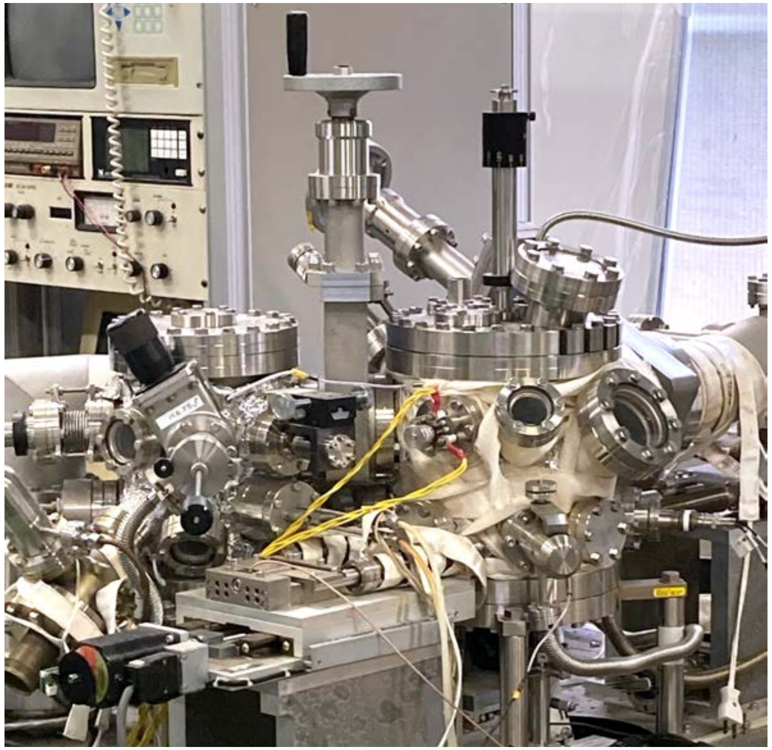
研究紹介

安藤研究室

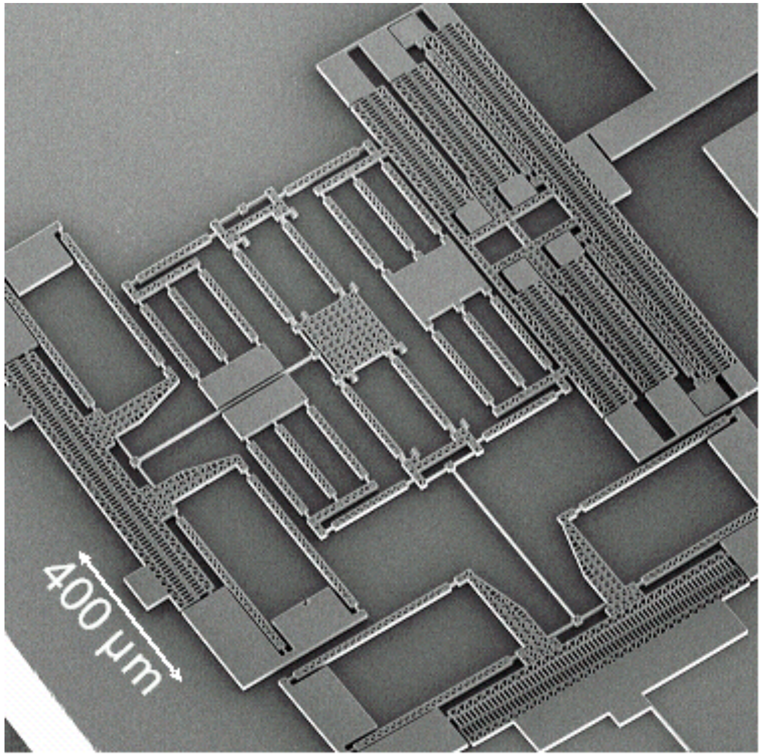
2つの主要テーマ

マイクロ／ナノトライボロジー



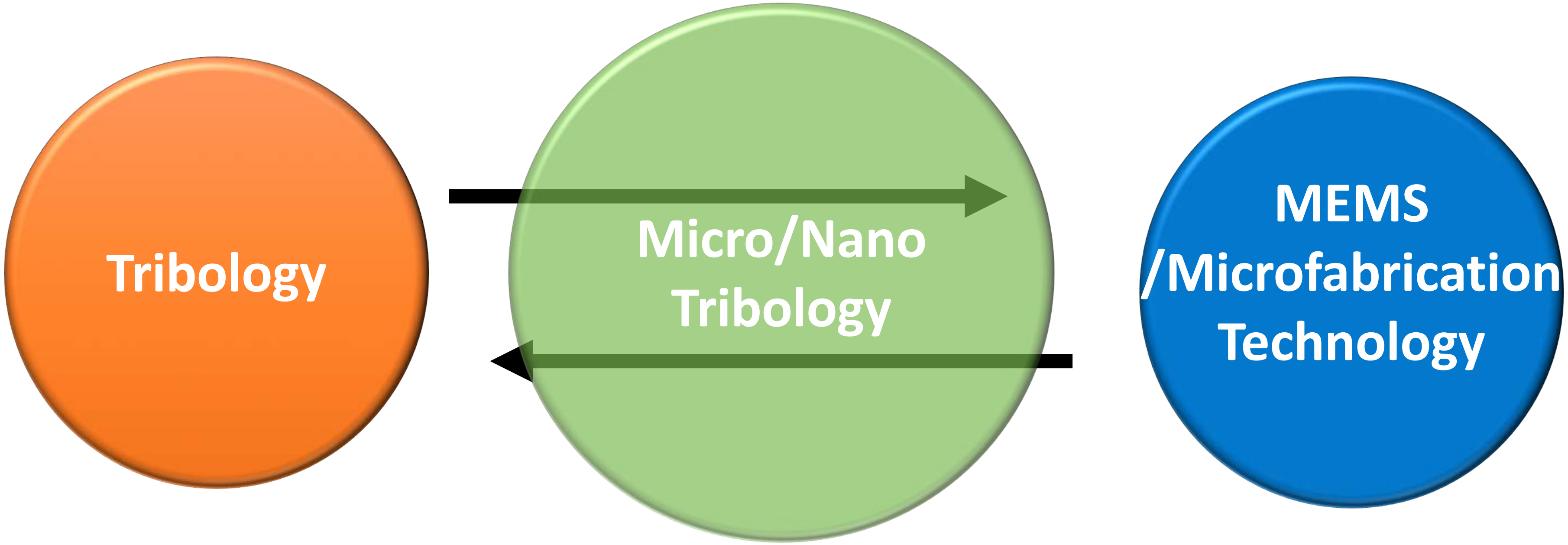
ナノストライプ表面
凝着力
AFM（原子間力顕微鏡）
マイクロ/ナノ表面パターニング
分子動力学計算
流体計算

MEMS及び関連技術



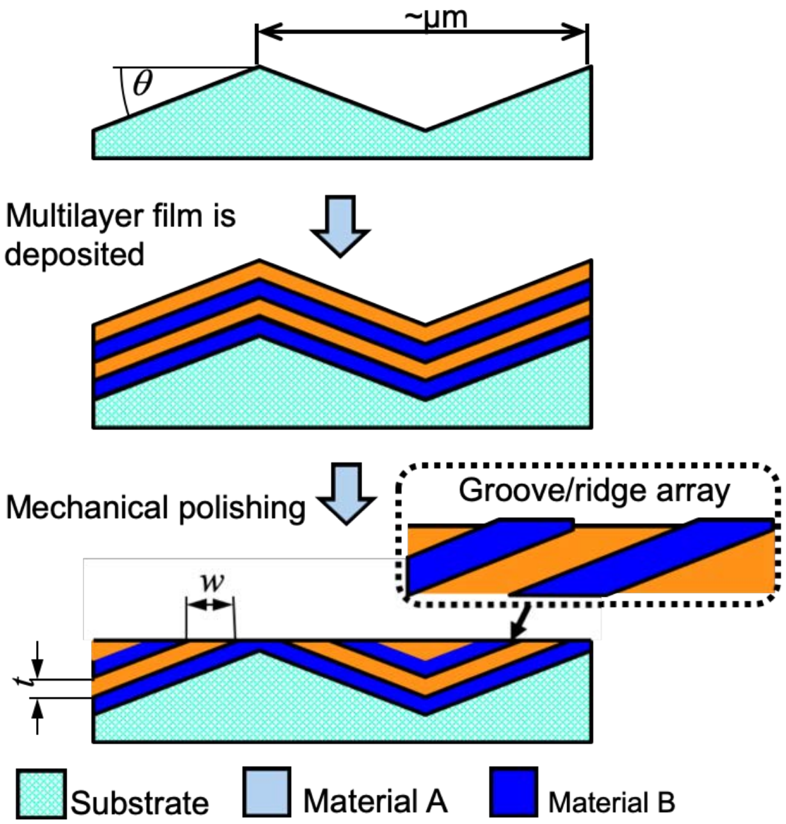
3次元マイクロステージ
AFM組み込みMEMSサンプル
フォトリソグラフィー
結晶異方性エッチング
DRIE（deep reactive ion etching）
集束イオンビーム

