Infrared Photo-induced Force Microscopy (IR PiFM)

Potential for EUV Metrology

EUV Supplier Showcase
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Current Status of Analytical Techniques

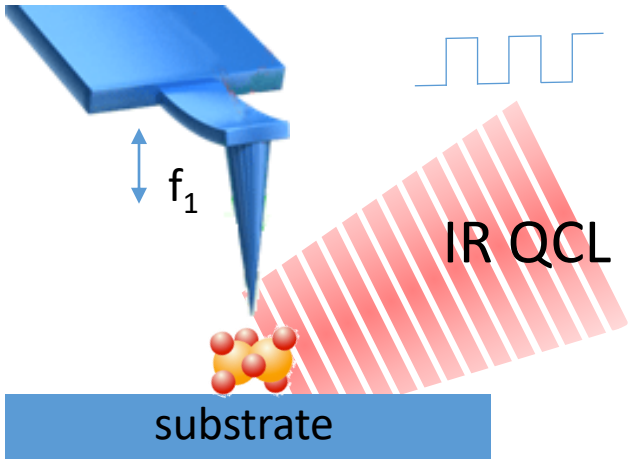
	Raman	FTIR	TOF-SIMS	XPS	TXRF	SEM/EDS	TEM	Auger
Species Detected	M.I.	M.I.	M.I.	M.I.	E.I.	E.I.	E.I.	E.I.
Chemical Mapping	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lateral Resolution	> 0.5 μm	> 10 μm	> 0.2 μm	10 μm – 2 mm	~ 10 mm	1 nm* 0.5μm EDS	0.2 nm	> 10 nm
Depth Probed	> 500 nm	1 μm	1 nm	10 nm	10 nm	1 μm	~ 100 nm	10 nm

* Imaging M.I. Molecular information E.I. Elemental information

Elemental information cannot identify nanoscale organic defects and ultrathin residues, which are becoming more commonplace. Existing tools for molecular information do not have spatial resolution to analyze sub-200 nm particles.

Infrared Photo-induced force microscope(IR PiFM)

Dipole-dipole attractive force from nano-sized sample absorption region is detected via AFM cantilever.



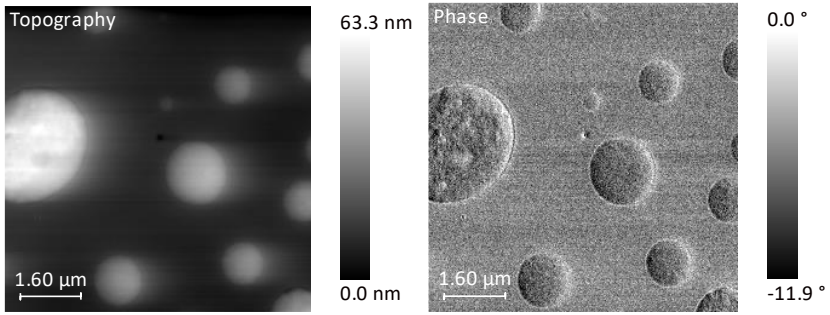
QCL (quantum cascade laser): tunable IR laser (770 – 1900 cm^{-1})

IR PiFM combines IR spectroscopy with AFM to acquire topography and both IR absorption (PiF-IR) spectra and chemical map images with sub-10 nm spatial resolution.

One vibrational resonance of the cantilever is used to perform standard modes of AFM.

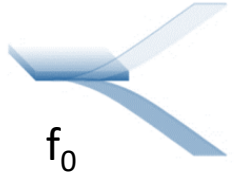
feedback & topography

PS-LDPE Blend

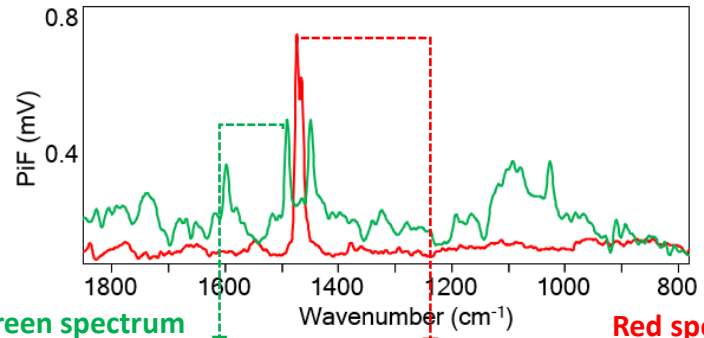


Standard AFM topography and phase images are acquired at f_1. As typical with AFM images, the molecular identity of features are unknown even though spatial resolution is excellent.

Concurrently, a second resonance of the cantilever is used to detect photo-induced force (PiF) of the sample.

