Plasmonic Metamaterials for Enhancement of infrared and Photothermal Spectroscopy of Biomolecules

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Vibrational infrared spectroscopy is an exquisitely specific tool for studying biomolecules. The molecules are characterized by a large number of normal modes, which are intrinsic to proteins nucleic acids, lipids and metabolites. The absorption cross-sections of some infrared active modes are nearly ten orders of magnitude greater than the corresponding Raman cross-sections. However, that is still seven orders of magnitude smaller than cross-sections in fluorescence spectroscopy, which requires a molecular label.

A collaboration at Boston University (Altug, Averitt & Erramilli) has been designing Plasmonic Metamaterials for enhancing specific protein normal modes. A combination of simulation, followed by electron-beam lithography, and infrared microscopy has shown that the signals can be enhanced by more than five orders of magnitude, with demonstrated detection and characterization of proteins at the attomole level. The enhancement occurs in the near-field, and is due both to collective and local effects. Unlike other methods of ultrasensitive detection, infrared spectroscopy also provides information about protein conformational changes, and promises to provide a new tool for studying protein function. New detection methods based on the Photothermal effect appear to be even more promising. The advent of new infrared sources, based on accelerators, quantum cascade lasers and ultrafast femtosecond lasers, means that the field of Plasmonic infrared spectroscopy is poised for takeoff.