新しい分野創出を目指す2つの研究分野

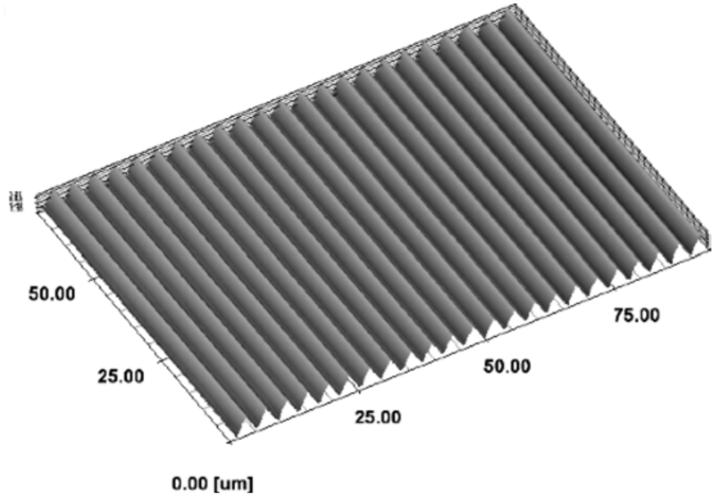


研究テーマの例

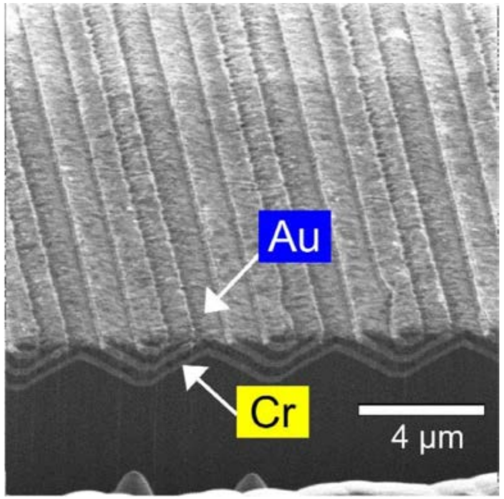
ナノストライプの加工法



ナノストライプ作製法の概要



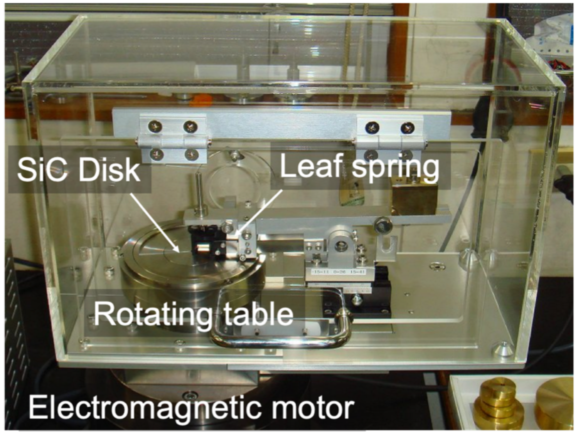
Si(100)面上に結晶異方性エッチングで作製した周期的傾斜構造（レーザ顕微鏡で計測）



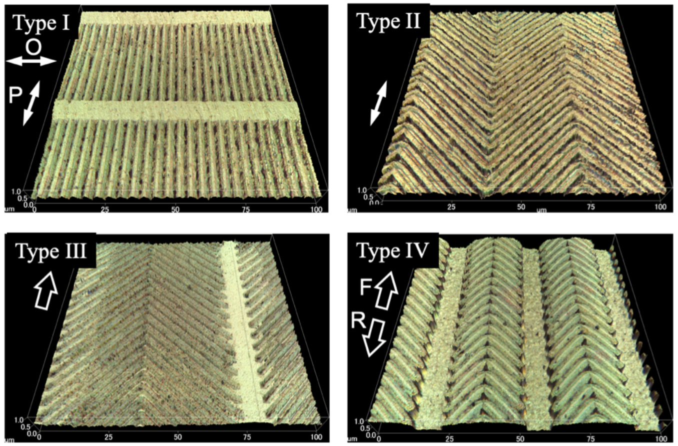
2種類の金属からなるナノストライプ構造の断面

Ando, Y., Miyake, K., Mizuno, A., Korenaga, A., Nakano, M., Mano, H.: Fabrication of nanostripe surface structure by multilayer film deposition combined with micropatterning. Nanotechnology. 21, 095304 (2010). https://doi.org/10.1088/0957-4484/21/9/095304

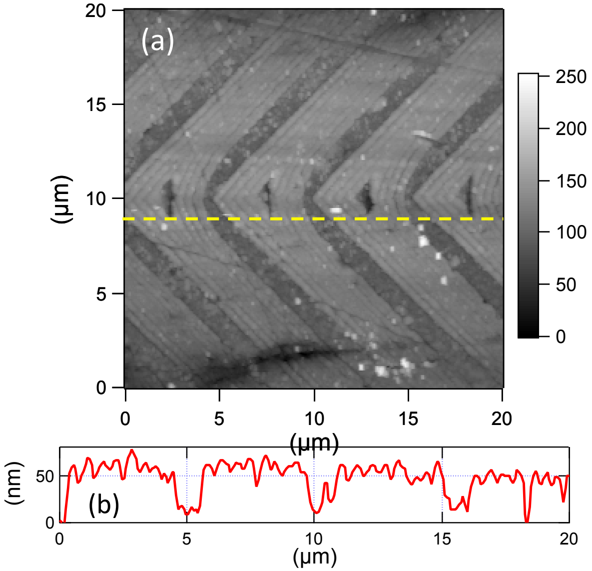
ナノストライプの潤滑特性(1)



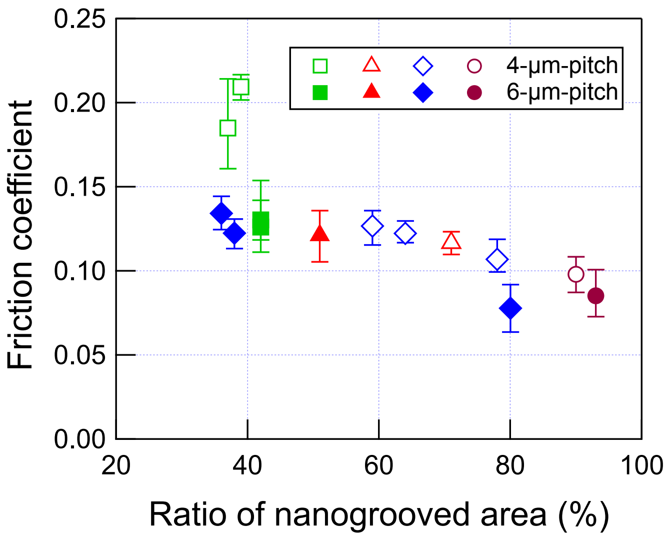
Disk rotating friction tester



実験に用いた4種類のナノストライプ構造



摩耗した領域にもナノ溝が残っている



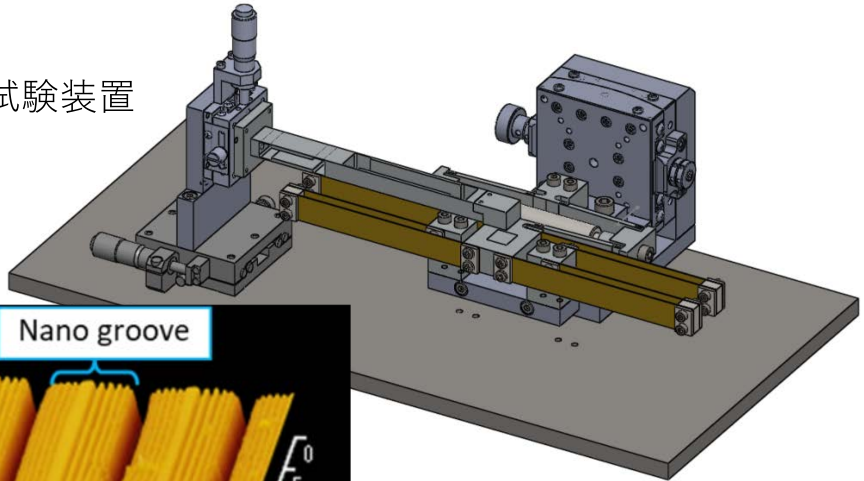
低速ではナノ溝が摩擦係数を低下させる

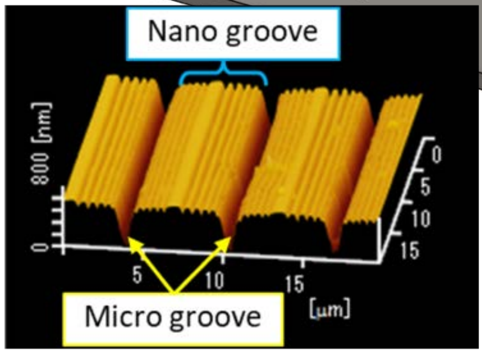
Type I(□, ■), Type II (△, ▲), Type III (◇, ◆), Type IV (○, ●)

Ando, Y., Sumiya, T.: Friction properties of micro/nanogroove patterns in lubricating conditions. Tribol. Int. 151, 106428 (2020). https://doi.org/10.1016/j.triboint.2020.106428