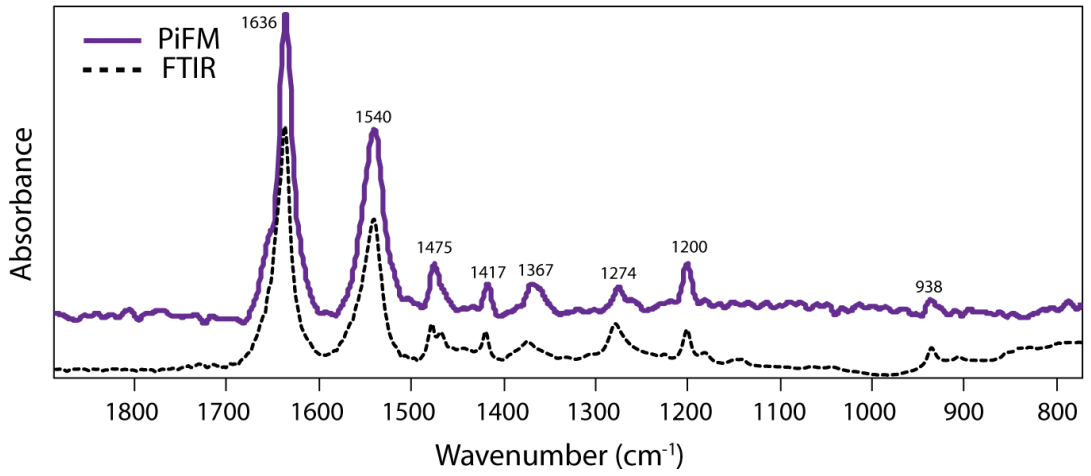


PiF-IR spectra & chemical map with ~ 5 nm resolution

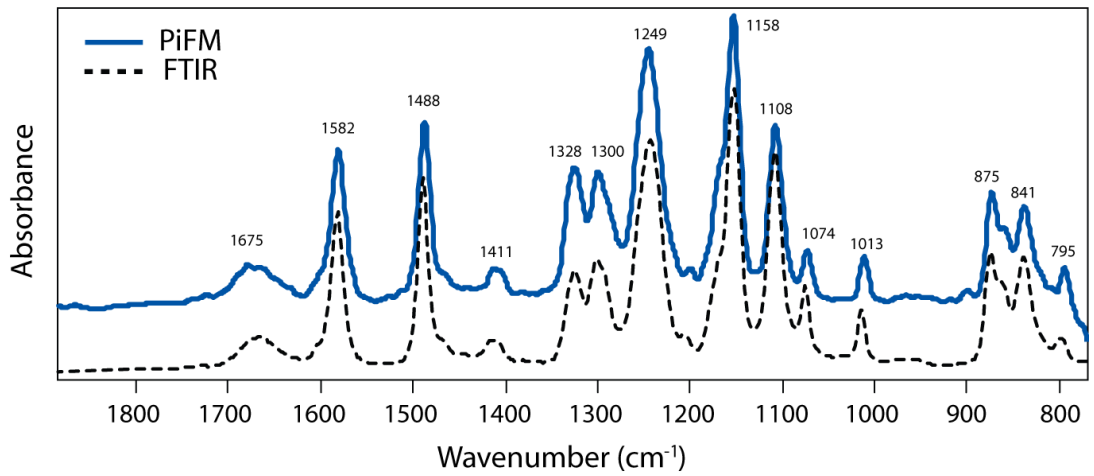


Excellent Agreement between Nanoscale PiF-IR and FTIR Spectra

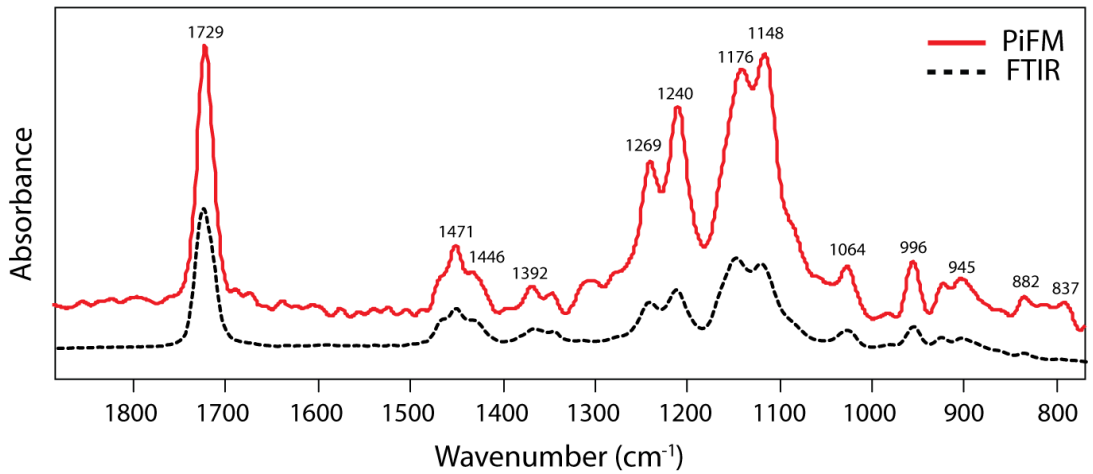
PiFM and FTIR of Nylon



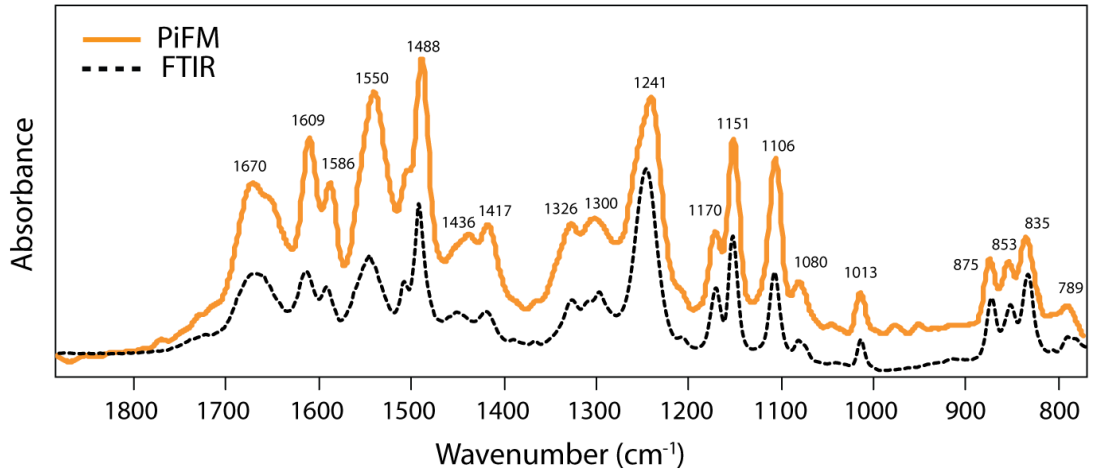
PiFM and FTIR of PES (Polyethersulfone)



PiFM and FTIR of PMMA - Poly(methyl methacrylate)



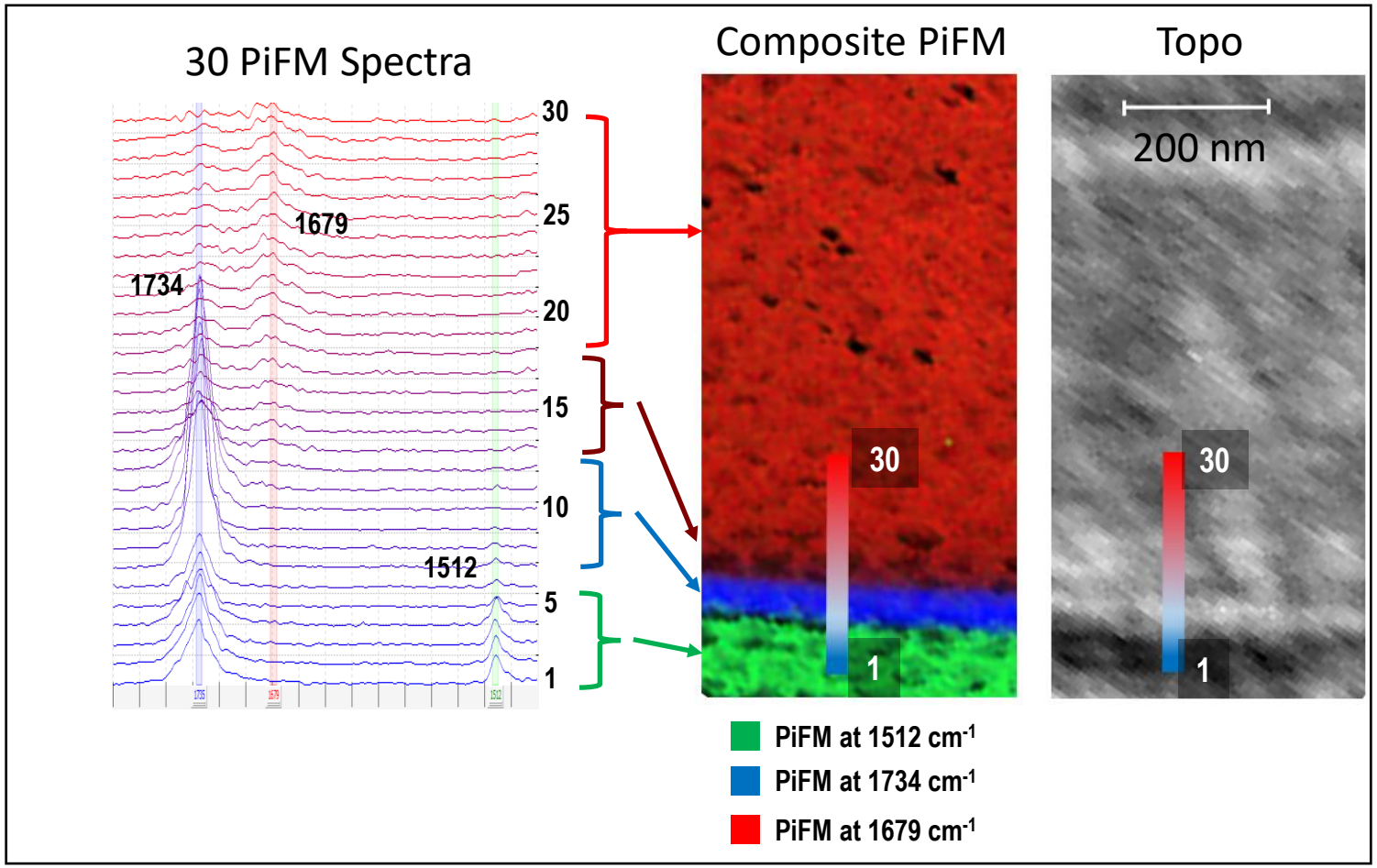
PiFM and FTIR of Polyimide



Chemical Analysis across Polymer Interfaces

Sample Description

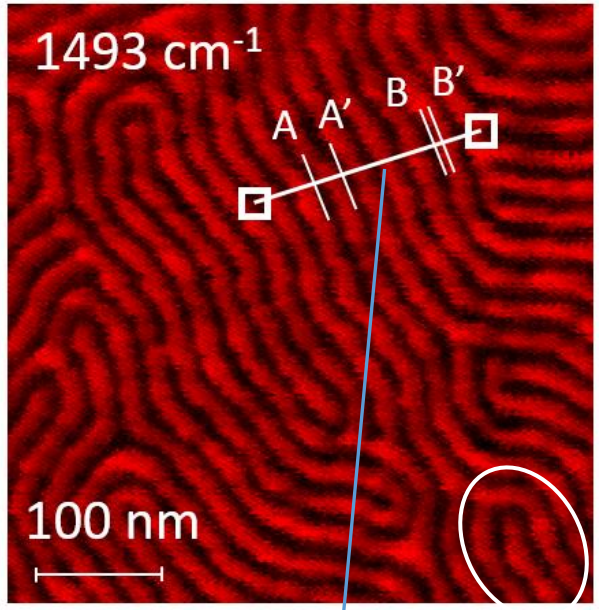
examined interface (microtomed)

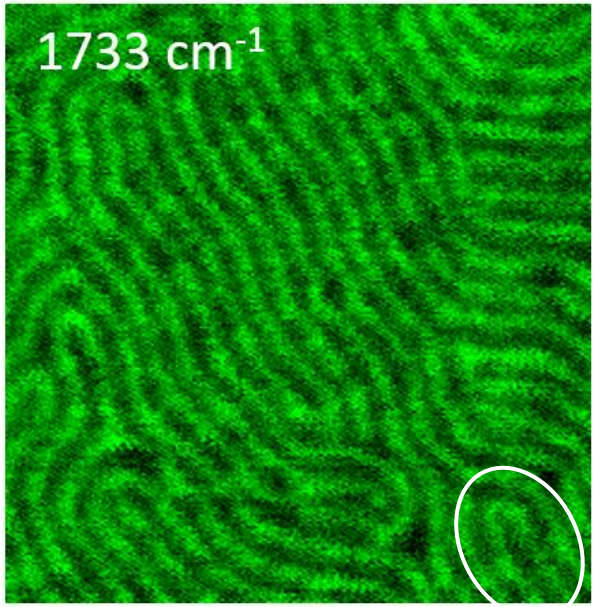


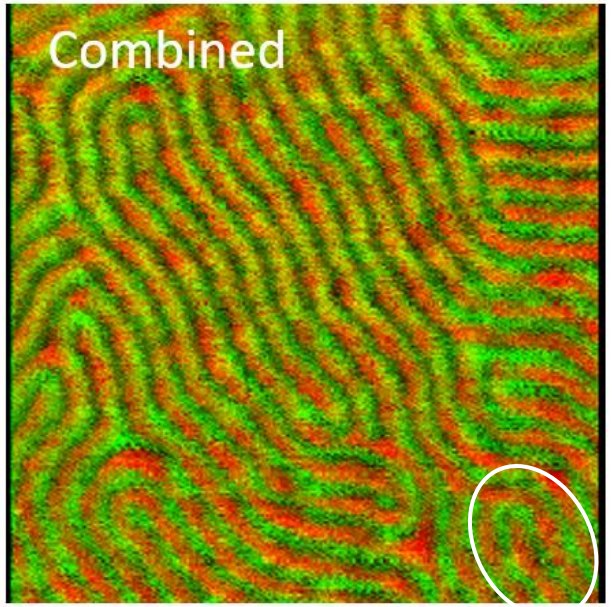
- Microtomed sample to analyze interface between two polymer layers
- 30 spectra across the interface with 10 nm spacing show gradual and sudden changes in peak strength with single steps
- ~ 50 nm mixing in the interface shown in spectra 13 to 18
- Demonstrates PiFM sensitivity and spatial resolution

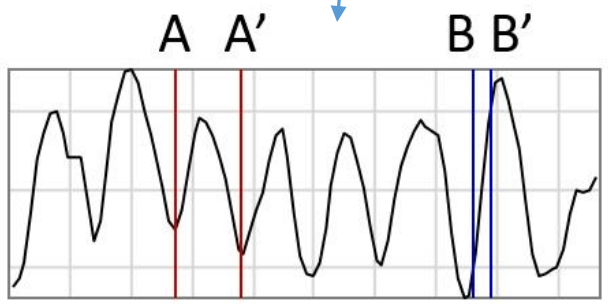
Exceptional Spatial Resolution in Chemical Mapping

