9. Development of Optical Methods for Chemical Sensing

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Objective: To develop new techniques based upon absorption spectroscopy for sensitive and selective chemical sensing.

Problem: This project is funded by the Department of Energy with the goal of developing novel chemical sensing technologies to clean up the Nation's Cold War legacy. Supplemental support by NIST's Advanced Technology Program is directed towards developing ultra-sensitive optical techniques for probing the surface chemistry of SiO_2, which plays a critical role in microelectronics, chemical separations, environmental chemistry and chemical sensing.

Approach: Cavity ring-down spectroscopy (CRDS) measures the optical absorption of gases with extremely high sensitivity by utilizing the photon decay time in a high-finesse optical cavity as the absorption sensitive observable. We are developing a novel implementation of CRDS, termed evanescent wave cavity ring-down spectroscopy (EW-CRDS). This approach extends the CRDS technique to surfaces and condensed media. EW-CRDS utilizes novel optical cavity designs that employ total internal reflection (TIR) at ultra-smooth surfaces. These surfaces have a root-mean square surface roughness of typically less than an atomic diameter, thus enabling the realization of ultra-low loss optical resonators. Applications for two cavity designs are currently being explored. The first design is a miniature monolithic TIR-ring cavity (typically made of fused silica or other low loss optical material) that employs photon tunneling for excitation and detection of cavity modes. This system provides broad

Analyte Detection with Non-specific Binding Matrix on Fused Silica

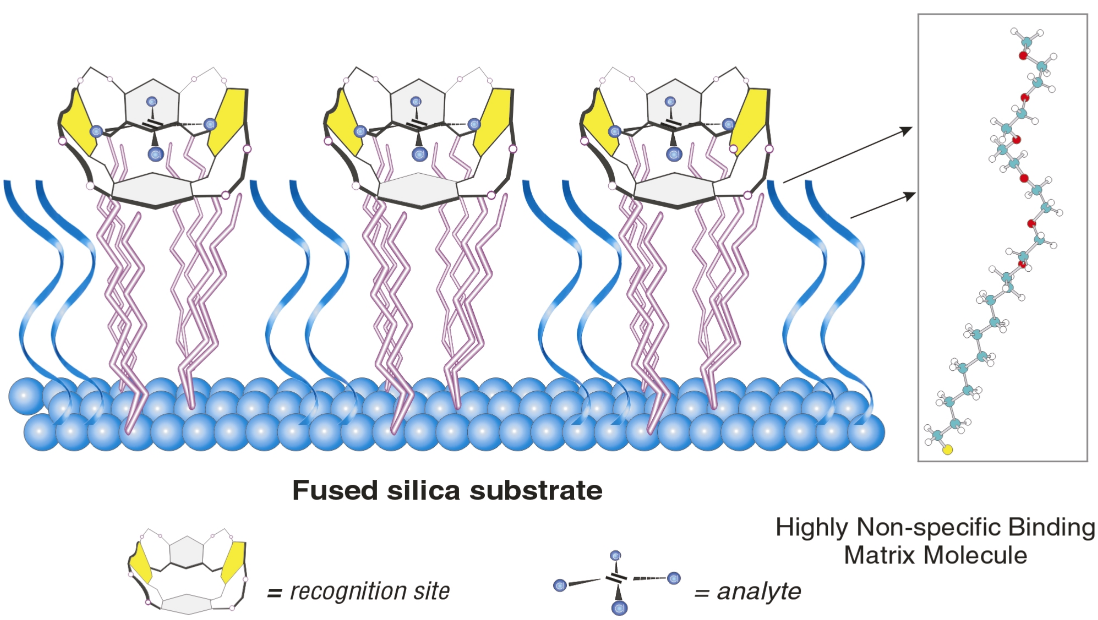

Figure 1. Molecular recognition scheme for chemical selective sensing at the surface of an EW-CRDS resonator. The target analyte is selectively adsorbed on the bucket-shaped molecule. The remainder of the sensing surface is covered with a matrix that inhibits non-selective adsorption.

spectral bandwidth and thereby allows multiple surface species to be probed with a single device. The second design is a monolithic folded cavity that has a narrow bandwidth yet simplified operation. sensor surface. EW-CRDS provides a new tool for fundamental studies of surface chemistry and physics, while forming the basis for a new chemical sensing technology.

Results and Future Plans: Over the next few years, we will combine the sensitivity of EW-CRDS with the selectivity of molecular recognition chemistry by functionalizing the ultra-smooth TIR surfaces of EW-CRDS resonators. We will also explore the formation, structure, and application of

Extreme sub-monolayer detection sensitivity has been demonstrated with both designs, along with the ability to determine molecular orientation at the

nano-structured EW-CRDS surfaces. Novel experimental and theoretical projects abound, including studies of the surface chemistry and physics of small molecules or molecular-recognition systems (including biological systems), surface optical activity, and optical properties of nano-structures. Collaborations with industrial partners, national laboratories, and academia are expanding the breadth and future of our research.