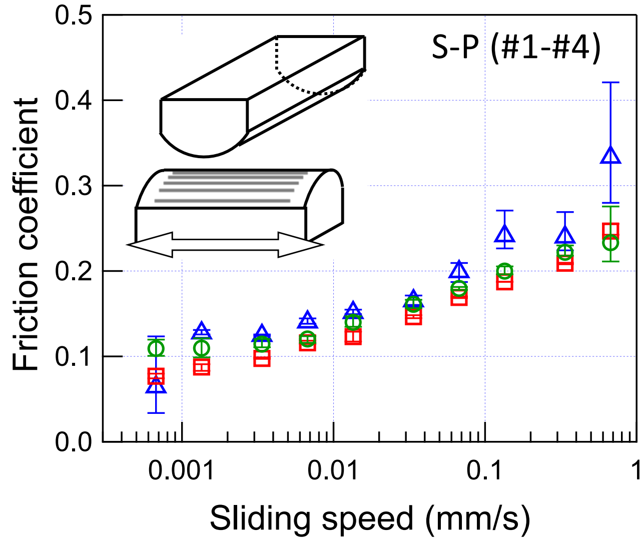
ナノストライプの潤滑特性(2)

試験装置



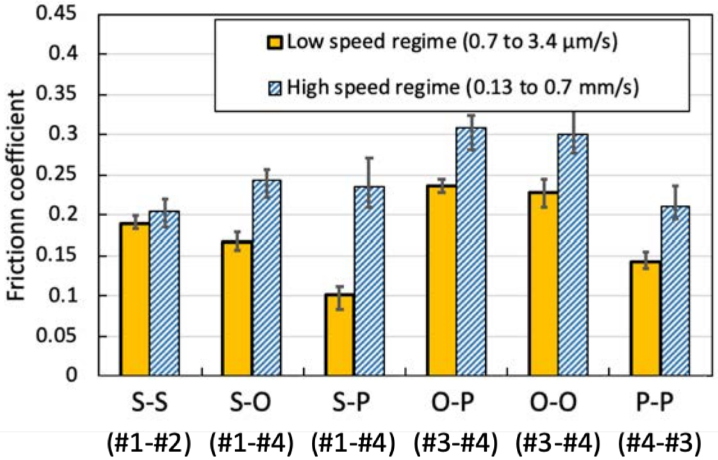


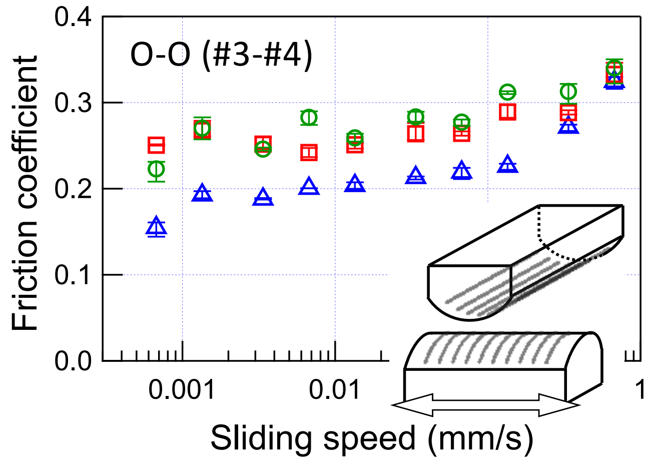
薄膜Siウェハ上の
ナノストライプ



最も低い摩擦係数を示す組合わせ

結果の
概要



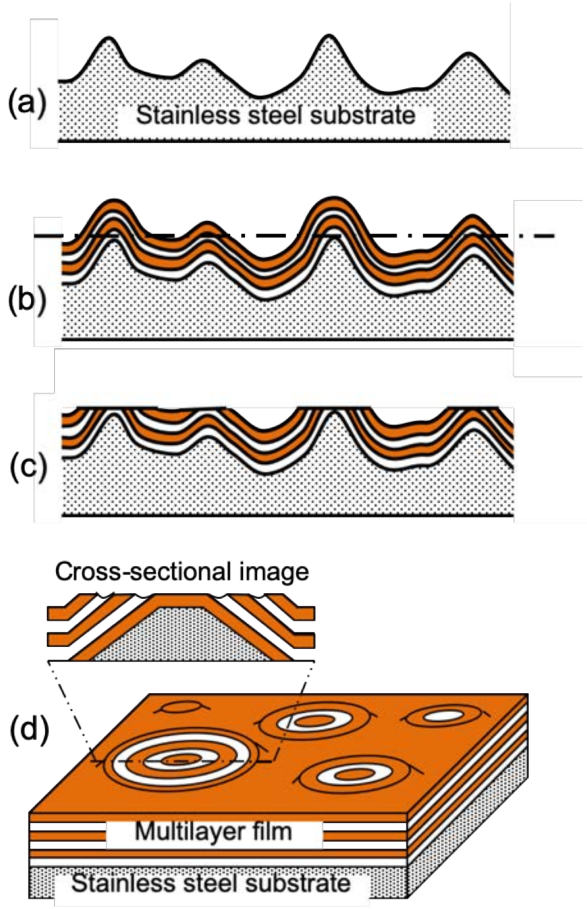


最も高くほぼ一定の摩擦係数を示す組合わせ

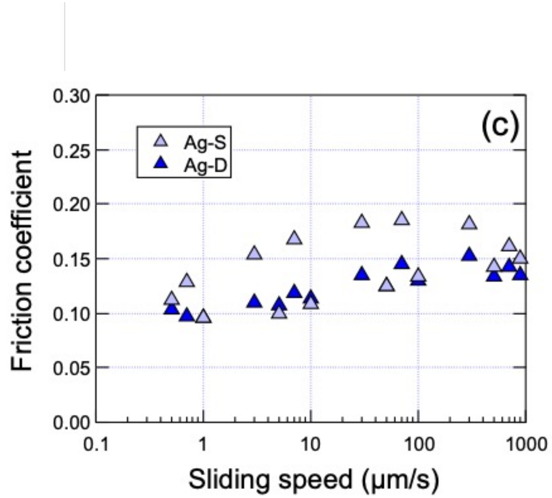
Hayashi, M., Ando, Y.: Friction characteristics between two nanostripe surfaces. Tribol. Int. 136, 165–172 (2019).
https://doi.org/10.1016/j.triboint.2019.03.046

等高線型ナノストライプの潤滑特性

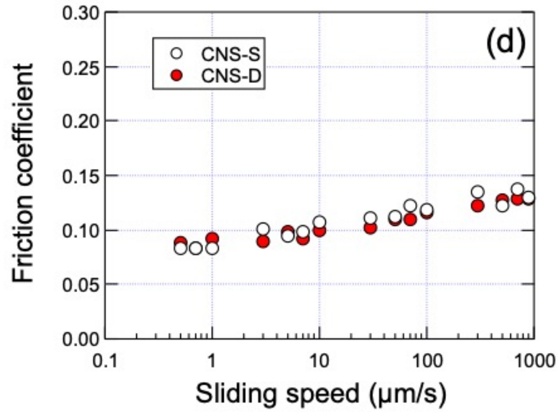
Tribology



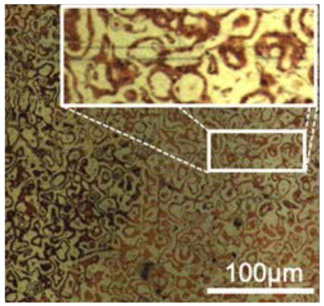
(a) formation of random dents and asperities by shot blasting, (b) formation of multilayer films, (c) polishing of surface, and (d) generation of contoured groove/ridge pattern.

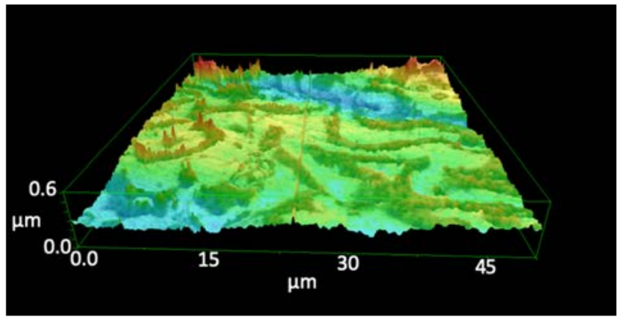


Ag-coated surfaces showed unstable friction coefficient



CNS surface showed lowest friction coefficient





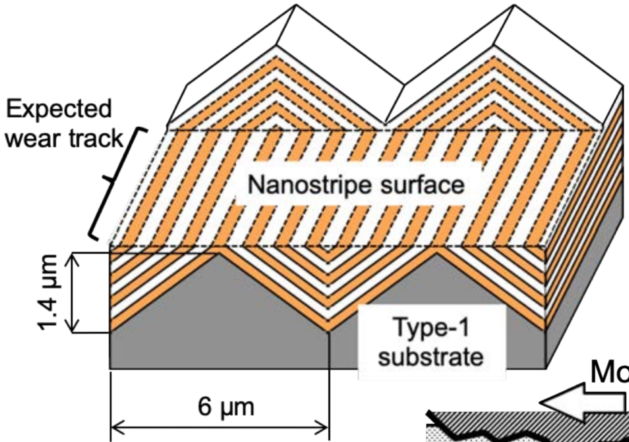
CNS-D substrates observed after friction tests. Nanoscale ridges remained in the wear scar

