developed a dual probe UHV-STM with in-situ external stress/strain application capability.

Summary

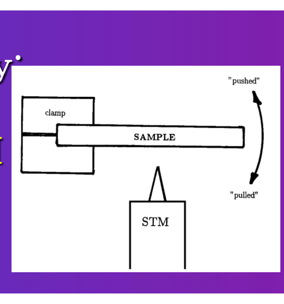
Si(100) surface was selected as a suitable model system to clarify the performance of our stress-applicable UHV Dual-probe STM. Original vicinal Si(100) surface showed even distribution of (1×2) and (2×1) domains. At elevated temperatures, we have succeeded in in-situ observation of domain redistribution on Si(100) surface induced by applying a uni-axial stress with atomic resolution. Domains for which an applied tensile stress is directed along the dimer bond become less stable and shrink. By this way, quasi single (1×2) domain surface can be fabricated.

Historical Background

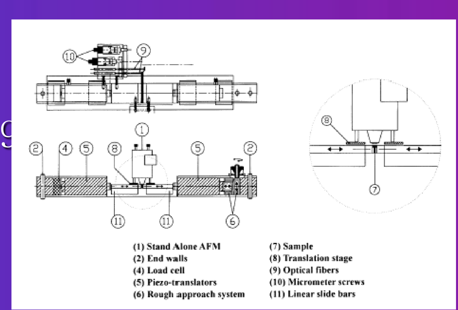
1988 Men, Packard, Webb:
Phys. Rev. Lett., 61, 2469
Si(100) Surface under an Externally Applied Stress
LEED in-situ Observation



1990 Swartzentruber, Mo, Webb, Lagally:
J. Vac. Sci. Technol. A, 8, 210
Strain Effects on Si(001) using STM
UHV-STM ex-situ observation after Stress Application

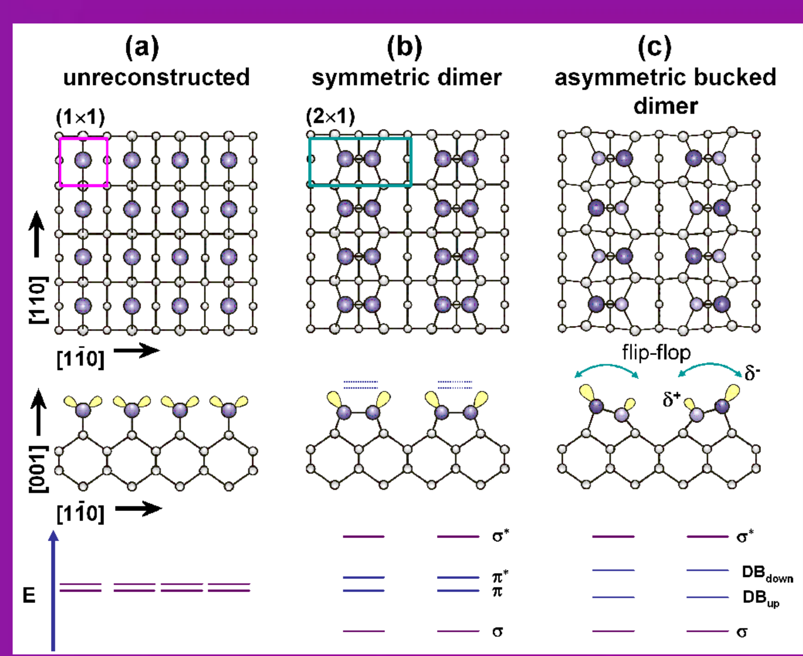


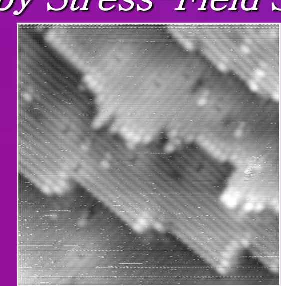
1998 Coupeau, Girard, Grilhe:
J. Vac. Sci. Technol. B, 16, 19
AFM in-situ Observations under Deformation in Air