PS-*b*-PMMA Block Copolymer, L_0 = 22 nm









Cross-section of PiF signal for PS

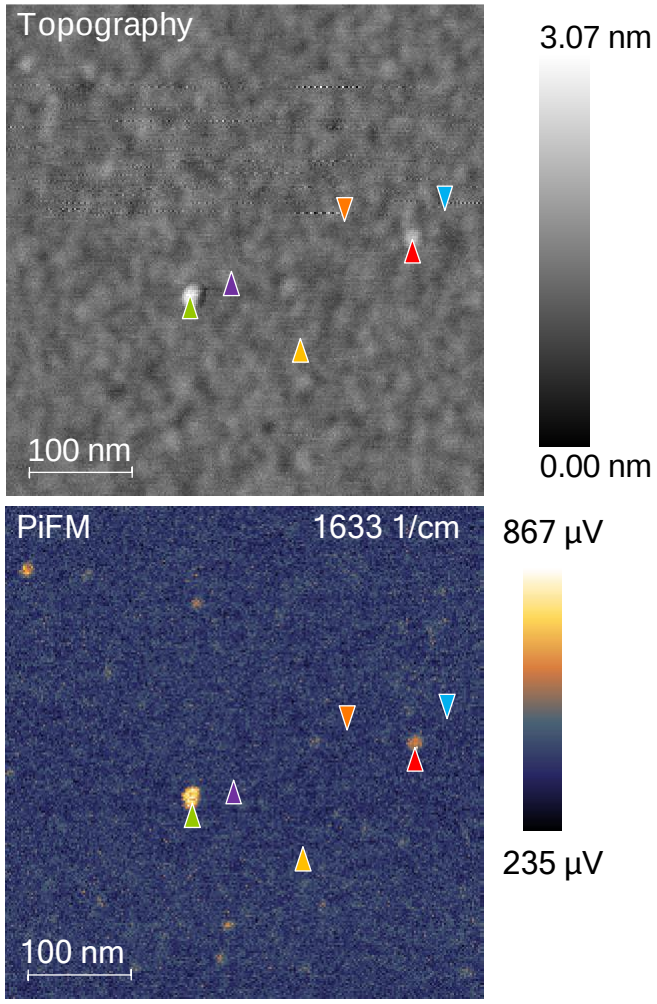
A-A': 21 nm

B-B': 6.5 nm

PMMA PS

IR PiFM can monitor chemical homogeneity of photoresist with ~ 5 nm spatial resolution

PiFM Sensitivity - Incomplete Monolayer of Peptoid Molecules



Height: 1.2 nm x Width: 16 nm

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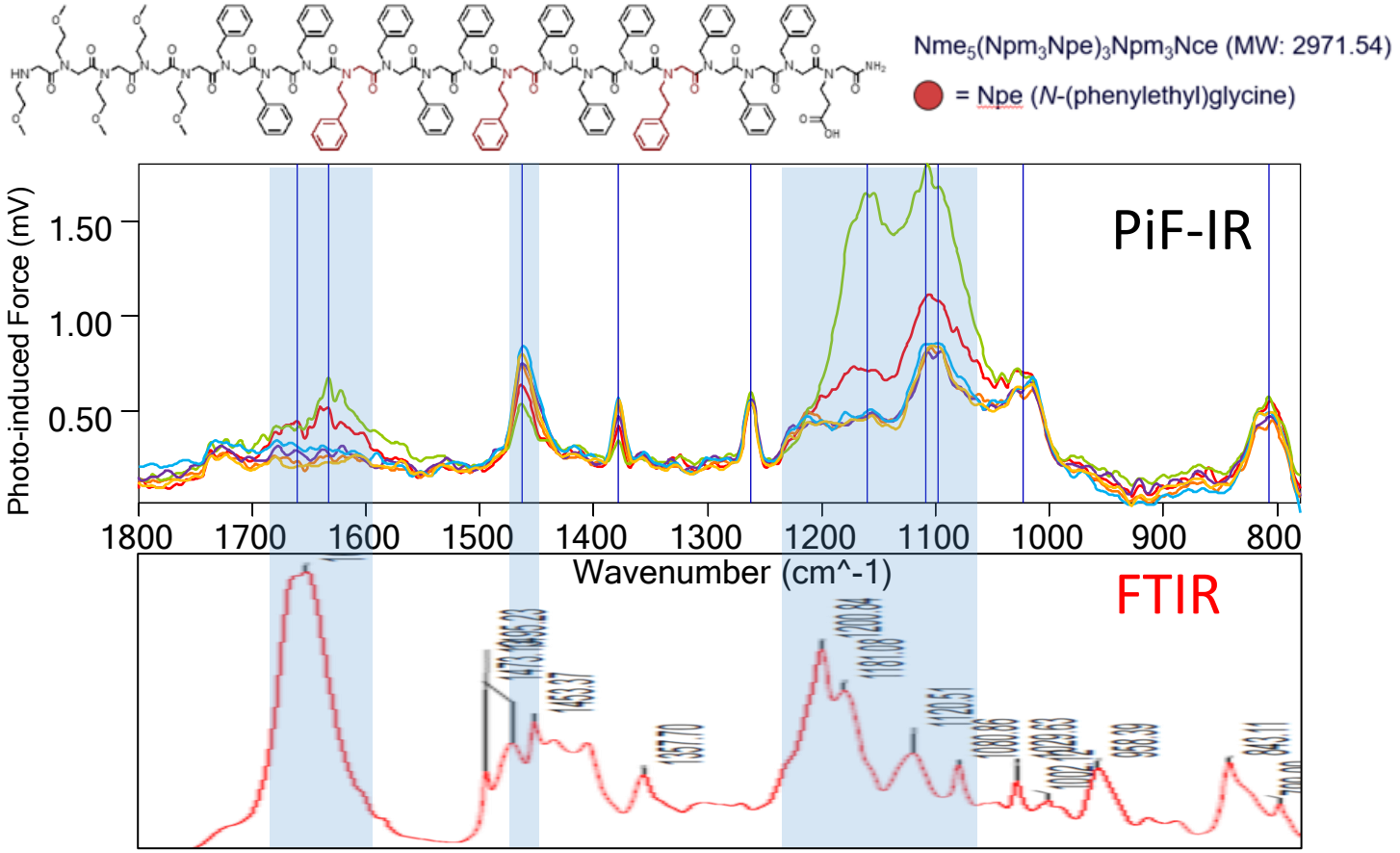
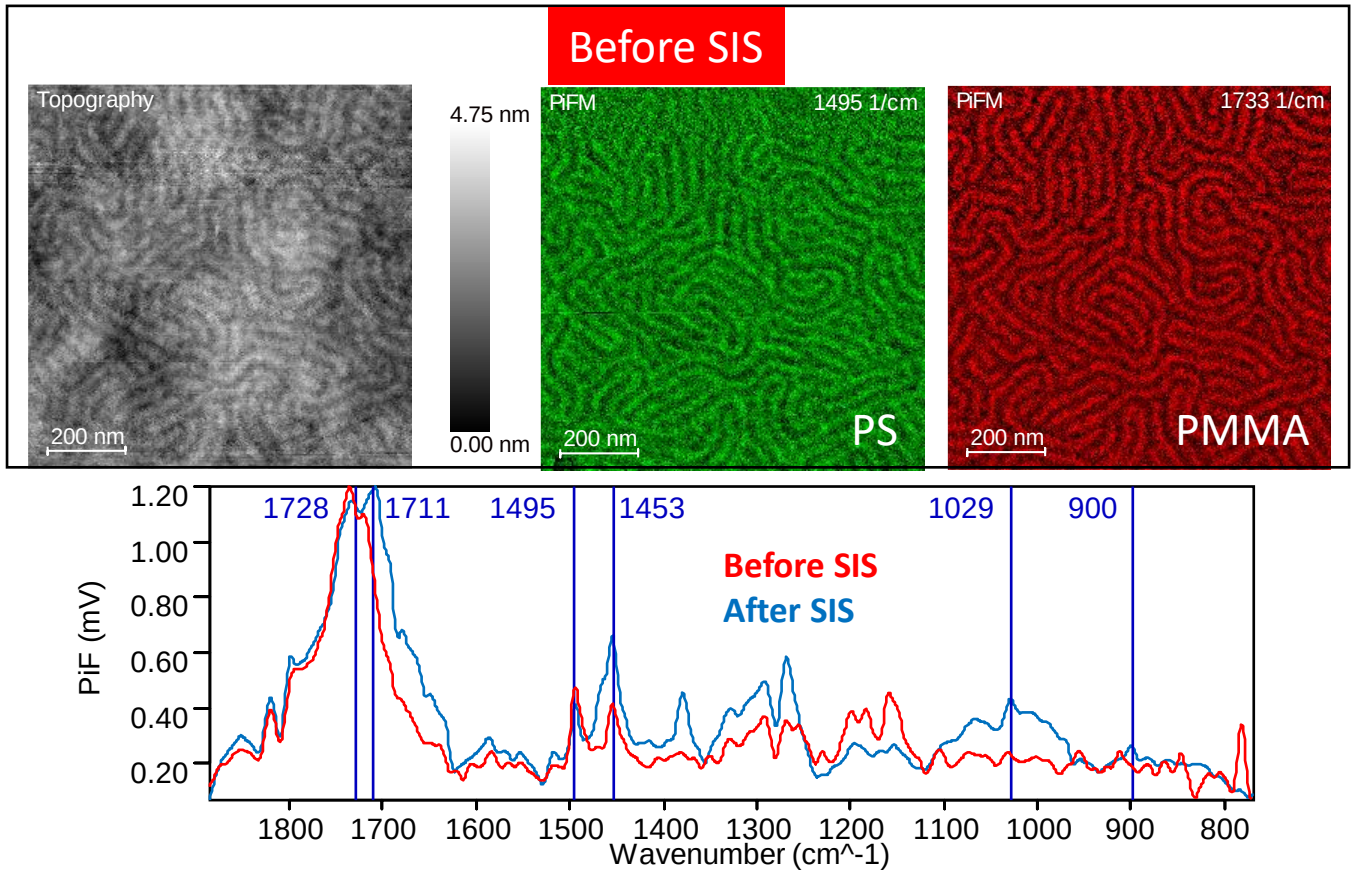
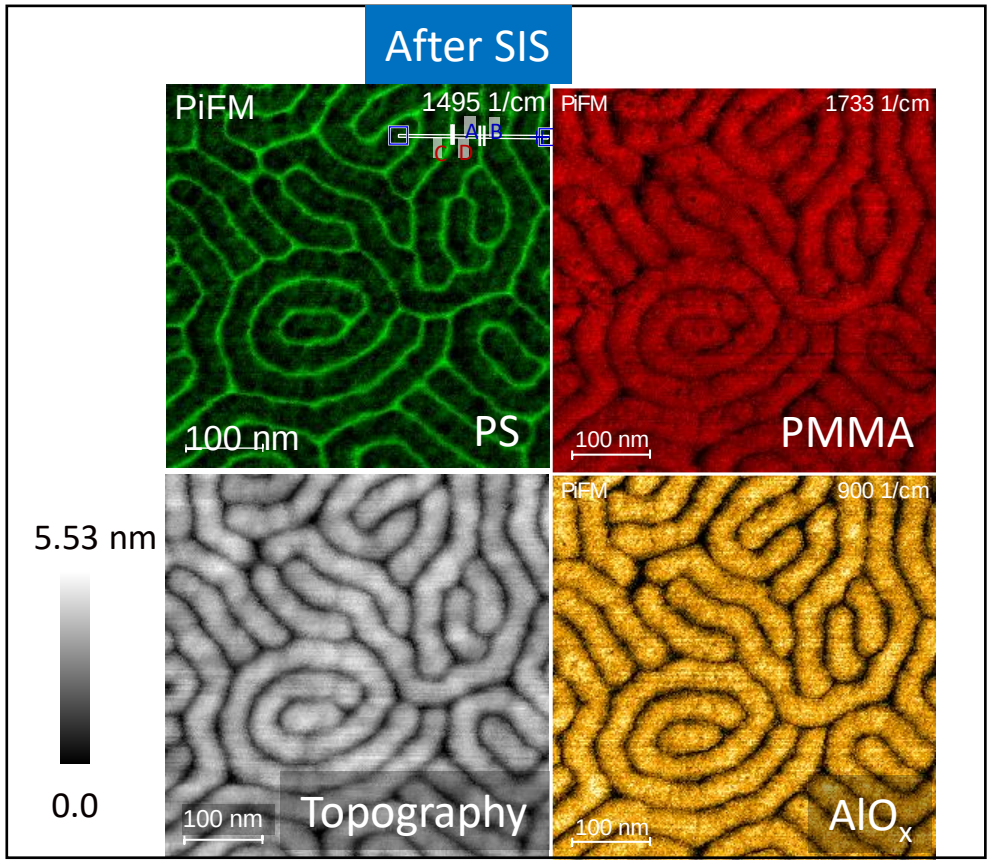