Ando, Y., Imai, H., Ito, H.: Fabrication and Lubrication Properties of Contoured Nanostripe Surfaces. Tribol. Lett. 63, (2016). https://doi.org/10.1007/s11249-016-0703-x

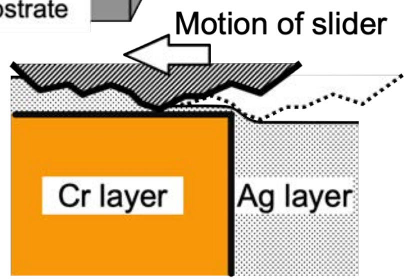
ナノストライプ誘導構造の乾燥摩擦特性

Tribology

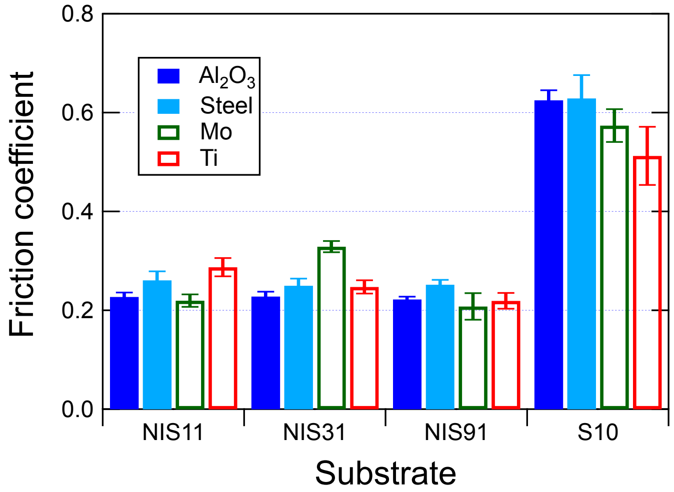
MEMS /Microfabrication Technology



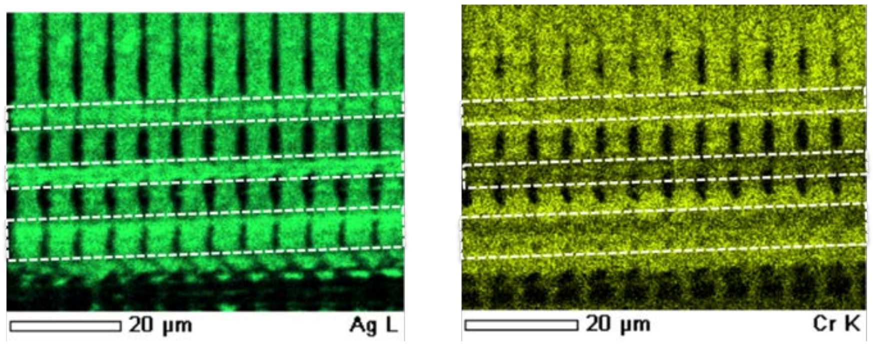
Schematic of NIS



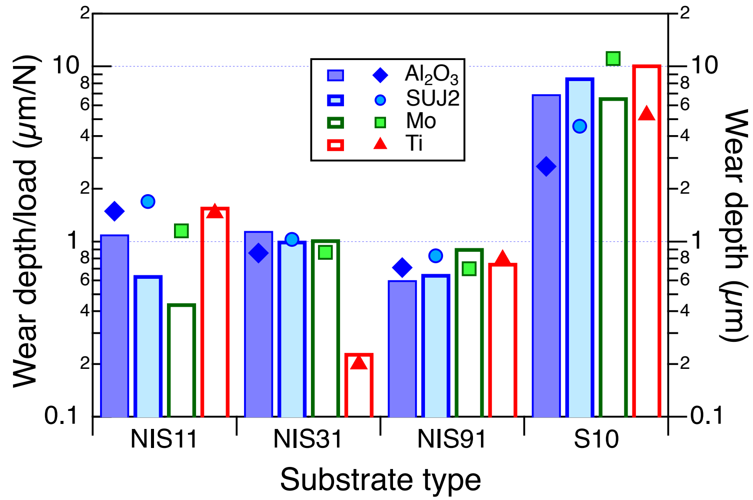
Schematic of NIS



Average friction coefficients in a vacuum



SEM–EDX results for NIS11 rubbed with Al_2O_3

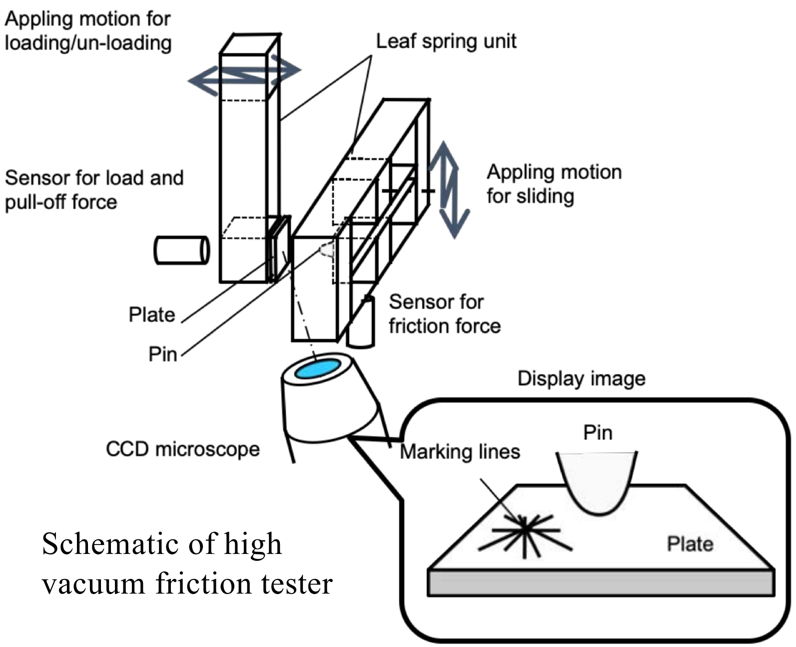


Wear scar depths (symbols) and wear rate (bars)

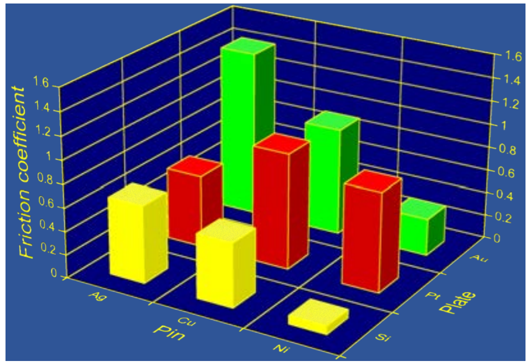
Ando, Y., Abe, S.: Friction and wear properties of nanostripe-inducing structures in vacuum environment. Wear. 424–425, 62–69 (2019). https://doi.org/10.1016/j.wear.2018.11.008

原子間隔差が摩擦係数に及ぼす影響

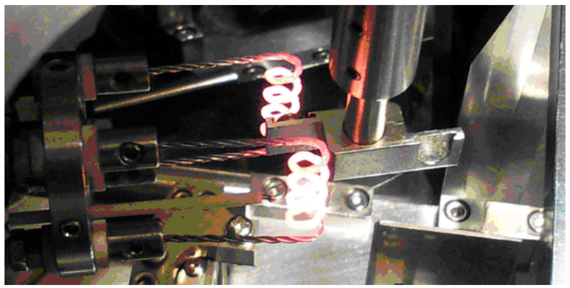
Tribology



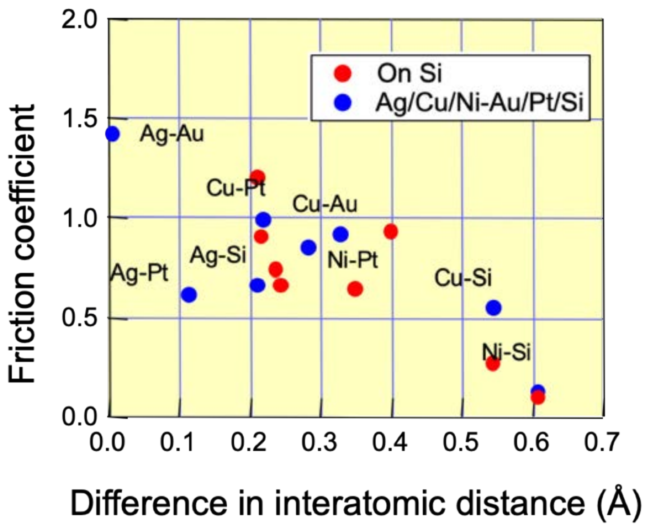
Schematic of high
vacuum friction tester