Si(100) Model

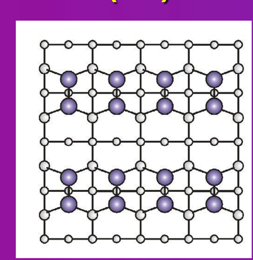
STM Image taken by Stress-Field STM





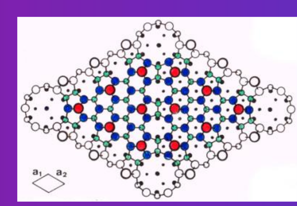
V = +0.8V, I = 120 pA

(1×2)

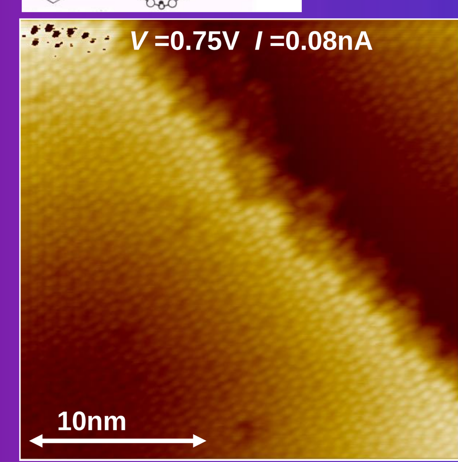


Si : $E = 1.805\times10^{11}$ N/m^2

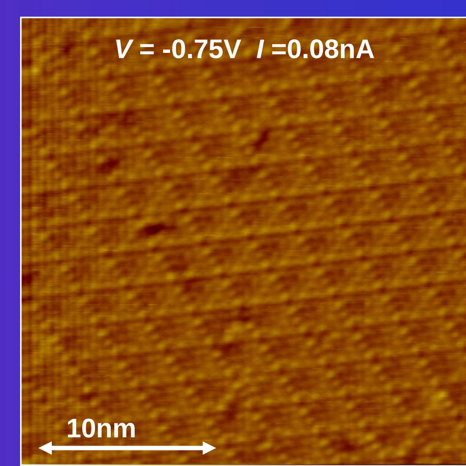
Atomic Resolution



Si(111) n-type P-doped 0.01Ωcm 250µmt
Bending Stress
(δ = 125 µm, ε = 0.155%, σ = 280 MPa)



Empty State



Filled State

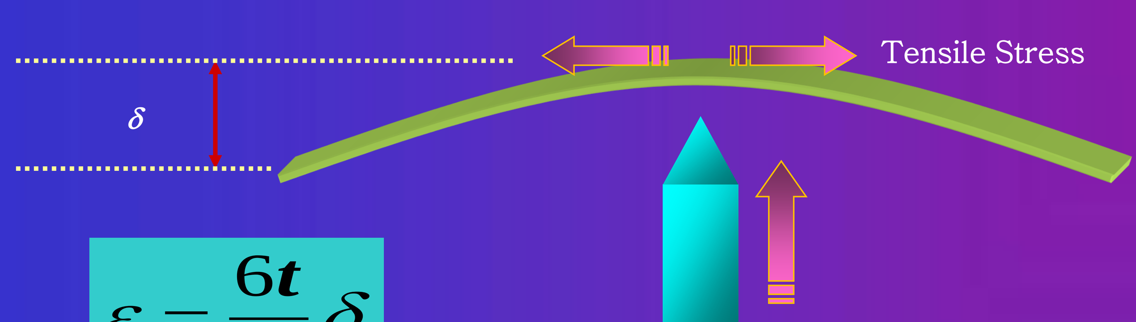
Tensile Stress σ

Purpose

Development of in-situ Stress-Field STM in UHV with Atomic Resolution Imaging

Demonstration of the Performance of the Stress-Filed STM by its Application to Double-domain Si(100) Surfaces