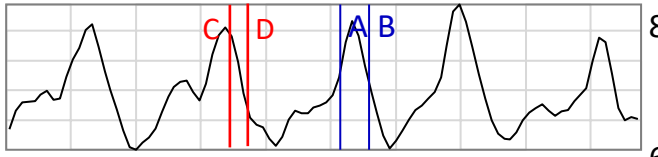
Only the green and red spectra from tiny regions show the amide peak at ~1650 cm^{-1}, indicating that all the peptoid molecules are washed away except for some fragments. The PiFM image at 1633 cm^{-1} highlight only the remaining peptoid molecules some of which are so small that topography cannot highlight them due to the roughness of the substrate. IR PiFM routinely demonstrates single molecule and monolayer sensitivity.

SIS AlO_x PS-b-PMMA (41 nm FP Lamellar) PiFM Images





Selective infiltration of trimethyl aluminum (TMA) into PMMA molecules and subsequent exposure to water vapor forms aluminum oxide only in the PMMA block of the PS-b-PMMA block copolymer. Before SIS, the width of PS and PMMA blocks are equal as seen above. After SIS, PS width is reduced to 8.9 nm from 21 nm (see PS profile plot). PiFM image @ 900 cm^{-1} highlights the alumina molecules, which are located only in PMMA blocks as expected.



d_{A-B} = 8.9 nm d_{C-D} = 5.2 nm

Complements other Nanoscale Analytical Techniques

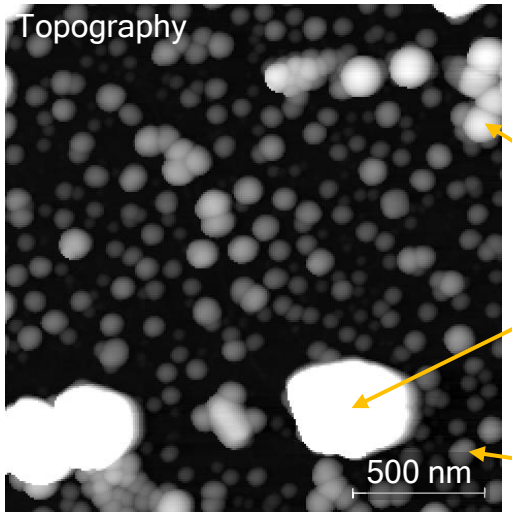
	IR PiFM	Raman	FTIR	TOF-SIMS	XPS	TXRF	SEM/EDS	TEM	Auger
Species Detected	**M.I.**	M.I.	M.I.	M.I.	M.I.	E.I.	E.I.	E.I.	E.I.
Chemical Mapping	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lateral Resolution	**~ 5 nm**	> 0.5 μm	> 10 μm	> 0.2 μm	10 μm – 2 mm	~ 10 mm	1 nm* 0.5μm EDS	0.2 nm	> 10 nm
Depth Probed	**20 nm & bulk**	> 500 nm	1 μm	1 nm	10 nm	10 nm	1 μm	~ 100 nm	10 nm

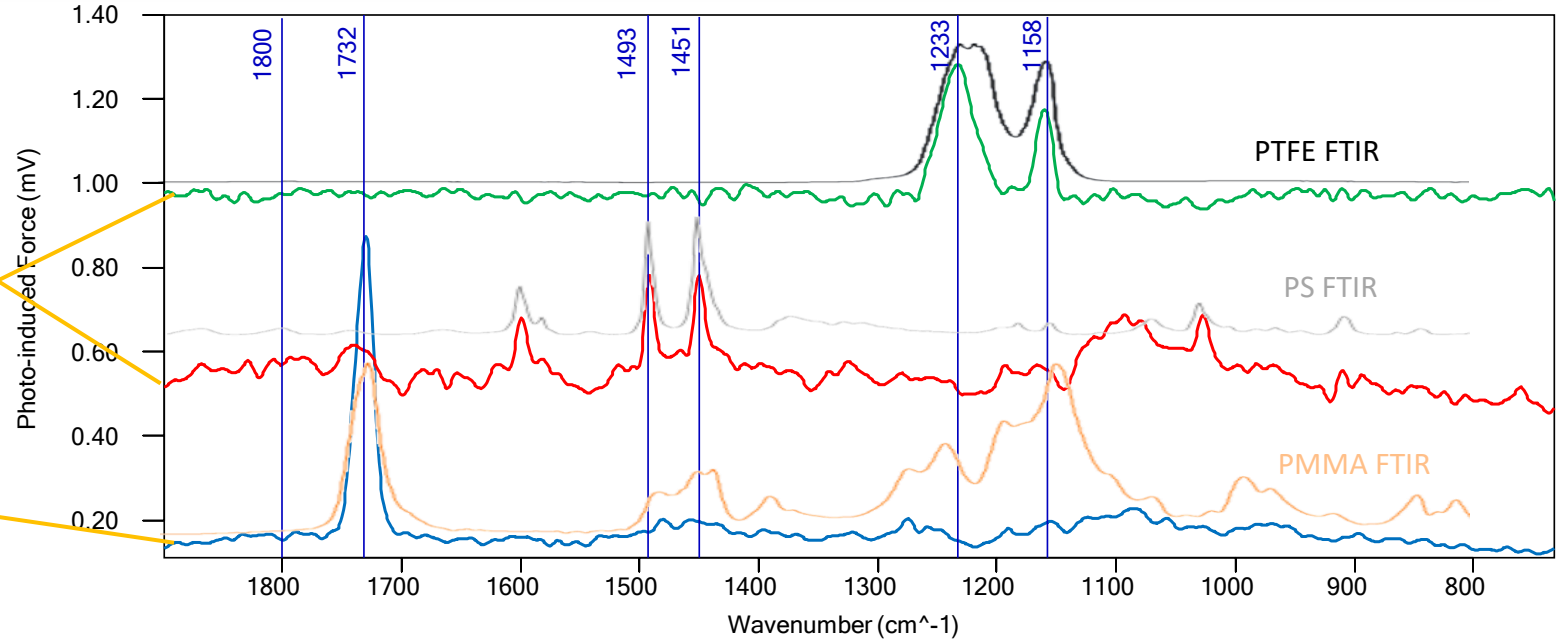
* Imaging M.I. Molecular information E.I. Elemental information

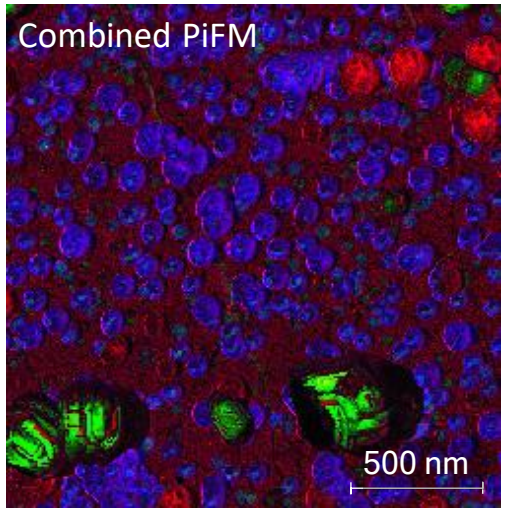
IR PiFM brings molecular analysis to the realm of true nanoscale, providing both IR absorption spectra and chemical mapping with ~ 5 nm spatial resolution and monolayer sensitivity.

