NANO HIGHLIGHT

Plasmonic Nanostructured Devices for Chemical and Biological Sensing

NSF NIRT Grant ECS-0403865

PIs: **Hong Koo Kim, Hrvoje Petek, David Waldeck, Rob Coalson, and Gilbert Walker**
University of Pittsburgh

This NIRT project focuses on investigating the fundamentals of plasmonic phenomena in nanoscale metallic structures and exploring the use of plasmonic chip technologies in bio-chemical sensing. We have investigated metal nanoslit arrays as a base structure that provides wavelength-dependent transmission of light via plasmonic interactions. We have analyzed the spatial and temporal evolution of surface plasmon resonances occurring in various regimes of transmission spectra. The finite-difference-time-domain (FDTD) analysis of plasmonic fields, charges and energy flow reveals that different modes of surface plasmon resonances involve different sections of metal surface, an important finding for optimally designing plasmonic nanoaperture structures for sensing applications. In experimental studies, we have measured the distributions of the fields (in the near to far field regime) emanating from the apertures by employing an interference technique in conjunction with a scanning nanoprobe (Figure 1a). We have also imaged the plasmon dynamics (spatio-temporal evolution) by recording a movie with an unprecedented time resolution (330 attosecond per frame) (Figure 1b). These visualizations allow us insights on plasmon characteristics, such as energy dissipation and concentration, decoherence, spatial propagation and plasmon-plamon interferences.

We have chemically modified the metal nanoslit array surface using thiol-based chemistry, and studied the surface binding effects on the optical transmission. We have observed a major redshift (15nm) of surface plasmon resonance (SPR) wavelength when a self-assembled monolayer (SAM) of carboxyl-terminated alkanethiol (~1nm thick) was formed on Au-coated Ag nanoslit array surface (Figure 2). The sensitivity of this nanoslit-array-based SPR technique is measured ~1000nm/RIU (RIU: refractive index unit), which is significantly better than the conventional grating-based SPR (400nm/RIU) and the nano-hole array case (500nm/RIU). Metal nanoslit arrays offer a new strategy for massively parallel detection of chemical and biological analytes. In addition, the nanoslit arrays are amenable to miniaturization into a densely integrated sensor chip.

References

[1] Z. Sun, Y.S. Jung, and H.K. Kim, "Dynamic evolution of surface plasmon resonances in metallic nanoslit arrays," Applied Physics Letters 86, 023111 (2005).
[2] A. Kubo, K. Onda, H. Petek, Z. Sun, Y.S. Jung, and H. K. Kim, "Femtosecond imaging of surface plasmon dynamics in a nanostructured silver film," Nano Letters, 5, 1123 (2005), also featured in Photonics Spectra, page 104, September 2005.
[3] A. Kubo, K. Onda, H. Petek, Z. Sun, Y.S. Jung, and H. K. Kim, "Imaging of localized silver plasmon dynamics with sub-fs time and nanometer spatial resolution," in Ultrafast Phenomena XIV. T. Kobayashi, T. Okada, T. Kobayashi, and S. De Silvestri eds., Springer-Verlag, Berlin (2005), 645.
[4] Y.S. Jung, Z. Sun, H.K. Kim, P. Kaur, L. Wang, and D.H. Waldeck, "High-sensitivity surface plasmon resonance spectroscopy based on metal nanoslit array," (in preparation).