Friction coefficients measured in high vacuum



Test pieces were heated to remove moisture on the surface before measurements

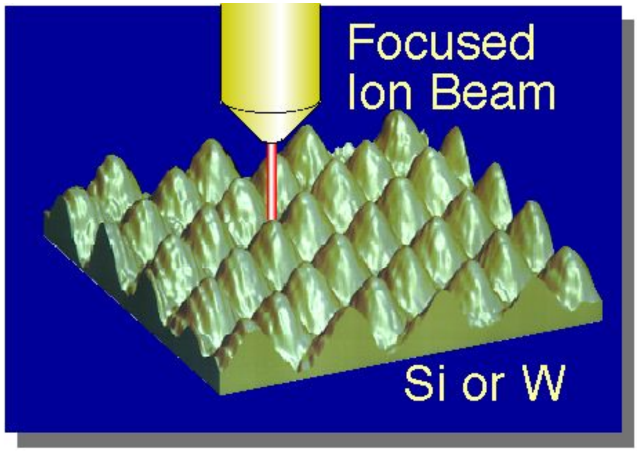


Lager difference in interatomic distance showed lower friction coefficient

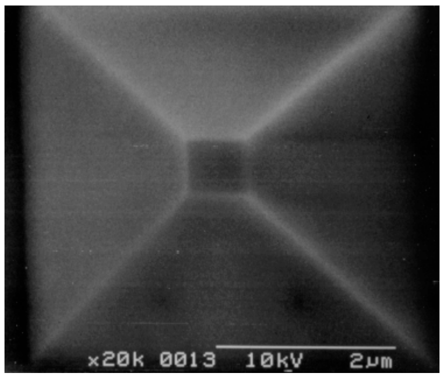
Ando, Y., Tamura, Y., Takahashi, H., Hiratsuka, K.: Experimental studies on revealing a dominant factor in friction coefficient between different metals under low load conditions. Tribol. Lett. 47, 43–49 (2012). https://doi.org/10.1007/s11249-012-9960-5

Fabricating nanoscale asperity arrays to control friction and adhesion force

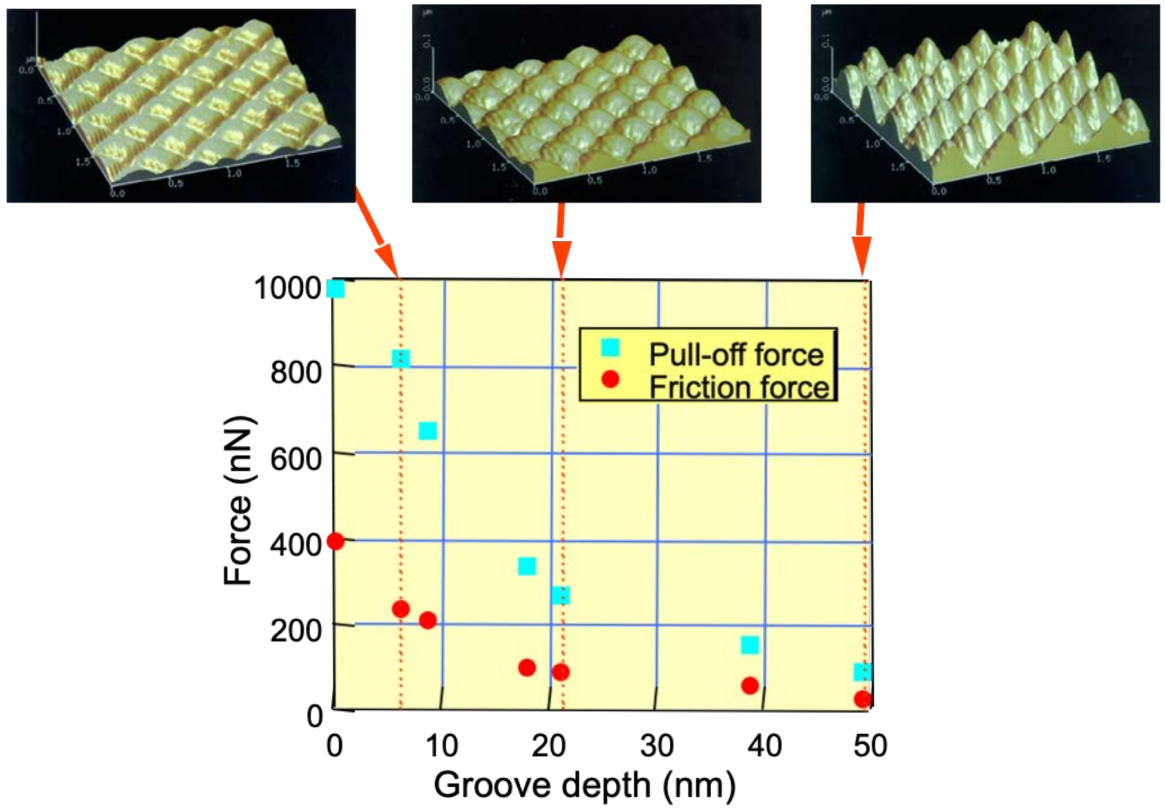
Micro/Nano Tribology



FIB was used to create periodic asperity arrays



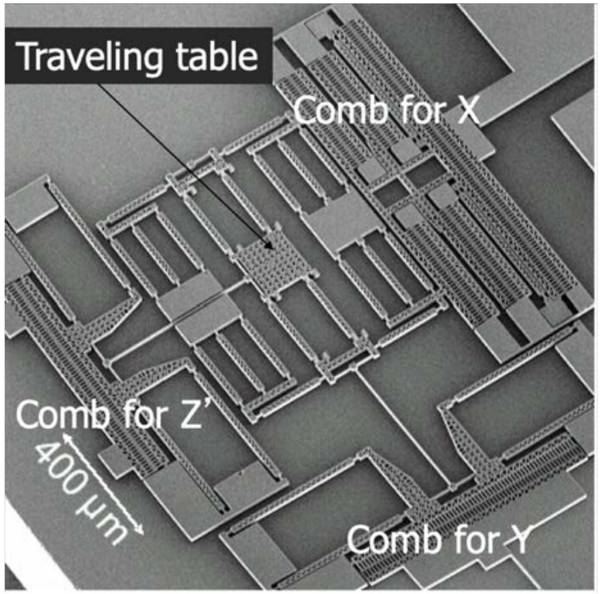
SEM image of scanning probe for AFM measurement

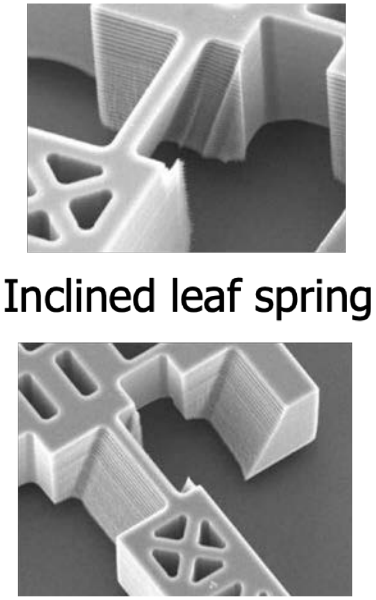


Friction and adhesion forces are reduced by applying periodic asperity array

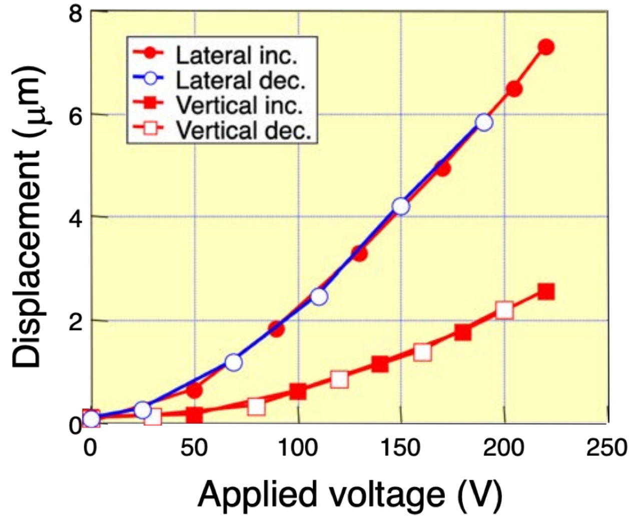
Ando, Y., Ino, J.: Friction and pull-off forces on submicron-size asperities. Wear. 216, 115–122 (1998). https://doi.org/10.1016/S0043-1648(97)00158-0

