Bioaerosol Detection via Nanoparticle Surface Enhanced Raman Spectroscopy

Awardee: Mary Laucks – postdoc, UW, Department of Chemical Engineering
Mentors: E. James Davis – UW, Cindy Bruckner-Lea (for Mark Kingsley)- PNNL, Richard Zheng –PNNL

Project Summary:

Conventional methods of sampling and analyzing bioaerosols do not presently provide rapid identification of potential bio-threats. Time-of-flight mass spectrometers have made possible the rapid detection of inorganic and some organic molecules, but these systems ablate the particles and the identification of the fragments would be especially difficult for bioaerosol particles. To detect small quantities of biomaterial against a high background of other commonly occurring atmospheric particles, any potential bio-detection system would require both high sensitivity (small quantities of material present) and the ability to separate the signal of interest from the background (much biomaterial is similar). Rapid identification requires that sampling and analysis occur in the same instrument.

The idea of this project is to study the potential of surface enhanced resonance Raman spectroscopy (SERRS) or surface enhanced Raman spectroscopy (SERS) as a method for detecting bioaerosol. We will use the recent advances in nanosurface techniques to produce a surface onto which we can deposit sample bioaerosol and chemically analyze it using SERRS or SERS.

We have made significant progress on the first phase of our research plan, which was to identify a surface preparation that would provide significant enhancement when a known material was adsorbed on it. As a baseline study, we used silver colloid suspensions (50-75 nm) to demonstrate enhancements of pyridine on the order of 10^9. We were able to detect the ~1050 cm^{-1} peak in a 10^{-9}M pyridine solution and compare it to the same peak from a non-enhanced (no silver colloid present) 1M solution of pyridine. For these experiments we used optical glass Raman cuvettes and the 514.5 nm line of an Ar ion laser. From this baseline study we found that our setup was able to detect nanomolar levels of pyridine, demonstrating that we will be able to detect these levels of other materials if we achieve similar enhancements on prepared surfaces.

We have also prepared silver film surfaces by etching them in nitric acid solution and have demonstrated large enhancements of the same pyridine peak on these surfaces. The prepared Ag surface was soaked in a 10^{-4} M solution of pyridine and then washed and air-dried. This enhancement was not measurable because we could not detect the pyridine peak on a non-etched Ag surface, even though we deposited pure pyridine (~13M) on it. However, we can say that the enhancement was larger than $7x10^5$. Figure 1 shows the comparison between pyridine adsorbed on a smooth, non-etched Ag surface and on a prepared (modified) surface.

In addition to pyridine we have deposited 100 nm latex nanospheres on the nitric acid-etched Ag surface and were able to see some enhancement. Particles smaller than 1 micrometer are very difficult to detect (and have not been detected to our knowledge) with Raman scattering, but Figure 2 provides evidence that nanometer particles may be detectable.

Another aspect of our research to date has been the study of the Raman scattering from common bacteria so as to determine if their spectra are different enough to be "fingerprints" for each type of bacteria. Dr. Cindy Bruckner Lea's group at PNNL has provided us with samples of gram negative (*E. Coli*), gram positive (*Staphylococcus epidermidis*), and spore (*Bacillus globigii*) bacteria as agreed upon in our proposal. We used 785 nm laser radiation to study these samples, but as yet have not been able to see any spectra. We are modifying our optics to allow the collection of more scattered light from the samples in hopes of increasing our signal-to-noise ratio. So far we have only deposited these bacteria on non-prepared surfaces, but we plan to test the enhanced surfaces soon.

We are planning to do a study of the surface characteristics of the etched Ag films using SEM, so as to be able to identify which surface preparation is optimal for enhancement. Our collaborator, Dr. Richard Zheng, at PNNL will provide some time on their SEM for this purpose.

We hope to be able to show enhancements of biomaterial on Ag surfaces soon.

Publications, Presentations, Proposals:

Proposals:

1) A team grant entitled, "Bioaerosol Detection via Nanoparticle Surface Enhanced Raman" was submitted by E. James Davis, Francois Baneyx, and Daniel T. Schwartz to NSF ($749,711) for 36 months funding (denied).

