The Aerosol Society
the science of airborne particles

Research Grant – Successful Submission

Miss Stella Corsetti – PhD Student University of Dundee – Awarded £2500

Surface Enhanced Raman Spectroscopy (SERS) of single aerosols

1. Aim of the Project

Surface Enhanced Raman Spectroscopy will be used to amplify the spectroscopic signatures of chemicals contained in multiphase aerosols. Droplets containing silver nanoparticles will be trapped, by using optical tweezers, and their Raman signal collected.

The aim of this project is to enhance the resolution in the measurements and to look at the possibility of trace small amount of chemicals in multicomponent micron size droplets.

2. Programme of Work

This project is an extension of my PhD work. I am studying the evaporation of liquid aerosols, primarily the evolution of binary phase biofuel mixtures. In particular, I have studied the evaporation as a function of the biofuel (ethanol) to conventional fuel ratio. However, ethanol absorbs a non-negligible quantity of water, which could be a problem for mixing with gasoline (which has a very low miscibility with water). This proposal aims to use surface enhanced Raman spectroscopy (SERS) to try and make much more sensitive measurements and to look at the possibility of trace elements in the mixtures, such as water. I see evidence of contaminants in the evaporation traces, but have not yet directly measured them. In addition, it is challenging to get spectra from such droplets due to their fast evaporation (a single gasoline droplet of 50 micron in diameter takes 0.4 sec to evaporate at 7C in a clear environment). With SERS it would be possible to get a strong signal more quickly than conventional techniques.

The work will be carried out in the University of Dundee, in the optical manipulation group of my supervisor David McGloin.

The project will be divided in 4 phases:

Phase one: setup of the system. A Raman line will be added to the existing optical tweezers system I used to carry out measurements on evaporation of biofuel droplets. In addition, a stabilisation of the environment in the trapping chamber will be provided. A system to control the relative humidity (RH) and the nitrogen flow around the droplet will be set up and the temperature in the chamber will be monitored.

Phase two: A system to efficiently generate droplets containing nanoparticles will be developed.
A dark field illumination system to detect the nanoparticles contained in the droplet will be used.

Phase three: Preliminary measurements to test the system will be done. Raman signals from water aerosols will be collected to be compared with the enhanced signal from water aerosols containing silver nanoparticles. We will also make comparisons with cavity enhanced Raman spectroscopy techniques. A study of the efficiency of SERS on aerosols will be done.

Phase four: Raman signal from binary mixtures aerosols containing silver nanoparticles will be collected and the aerosols temporal evolution will be studied.

This proposal is technically challenging, as placing such nanoparticles into the droplets could alter the trapping efficiency, the evaporation dynamics of the droplets through heating, and could render the droplets untrappable – but within the context of a small scale project, the pay-off is significant: a new tool with ultra sensitivity for probing the dynamics of rapidly evaporating aerosols in realistic environmental conditions. As such it is high risk, but high reward.

The tool that will be developed has much broader applicability that the immediate target project, and will in future be used to study a wide range of aerosol processes, if the approach is successful. I would suggest that it could be used to enhance droplet lasers, enable new studies of bioaerosols and also offer some interesting opportunities for using such particles as ice nucleators, with enhanced Raman build into the probing mechanisms.

3. Potential Applications

The SERS-Tweezers setup should allow us to handle droplets and to probe their evaporation and coagulation dynamics as a function of droplets composition and size with high resolution. Such kind of system can be use to study the dynamic behaviour of volatile components, such as short chain hydrocarbons and alcohols, of interest in the combustion field. It could also provide an efficient tool to understand better atmospheric phenomena. For example, the effect of small amount of organic surfactants on the evaporation rate of water droplets, which affect cloud formation.

The project will involve an active collaboration between my two supervisors David McGloin, in the University of Dundee and Johannes Kiefer, in the University of Bremen. Dr. David McGloin is an expert in optics, photonic and he is leader of an optical manipulation group. Prof Johannes Kiefer is an expert in spectroscopic techniques, in particular Infrared and Raman spectroscopy.

By using this technique it would be possible to enhance significantly the resolution in the measurement of very small amount of chemicals and contaminants contained in single droplets, and do so on fast timescales. This would be a benefit in a variety of academic and industrial fields. In medicine, for example, it could be use to do sensitive measurements on aerosols for drug delivery.

The duration of this project will be 6 months.