3次元マクロステージ

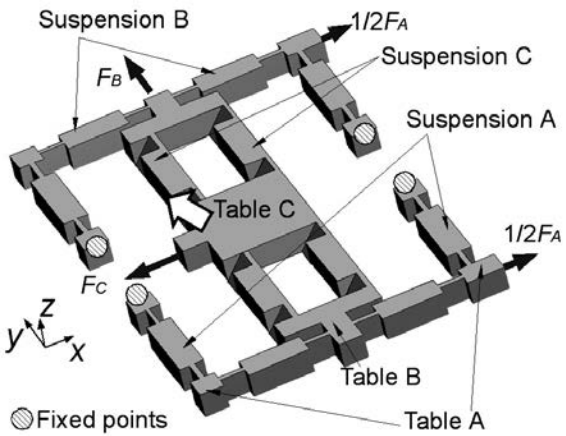




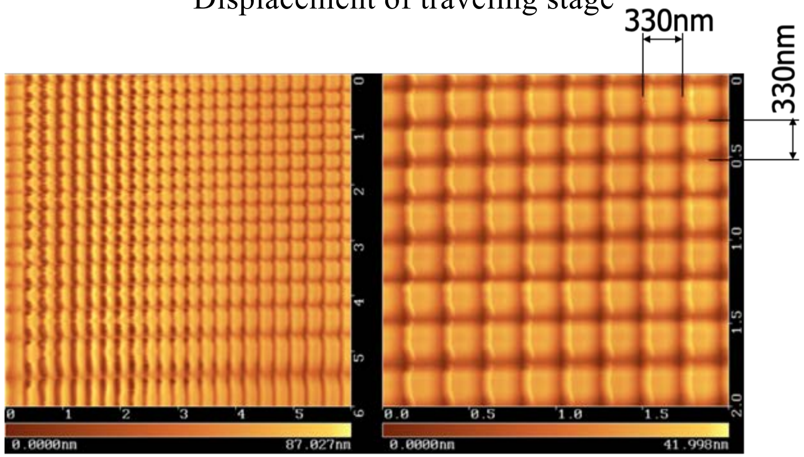
Inclined leaf spring



Displacement of traveling stage



Inclined leaf springs in suspensions enable displacement in z-direction



Larger scanning area Smaller scanning area

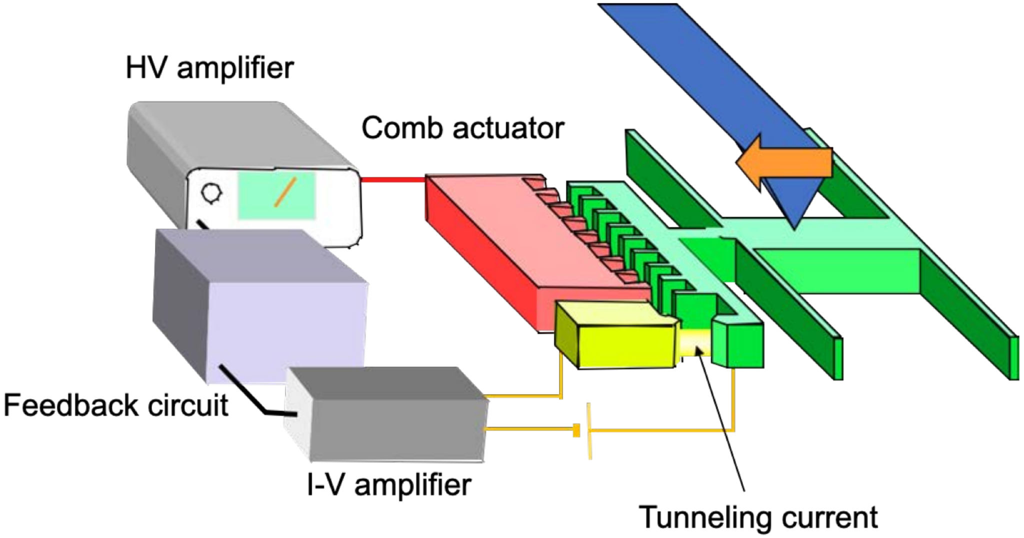
AFM image captured using 3D-microstage as scanning device

Ando, Y., Ikehara, T., Matsumoto, S.: Development of three-dimensional microstages using inclined deep-reactive ion etching. J. Microelectromechanical Syst. 16, (2007). https://doi.org/10.1109/JMEMS.2006.885848

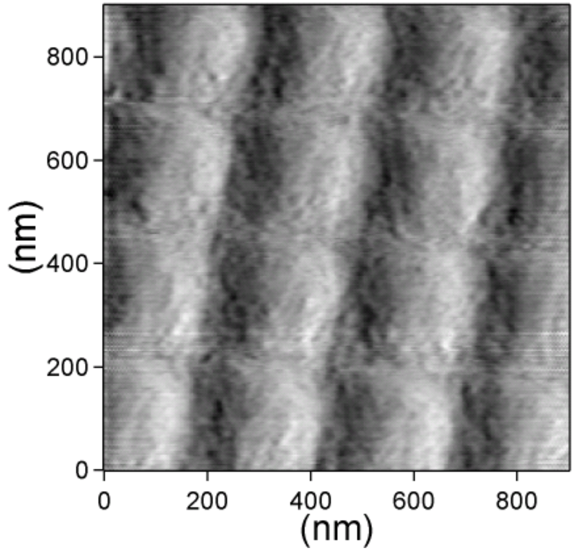
マイクロ水平力センサ

Tribology

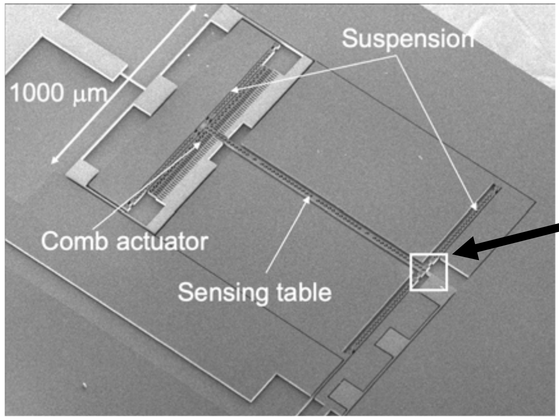
MEMS /Microfabrication Technology

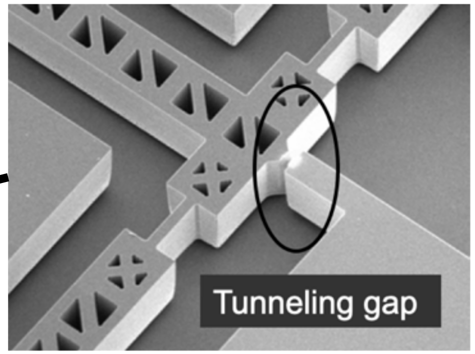


Using tunneling current to detect the displacement of force-sensing stage

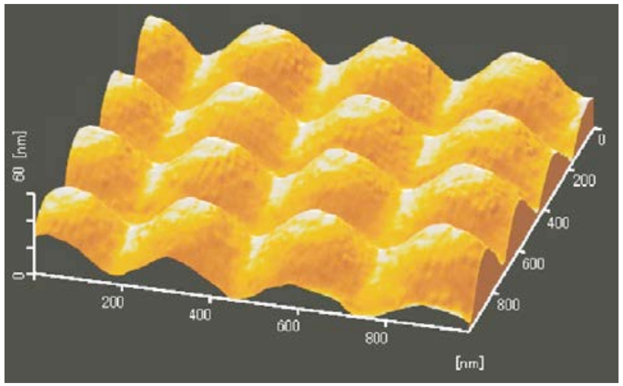


LFM image obtained using MLFS





SEM image of whole device and tunneling gap



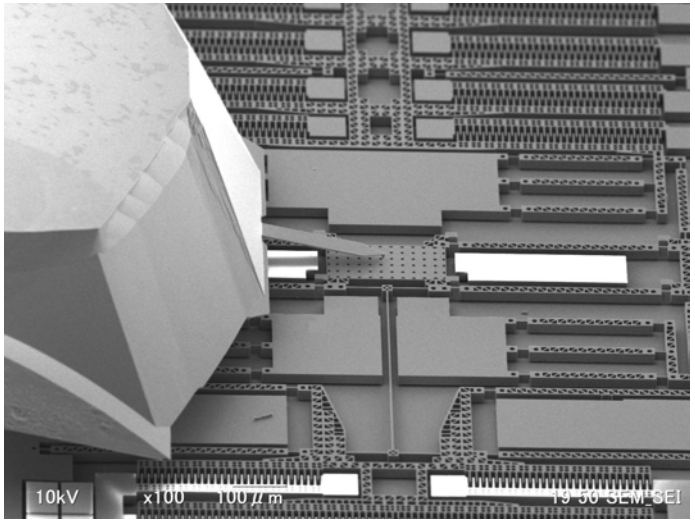
Testing area to measure LFM image

Ando, Y., Shiraishi, N.: Development of a microlateral force sensor and its evaluation using lateral force microscopy. Rev. Sci. Instrum. 78, 033701 (2007). https://doi.org/10.1063/1.2714038