Potential EUV Applications

Identification of Nanoparticles based on PiF-IR Spectra

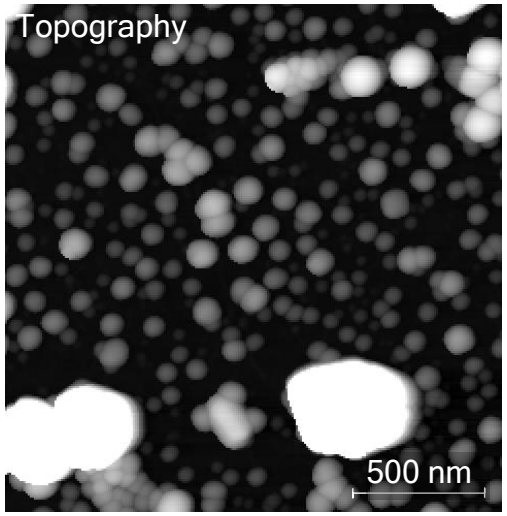


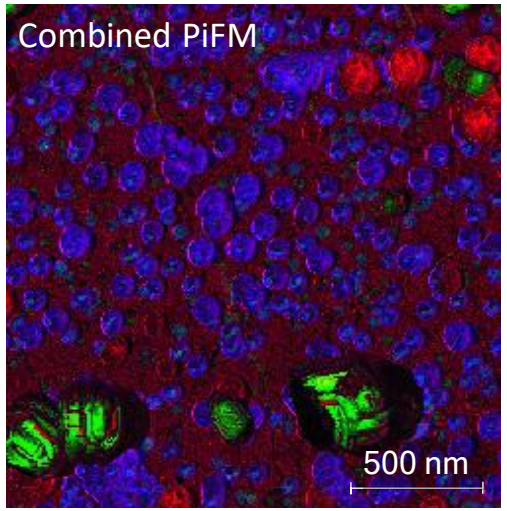




- PMMA (1732 cm^{-1})
- PS (1493 cm^{-1})
- PTFE & gold NP (1158 & 1800 cm^{-1})

Identification of Nanoparticles based on PiF-IR Spectra





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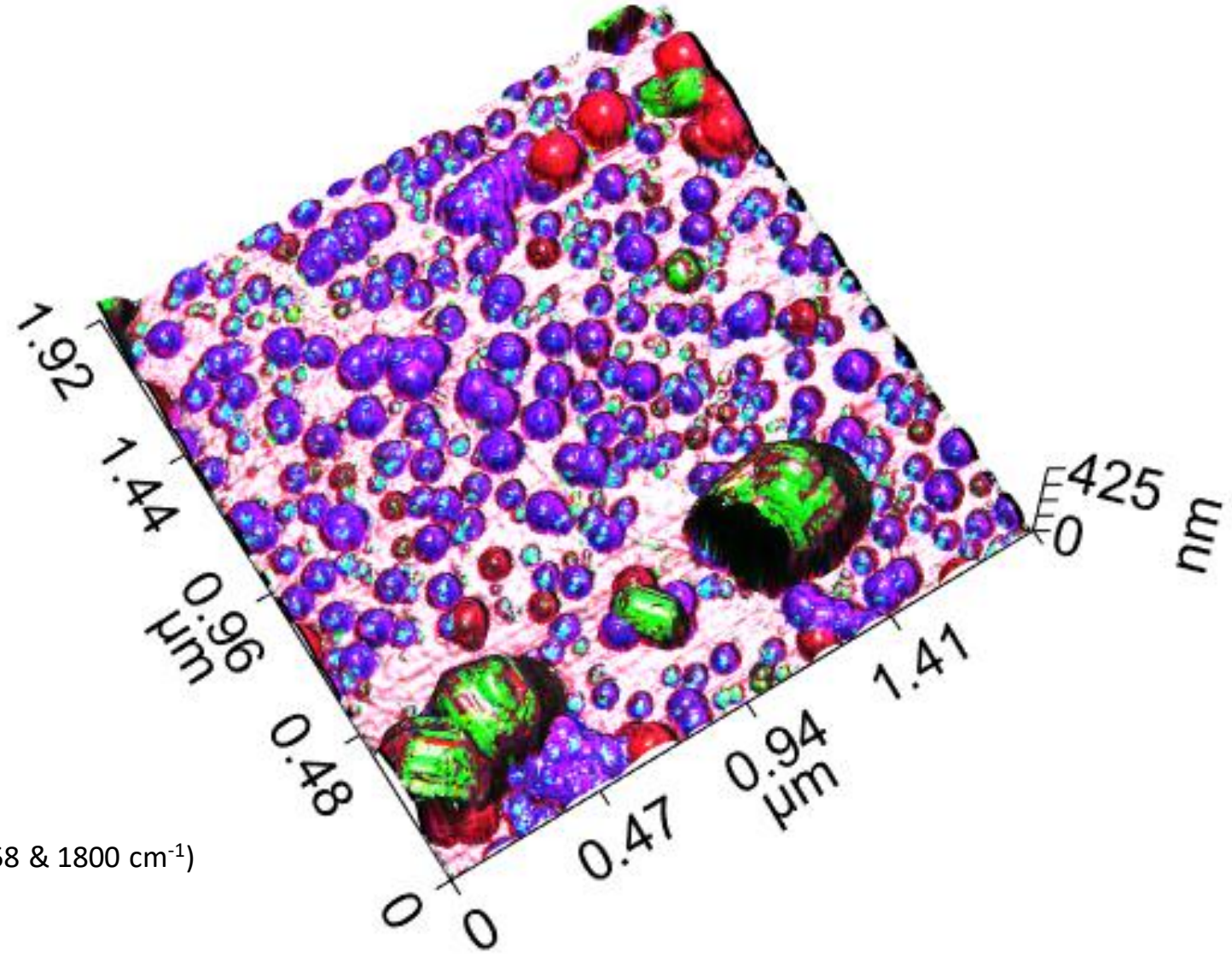
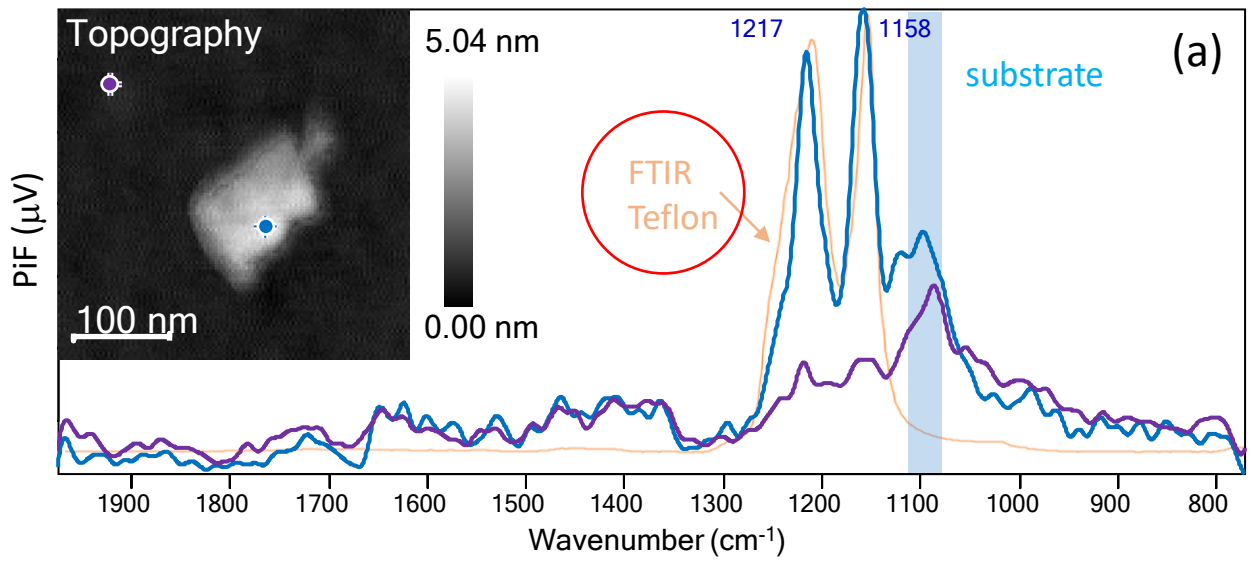
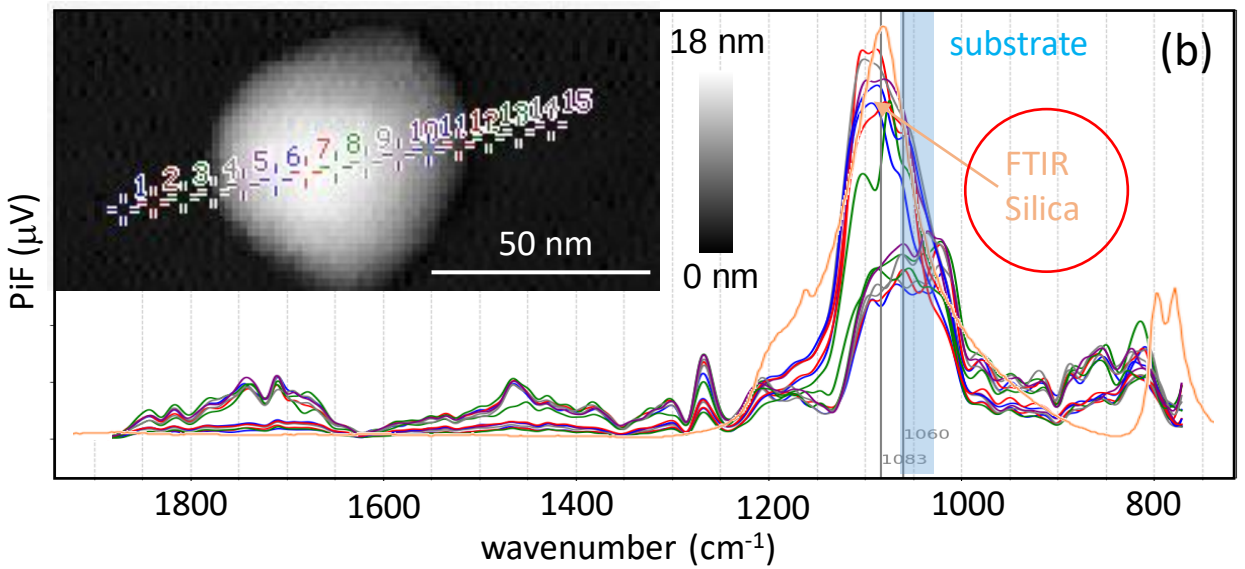
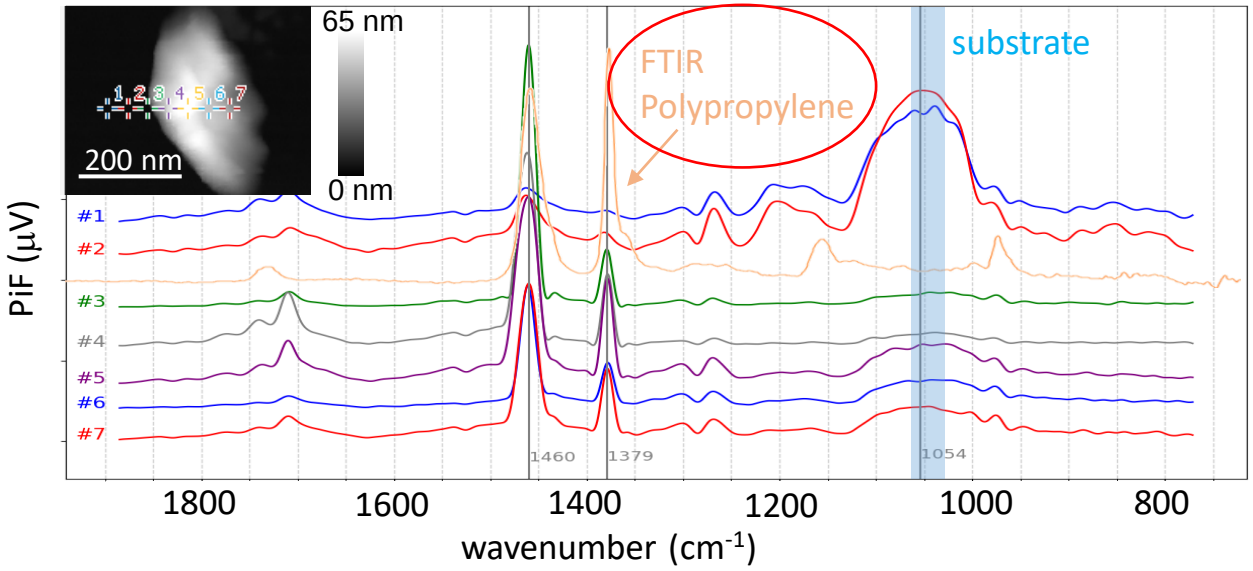
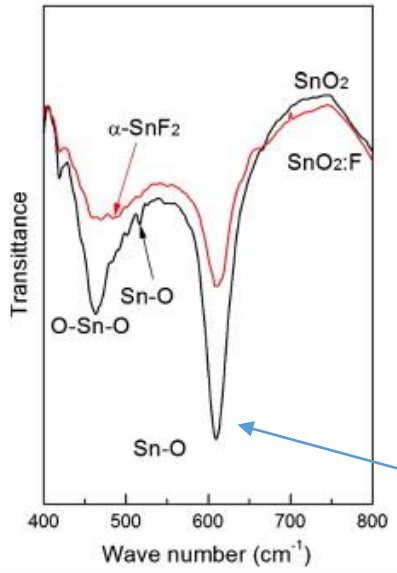