Material Mechanics

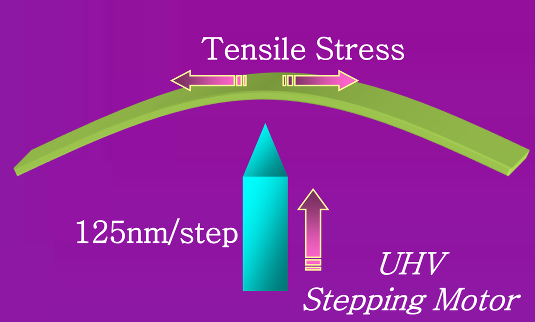


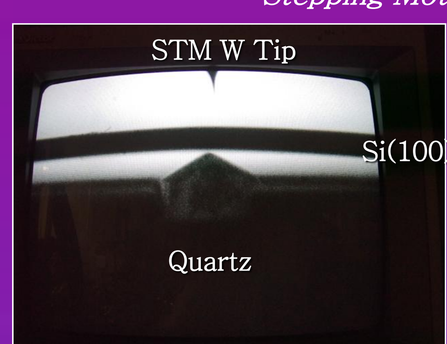
$$\varepsilon = \frac{6t}{l^2}\delta$$

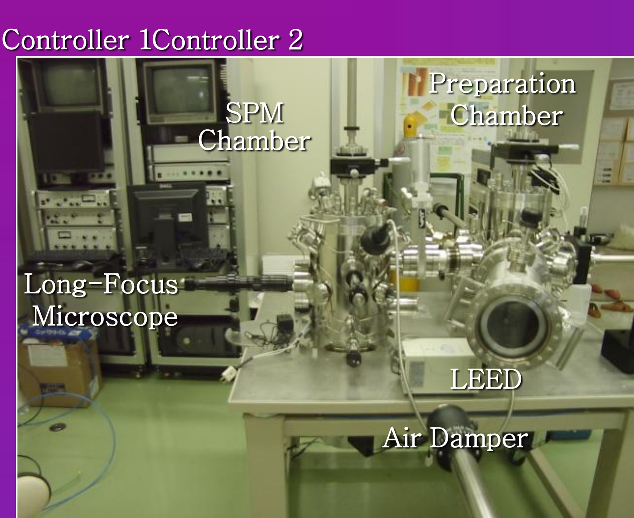
$$\sigma = \frac{6Et}{l^2}\delta$$

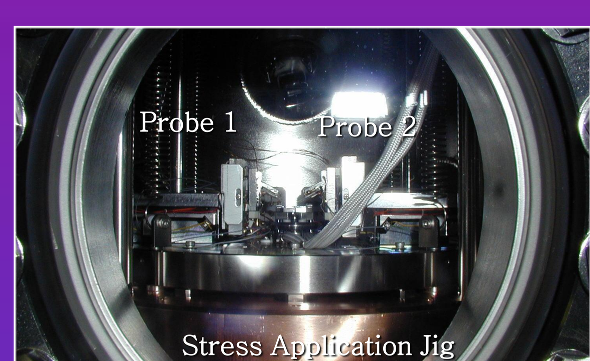
t : thickness [m]
l : length [m]
δ: deviation at the center [m]
ε: strain
σ: stress
E :Young's modulus [N/m^2]

