Facet-Specific Chemistry of Noble Metal Nanoparticles Using an Enhanced Scattering Infrared Scanning Near-Field Optical Microscope

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Purpose

- Detect and visualize explosives spectroscopically at high spatial resolution with high sensitivity.
- Determine the binding configurations of molecules on catalytic nanoparticles

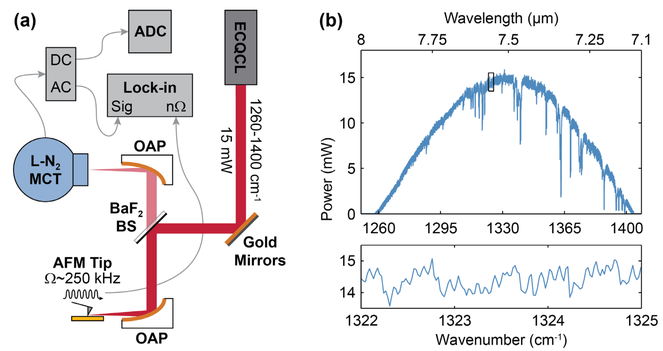
To accomplish this, we have developed a rapid and robust scattering infrared near-field optical microscope (*s*-IR SNOM) with exceptional spectroscopic identification and spatial resolution, combining atomic force microscopy with quantum cascade lasers (EC-QCL)

Key Successes

- Mapping of the NO_2 fingerprint region of pentaerythritol tetranitrate (PETN) and Research Department Explosive (RDX) on gold with spatial resolution of 25 nm, signal-to-noise ratio (SNR) >50, and spectral resolution <0.2 cm^{-1}
- Successful integration of EC-QCL into *s*-IR SNOM
- Development of model to deconvolute intrinsic lineshapes from non-resonant background scatter in data

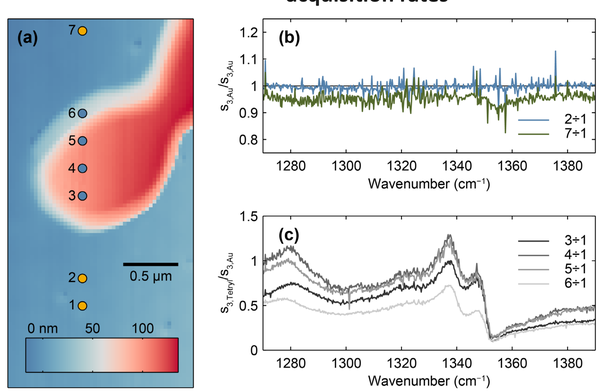
Research Accomplishments

Integration of EC-QCL with *s*-IR SNOM

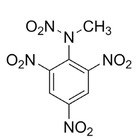


(a) Instrument configuration showing EC-QCL integration. (b) Sharp dips in the tuning curve are caused by atmospheric water absorption and used as references to calibrate the wavelength. Small oscillations in the power (bottom) are not noise, but are from reproducible mode-hops within the cavity.

Demonstrated signal reproducibility and high SNR at rapid acquisition rates

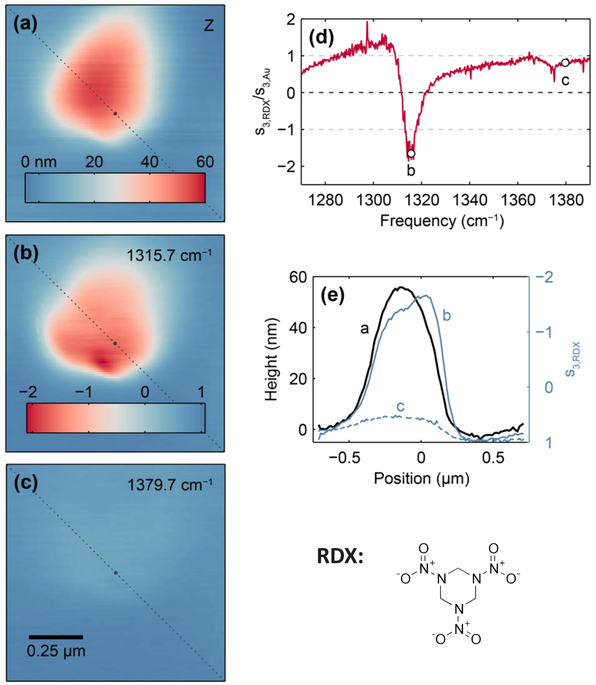


Tetryl:



(a) Atomic force microscope (AFM) tapping mode topography image of tetryl on gold. (b) Spectral scans taken at positions 2 and 7, normalized to spectral scan taken at position 1. (c) Spectral scans taken at positions 3-6 on top of the tetryl island do not change with position.

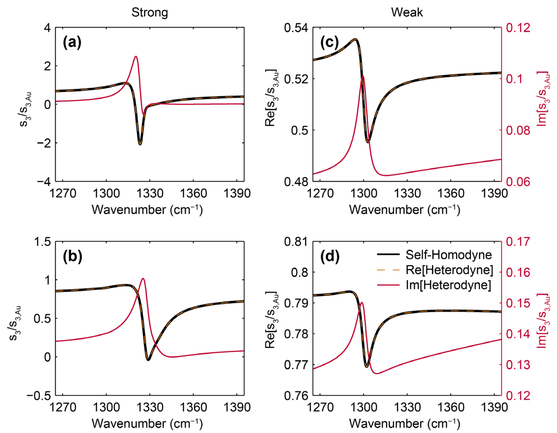
Chemical imaging of 50-attogram RDX particle



RDX:

(a) AFM topography of RDX on gold. (b,c) *s*-IR SNOM images taken at two different frequencies as indicated in the spectrum in (d). (d) Spectrum taken on center of RDX island. (e) Line scans across the diagonal of each image (indicated by dashed lines with a dot at the 0 position).

Extended *s*-IR SNOM modeling framework to interpret spectra from strong absorption resonances



Modeled *s*-IR SNOM signals for absorption resonances with strong and weak oscillator strengths. (a,c) finite-dipole tip model. (b,d) point-dipole tip model. Best agreement with experimental data is obtained with finite-dipole models.

Outcomes

- 3 peer-reviewed journal papers (1 published, 2 in preparation)
- 10 conference presentations
- 6 conference proceedings

Next Steps

- *s*-IR SNOM modularized to allow incorporation of EC-QCLs of different wavelengths; with appropriately selected laser can have applications in catalytic transformations, aerosol characterization, and national security
- Apply technique to catalytic systems beginning with examination of CO-binding configurations on different facets of noble metal nanoparticles
- *s*-IR SNOM system incorporated into EMSL as a user-accessible capability
- Complex index of refraction measurements position capability for Department of Homeland Security, National Nuclear Security Adminstration funding

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