Nanoscale Defect Identification via PiF-IR Spectra







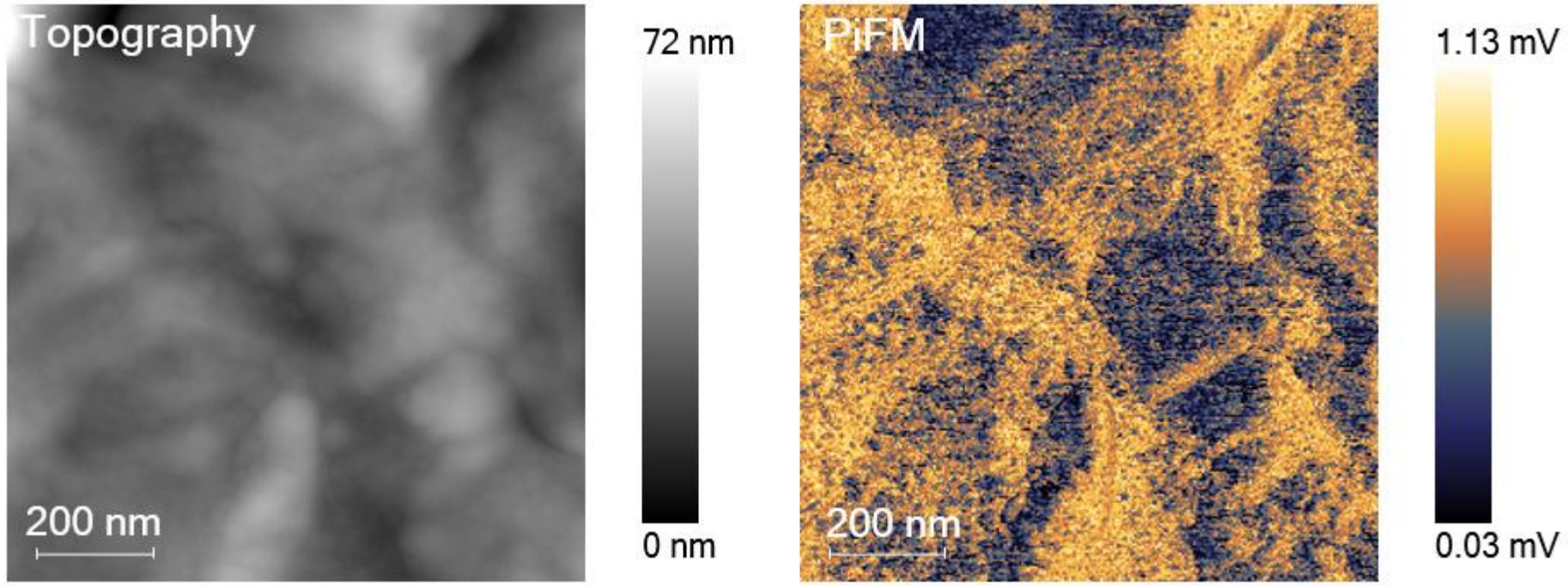


The characterization of fluorine doped tin oxide films by Fourier Transformation Infrared spectrum

Materials Letters
Volume 64, Issue 24, 31
December 2010, Pages 2707-2709

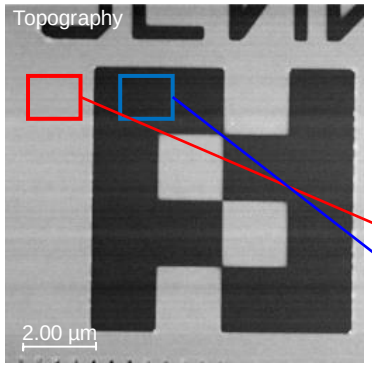
Sn-O band is accessible via a new laser.

Trace Residue Visualization & Identification



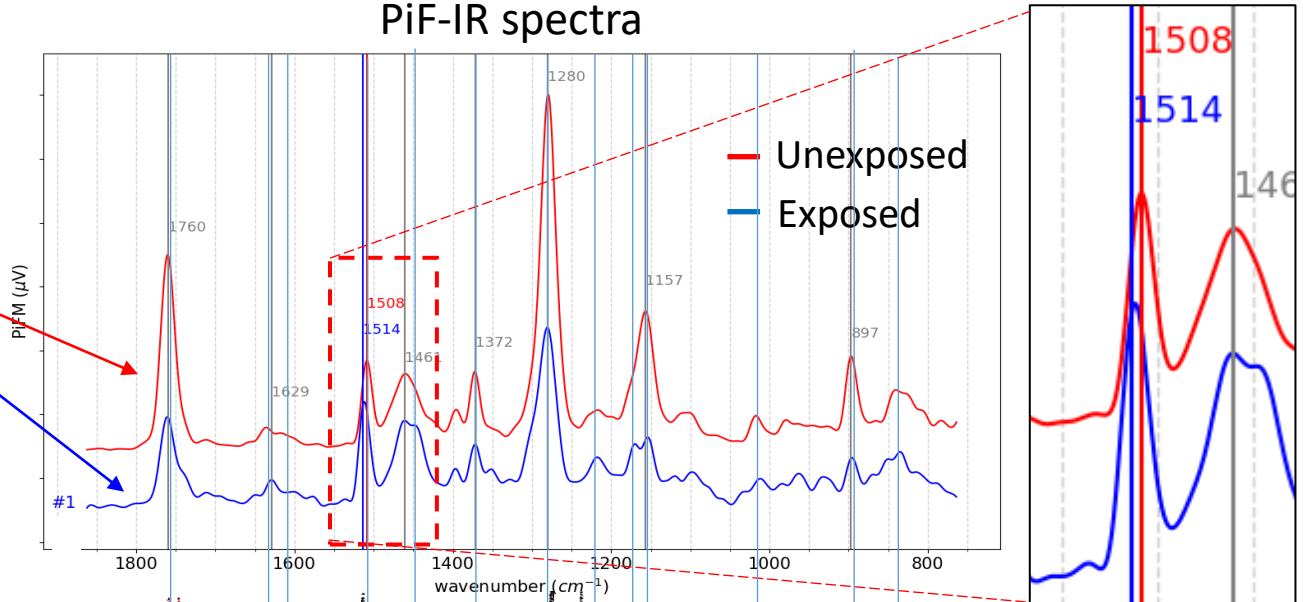
Monolayer of residue, which caused poor adhesion, identified via PiF-IR spectrum and mapped via IR PiFM.