2) A single investigator grant is in preparation to NSF by E. James Davis for 36 months of funding (not yet submitted).

Presentations: Center for Nanotechnology, NSF site visit, presented by Atanu Sengupta (graduate student) titled, "Chemical Analysis of Nanogram Quantities of Matter by Raman Enhancement using Nanoscale Surfaces"

Papers: none so far

Funding that has resulted from this research:

None so far

Figures:

Figure 1. Raman spectra of pyridine on two surfaces. On the modified surface we adsorbed 10^{-4} M pyridine and on the original surface we adsorbed pure pyridine (~13M). An enhancement of about 10^5 can be seen.

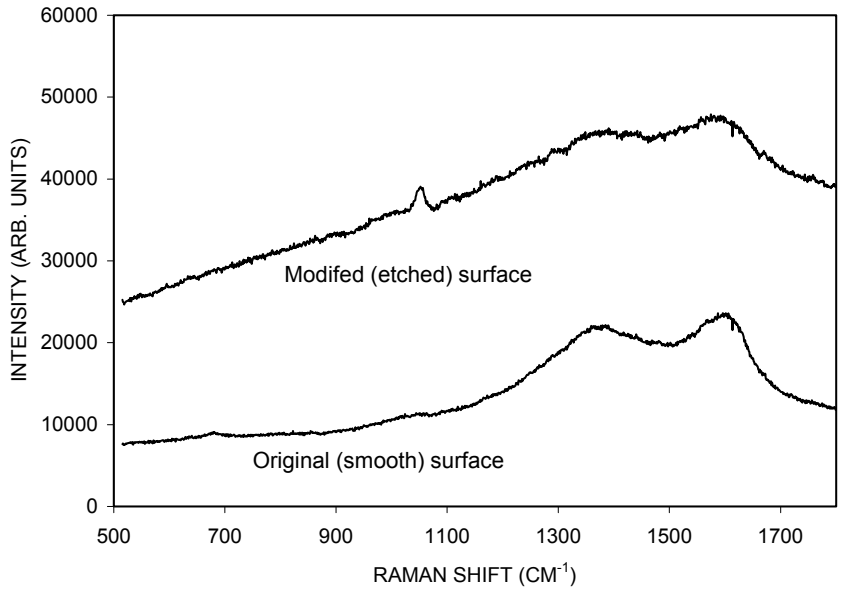
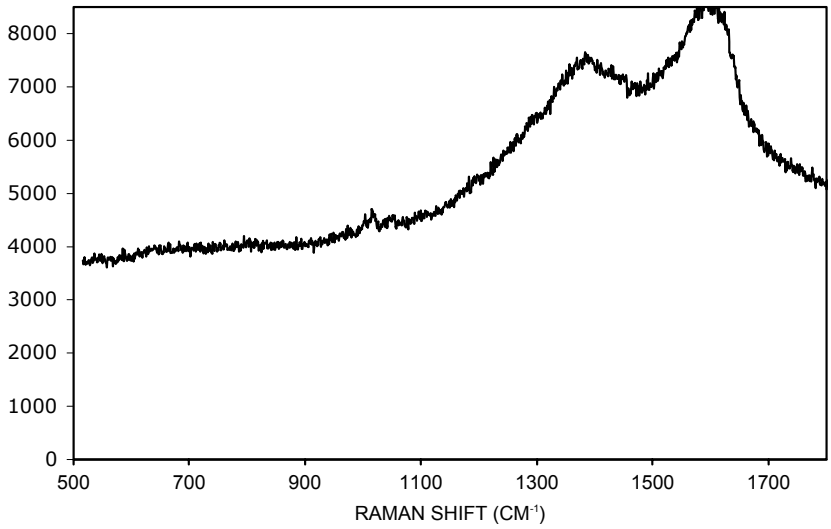
Figure 2. Preliminary data for 100 nm latex spheres deposited on a prepared Ag surface shows a small peak near 1000 cm^{-1}.