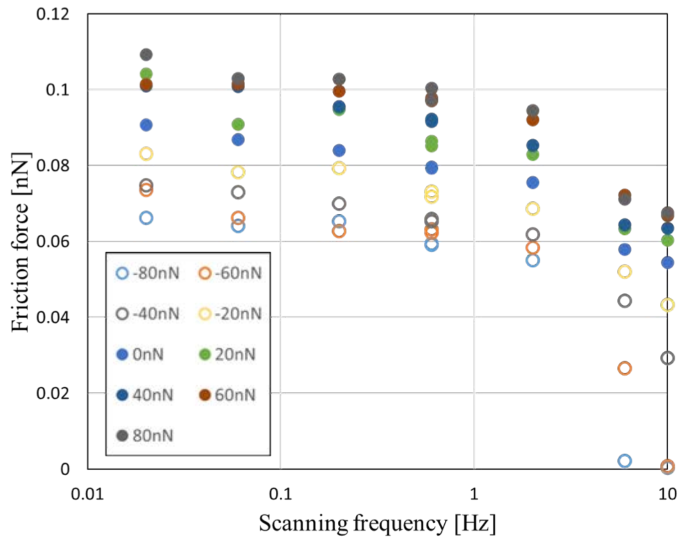
カンチレバー一体型μステージ

Micro/Nano Tribology

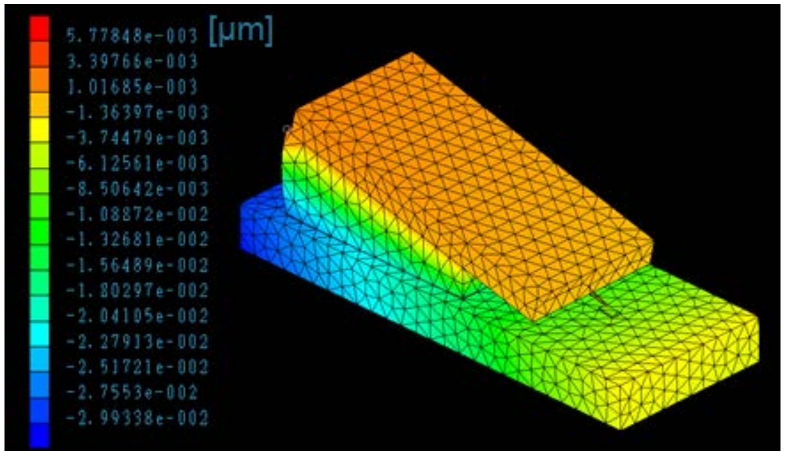
MEMS /Microfabrication Technology



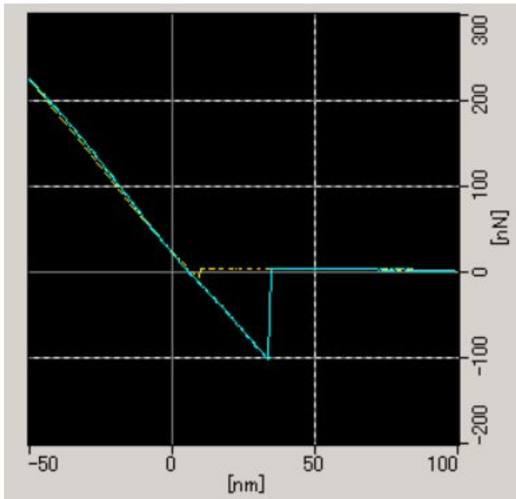
AFMカンチレバーが基板に直接固定されている



CI-3D-microstageで測定した摩擦力

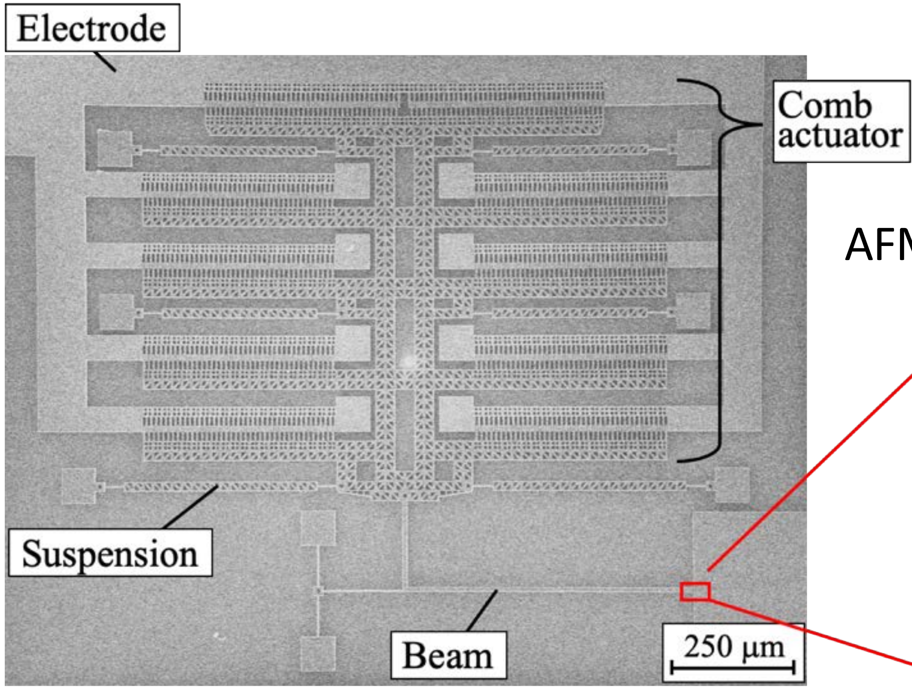


温度変化に対して荷重や位置制御が影響を受けない

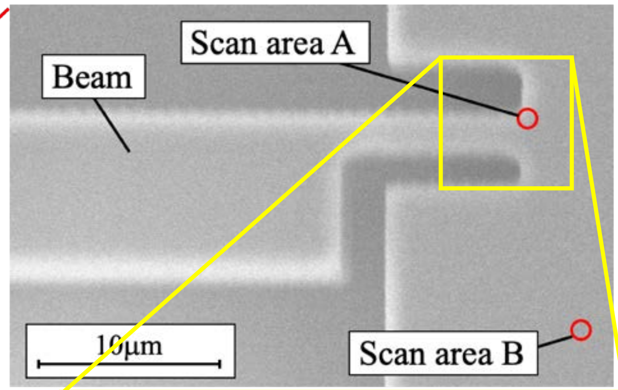


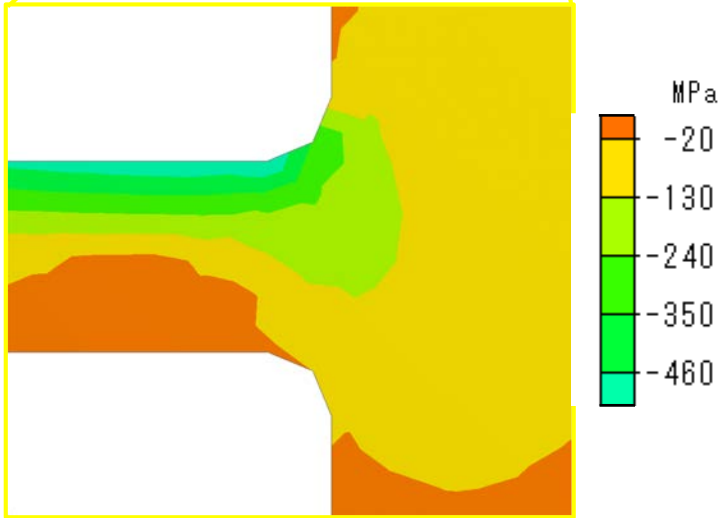
フォースカーブ測定がヒステリシスの影響を受けない

μデバイスによる歪みと摩擦の関係

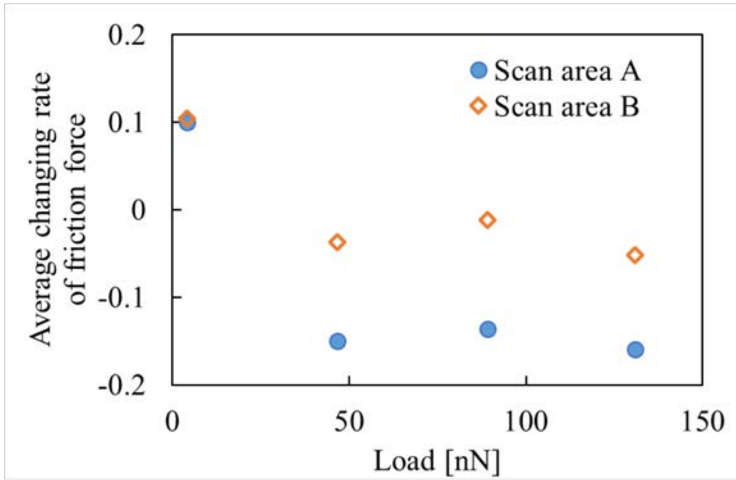


AFMに取り付けた応力集中μデバイス





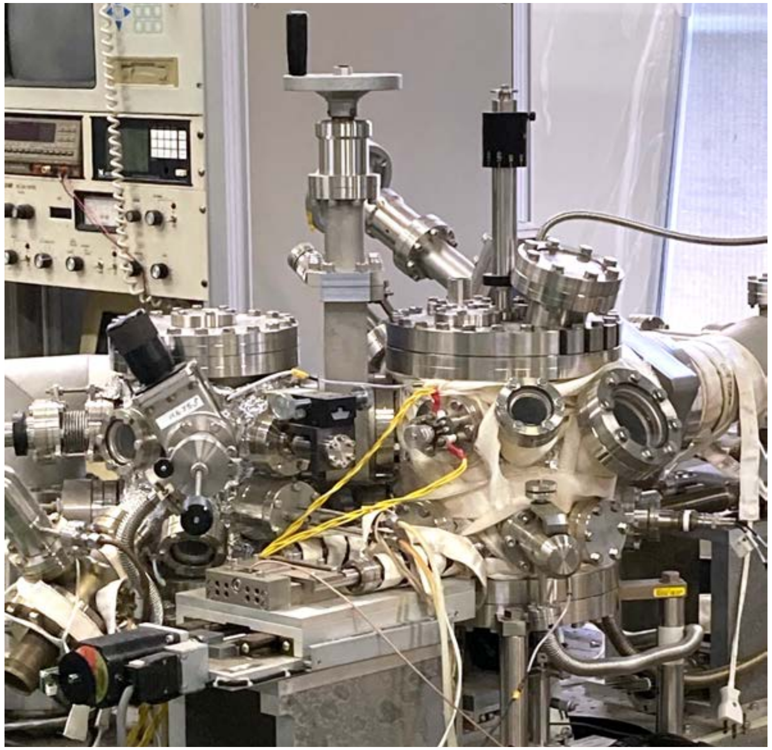
FEM解析結果

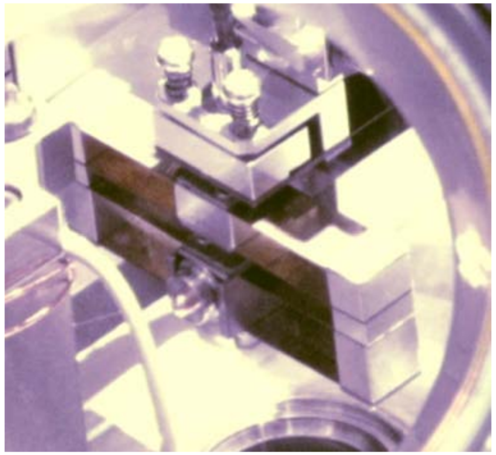


歪みにより15％程度摩擦力が低下した

代表的な研究設備

超高真空マイクロトライボロジー試験機





Specifications

Pressure: 10^{-7}Pa (Min.)