Imaging of Latent EUV Images in TBOC CA Resist

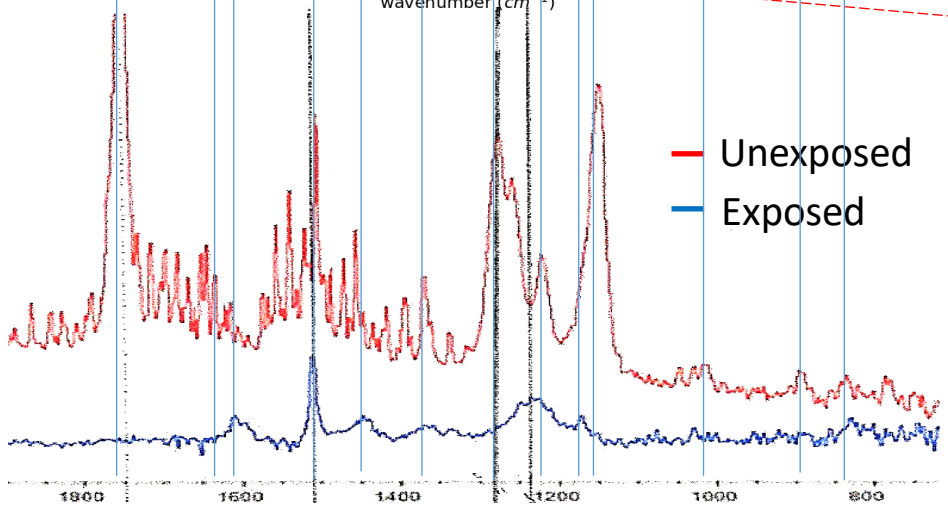


Exposure creates shrinkage, resulting in depression in topography.

PiF-IR spectra



FTIR spectra

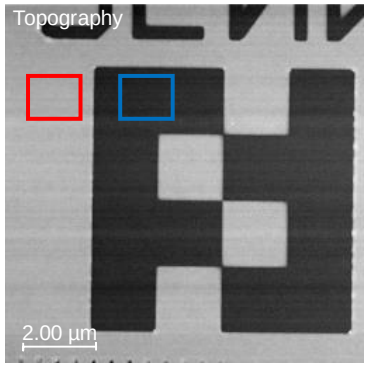


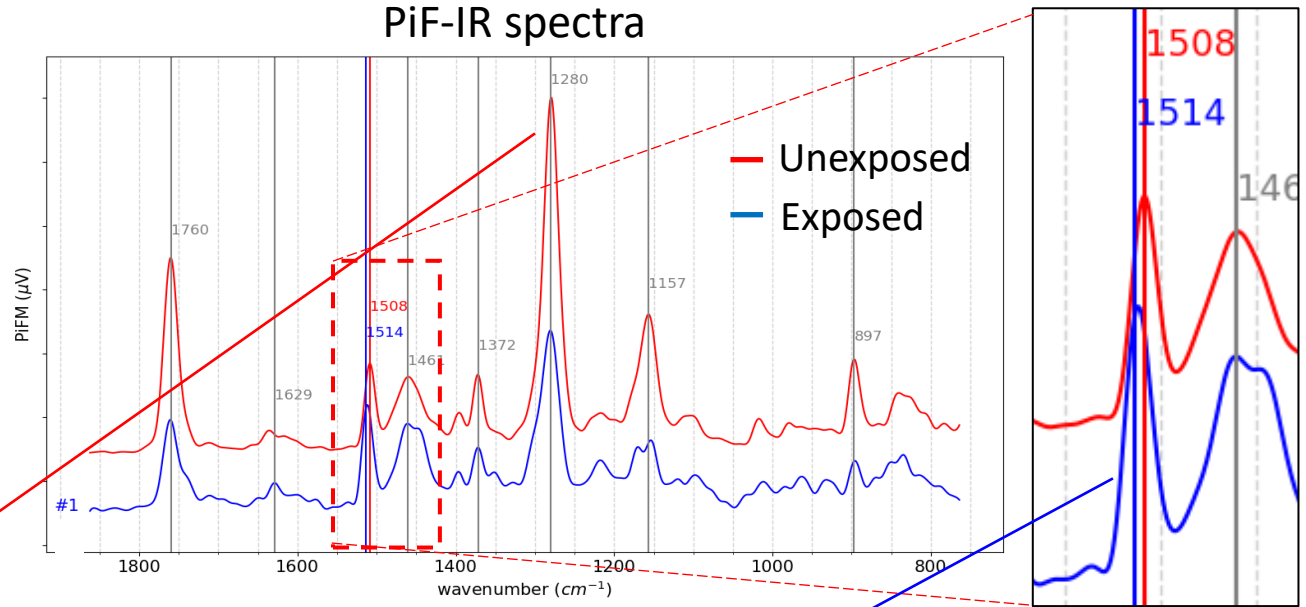
- Exposed to 13.5 nm EUV at ALS, Berkeley

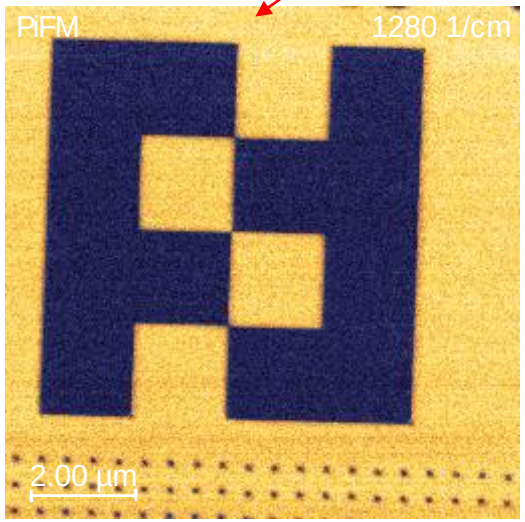
- PiFM can see chemical changes to molecular films

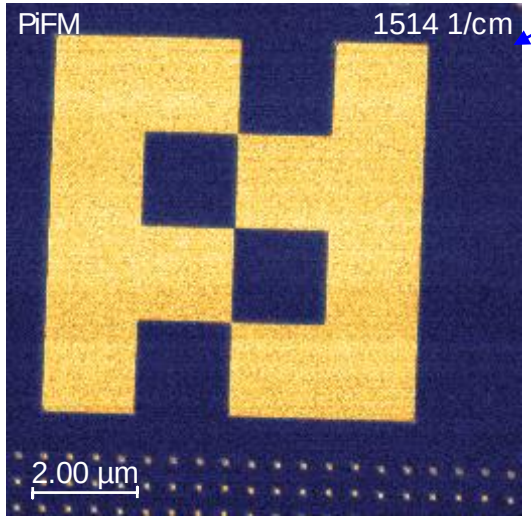
(collaboration with G. Wallraf, M. Sanchez, H. Truong – IBM Almaden)

Imaging of Latent EUV Images in TBOC CA Resist









- Exposed to 13.5 nm EUV at ALS, Berkeley

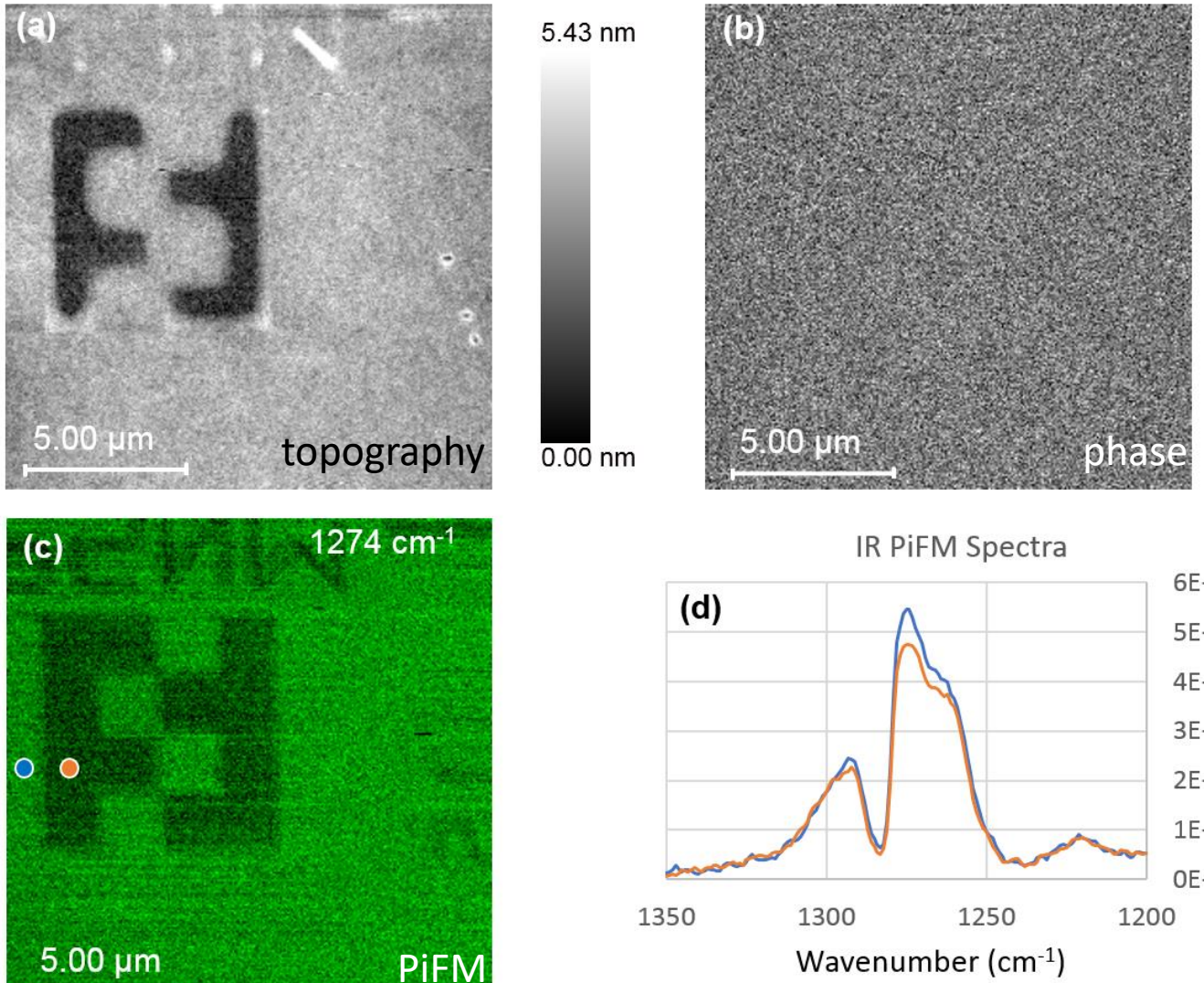
- PiFM can see chemical changes to molecular films