Stress-Field SPM

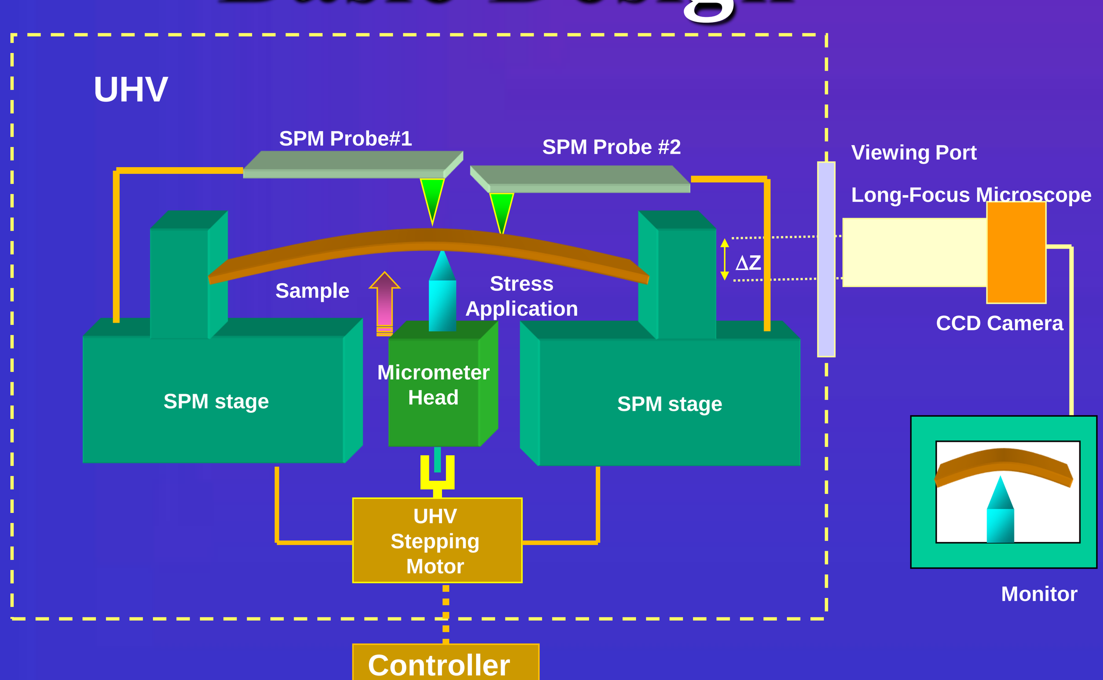


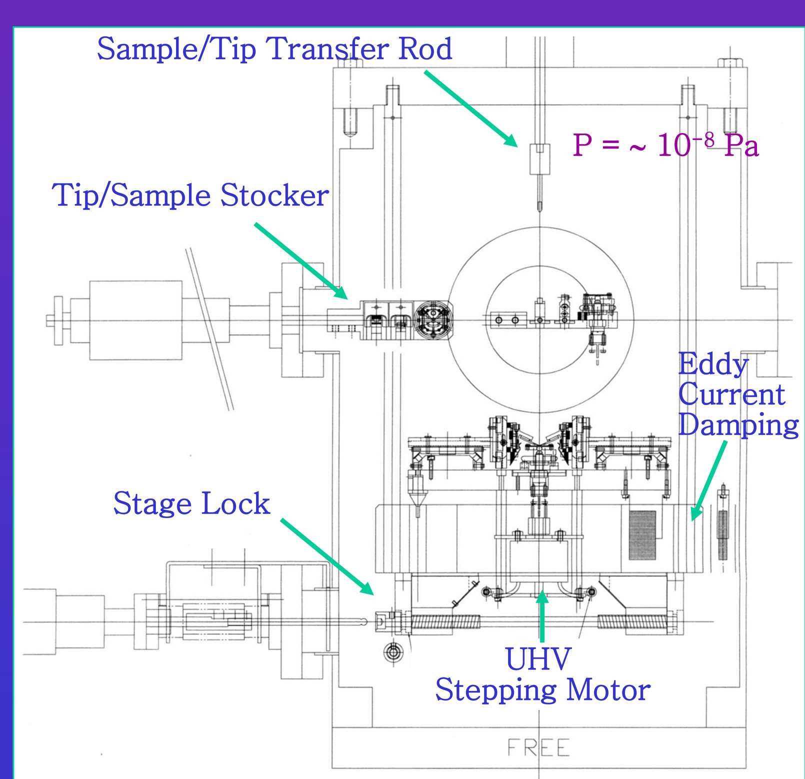






Basic Design

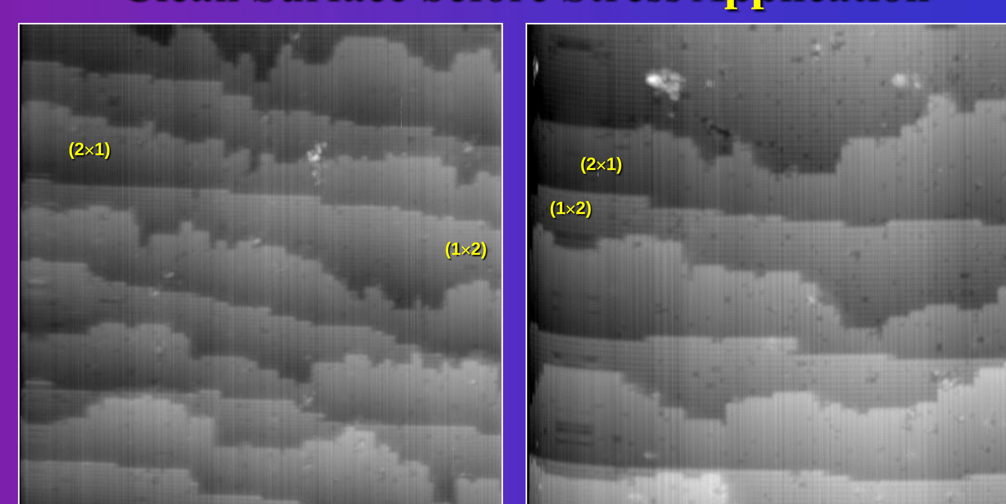




Si(100) Vicinal Surface

0.7deg. Off <110>
Si(100) n-type P-doped 0.02Ωcm 250µmt W tip at RT

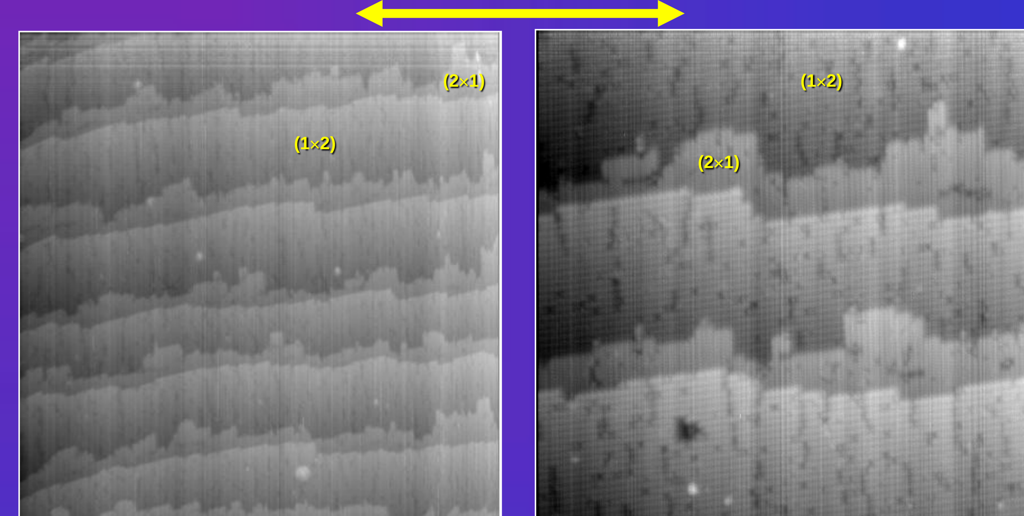
Clean Surface before Stress Application



(2×1) : (1×2) = 50% : 50%

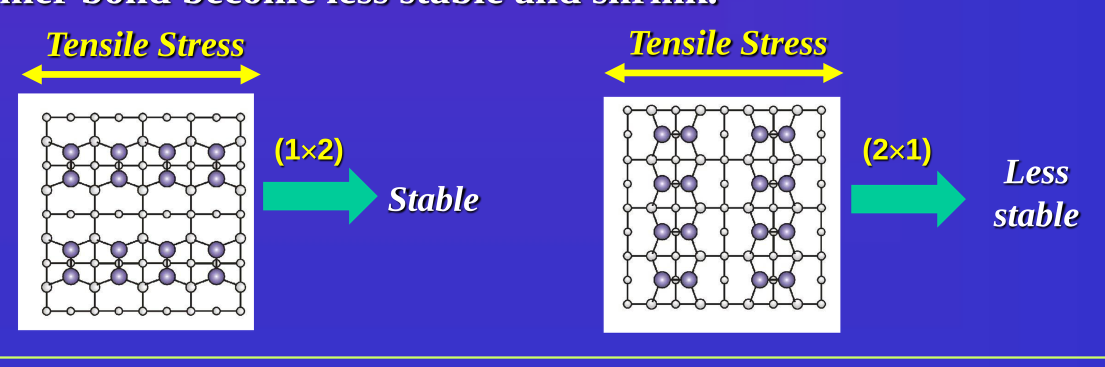
After Tensile-Stress Application

Bending Stress at ~600 deg C for 5 min.
(δ = 60 µm, ε = 0.074%, σ = 134 MPa)
Tensile Stress



(2×1) : (1×2) = 20% :80%

Domains for which an applied tensile stress is directed along the dimer bond become less stable and shrink.



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References

[1] F. K. Men, W. E. Packard, and M. B. Webb, Phys. Rev. Lett. 61, 2469 (1988)