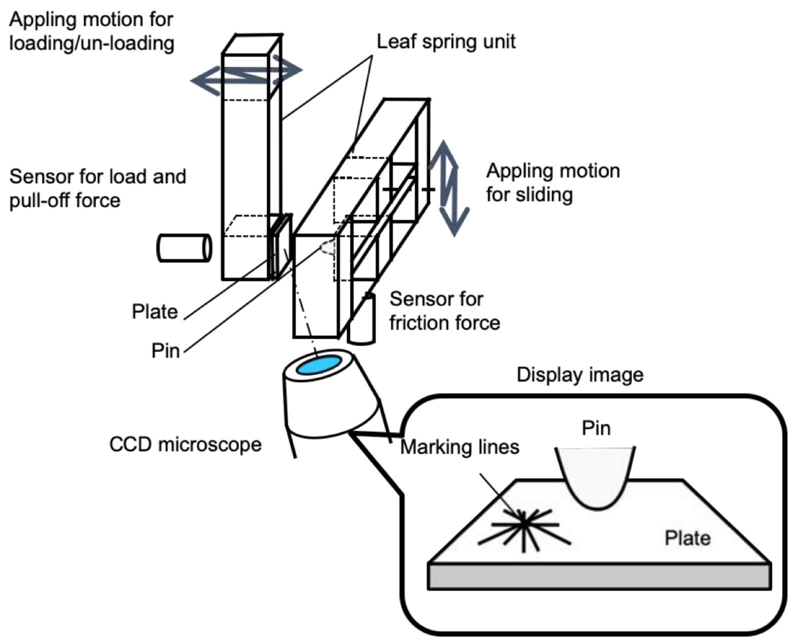
Force resolution: ~0.1 μN

Pull-off force measurement is possible

Sample heating in vacuum

Sliding stroke: 0.3 mm (Max.)

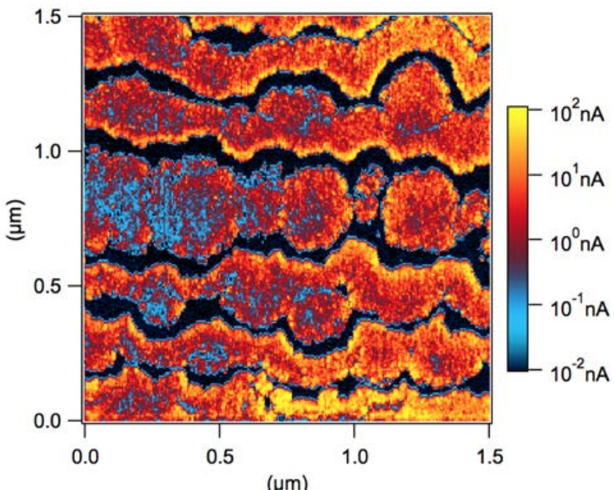
Installed on Active vibration isolator



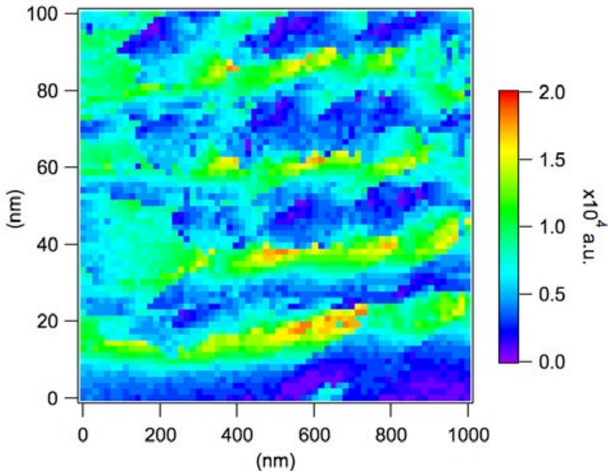
Samples can be changed and rotated in HV

高真空AFM（atomic force microscope）

Specifications
Pressure: 10^{-5}Pa (min.)
Substrate temperature: -60 to 300 ℃ (800 ℃)
Current distribution: max. bias voltage of 100V
Pull-off force distribution: adjustable contact period
DFM, LM-LFM, LFM, etc.

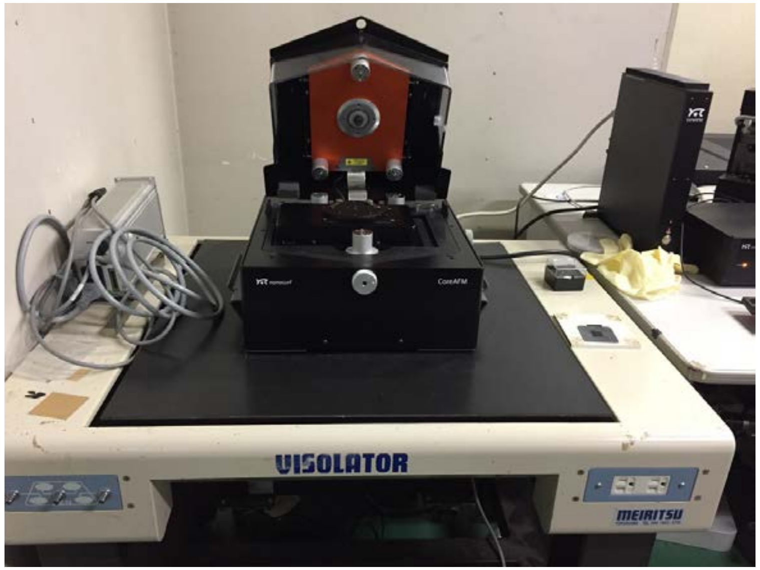


電流分布測定（バイアス電圧を特注で100Vまで増加させている）



高真空中で測定された引き離し力分布（接触時間を０～1秒の間で調整できるように改修）

表面観察装置



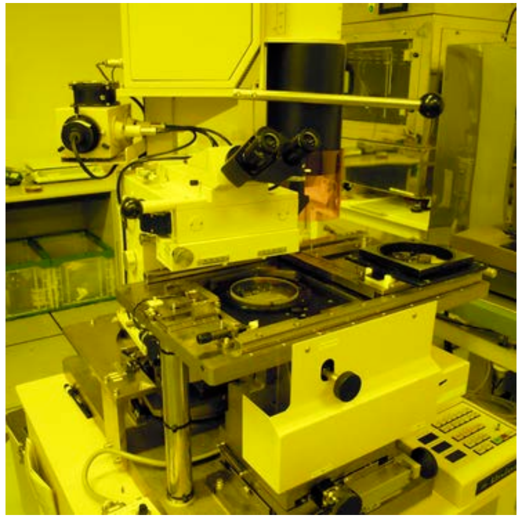
Nanosurf CoreAFM

Hitachi High-Tech Science AFM5010

Lasertec Corp. Optics Hybrid

Technex Lab Co. Tiny SEM

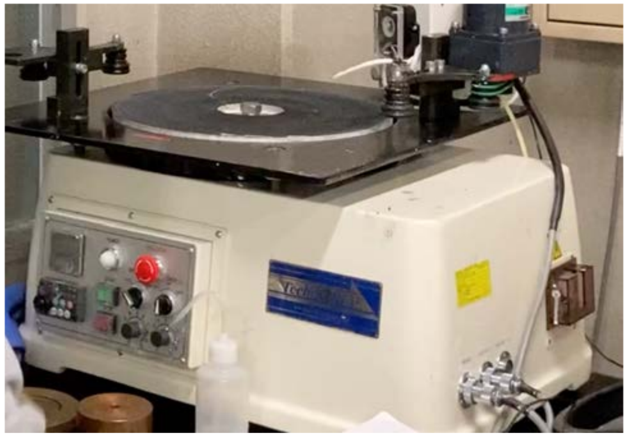
Fabrication facilities



RFスパッタ成膜装置

電気炉

両面マスクアライナ
4インチウェハ対応



研磨装置

小型スパッタ成膜装置

ダイシングソー