1280 cm^{-1}: highlights unexposed TBOC resist

1514 cm^{-1}: highlights exposed TBOC resist (peak shifts from 1508 to 1514 cm^{-1})

(collaboration with G. Wallraf, M. Sanchez, H. Truong – IBM Almaden)

Characterization of Low-dosage Exposure



Chemically amplified photoresist (tBOC)

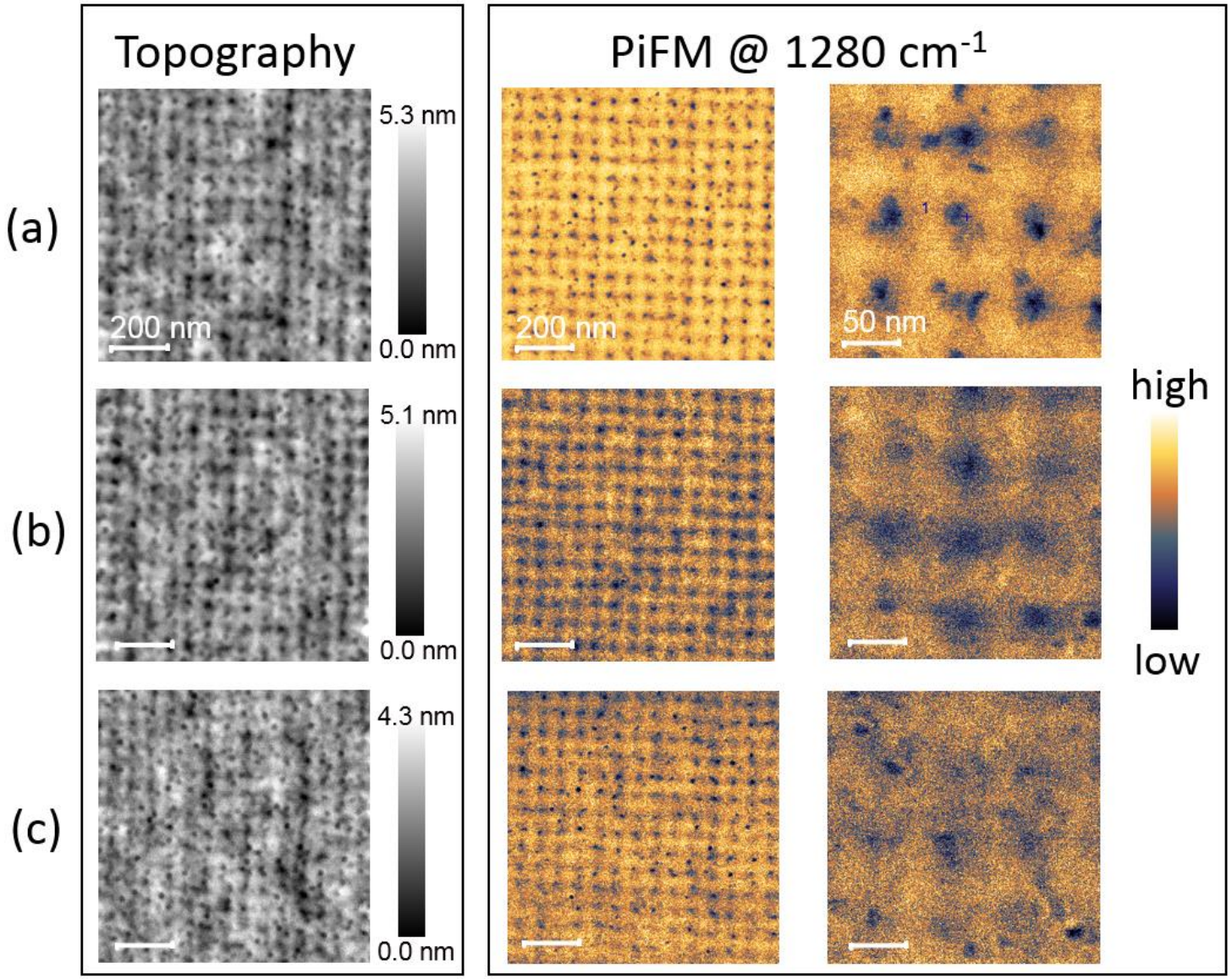
Exposed to EUV light (λ = 13.5 nm) at ALS Lawrence Berkeley National Laboratory.

Low dose exposure creates incomplete shrinkage, resulting in poor definition in (a). However, PiFM image at 1274 cm^{-1} highlights exposed regions (dark regions) by monitoring the drop in the IR absorption at 1274 band.

Blue – Unexposed

Orange – Exposed

Characterization of EUV Resist Exposure



Dose Level

90 mJ/cm²

78 mJ/cm²

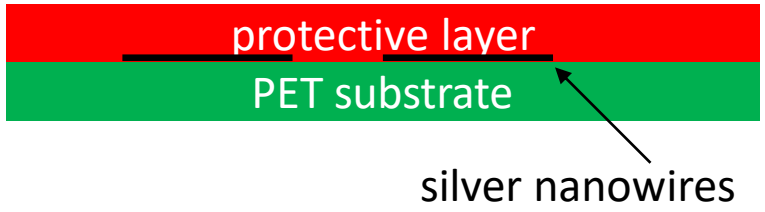
60 mJ/cm²

Topographical variations make it difficult to compare the effectiveness of dosage via AFM images.

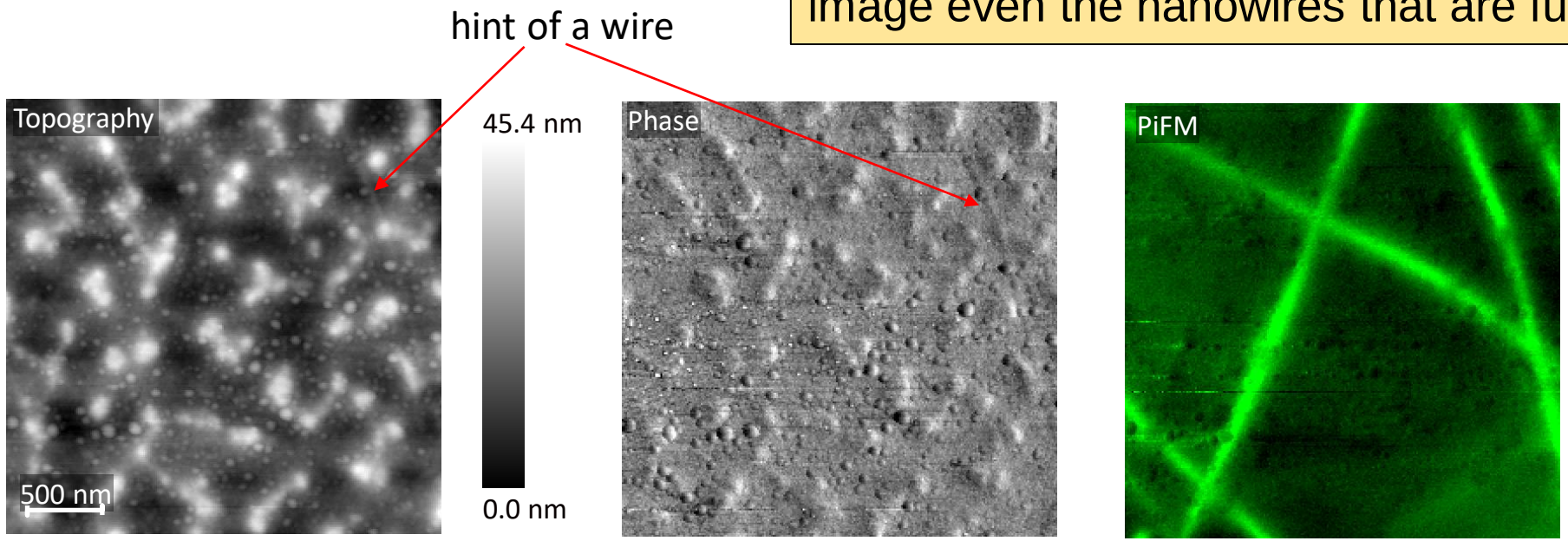
PiFM is immune from topographical variations and clearly show that 60 mJ/cm² is not sufficient dosage.

High resolution PiFM images show evidence of scatter.

Imaging Buried Conductive Layer



Metallic structures underneath a dielectric layer can be imaged by IR PiFM as demonstrated here with silver nanowires that are buried under 100 nm thick protective coating. While the topography and phase images can only show a hint of a buried silver wire that happens to be near the surface, PiFM can image even the nanowires that are fully buried.



Thank You

Email: info@molecularvista.com
Website: www.molecularvista.com