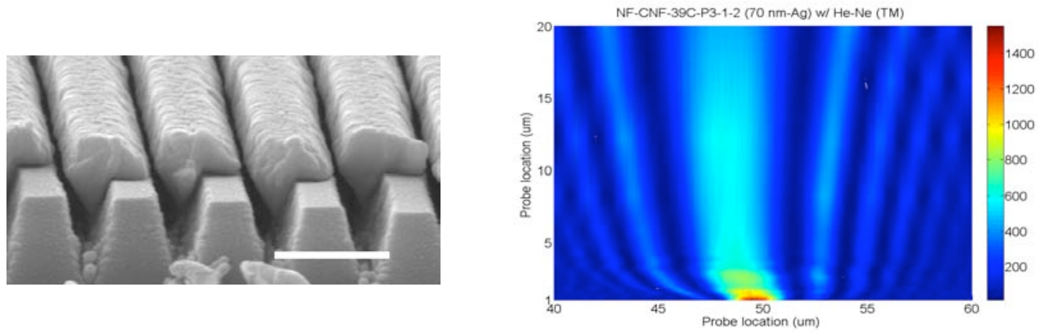

Figure 1a. SEM image of a silver nanoslit array formed on a mesa-etched quartz substrate (left). The scale bar is 500 nm, and the minimum slit width is 30-50nm. Optical transmission through a three-slit array (right): an interference pattern between a freely transmitting wave through a thin metal layer and a wave emanating from the nanoslits. An image obtained with a scanning nanoprobe.

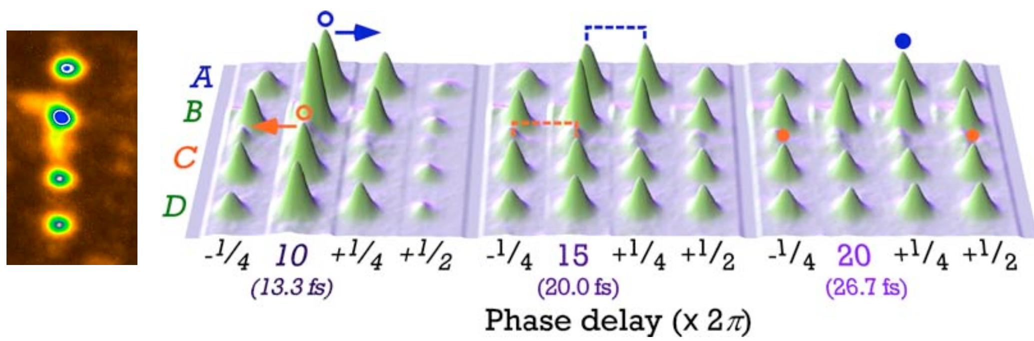

Figure 1b. Plasmon dynamics: selected frames from a time-resolved photoemission electron spectroscopy (TR-PEEM) movie showing the phase and amplitude evolution of individual plasmon modes in 330 attosecond per frame segments.

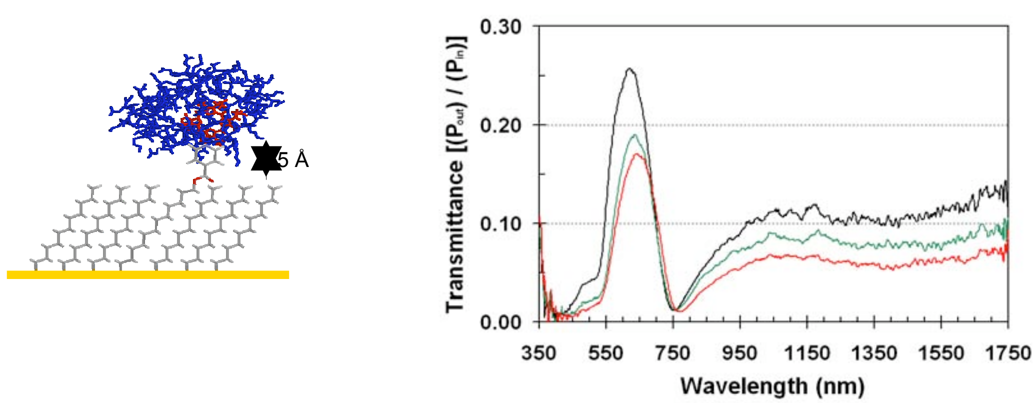

Figure 2. Chemical modification of metal surface (left). Transmission spectra of a Au-coated Ag nanoslit array (right): before modification (black) and after formation of a thiol-based SAM (green) and a poly-L-lysine layer (red).