Microfabricated, Low Power, Inorganic Water Quality Sensor based on Direct Current Argon Plasma Emission Spectroscopy

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Analytical water quality assessment is an extremely costly process that requires labor-intensive collection, transportation, and laboratory analyses of samples. In addition, even in the most careful of procedures, sample contamination can compromise the analysis. Clean sampling procedures, clean rooms, and super clean reagents and instruments are often required to analyze trace-level contaminants. Also, research laboratories currently employ sophisticated instruments to measure dissolved concentrations of inorganic and organic contaminants in our natural water systems. The cost associated with the purchase and maintenance of these instruments is extremely large. The development of an inexpensive multiple detector system that can routinely measure water quality parameters accurately, reliably, in situ, in real time, and at minimum cost would be an invaluable contribution to the field of environmental chemistry.

The primary objective of this project is to initiate the development of a microfabricated, low power sensor that utilizes DC argon plasma emission spectroscopy to monitor the inorganic chemical quality of water. The major components include: a sample delivery system, a DC plasma source, an argon reservoir and delivery system, optics (lenses, slits, mirrors), a diffraction grating, and a detector. The proposed microfabricated DC argon plasma emission spectrometer would significantly reduce the costs associated with environmental sampling. The labor costs for collection, transportation, and analyses mentioned above would virtually be eliminated by the proposed technology. Additional collection costs such as ship time on large sampling vessels (at a cost of thousands of dollars per day) would also be eliminated. Since the sample analysis is conducted in situ, the sample contamination effects described above would also be greatly reduced. A long-range goal of this project might be to engineer a functional microfabricated DC plasma spectrometer (made from either nontoxic or biodegradable components) that can be deployed in a manner that provides large-scale environmental monitoring directly from research laboratories that could be continents away. Finally, in addition to deployment in natural waters, the proposed system could be used in city water treatment plants or even in households to monitor the concentration of aqueous chemical species.

Project Update

During the first months of this project, we have been focusing on the development of a liquid electrode spectral emission chip (LEd-SpEC), which produces a microplasma between the anode and cathode. These are novel liquid anode and cathode electrodes, which attempt to avoid two problems facing the development of a micro-sized plasma device. Firstly, the liquid analyte is sputtered into the plasma from the cathode chamber elevating the need to develop a more complicated nebulizing system. Secondly, this liquid electrode system preserves the life of the electrode. It has taken a four mask process to produce this plasma chip. As shown in Figure 1, the device provides a reservoir and channels in a glass substrate, along with electrodes that bias the water sample. Liquid from the cathode chamber is sputtered into the discharge, for spectroscopic detection of impurities.

After developing the device, we used a small commercial spectrometer (Ocean Optics USB-2000) coupled to a fiber optic bundle located above the plasma to detect a Na analyte (concentrations < 10 ppm).

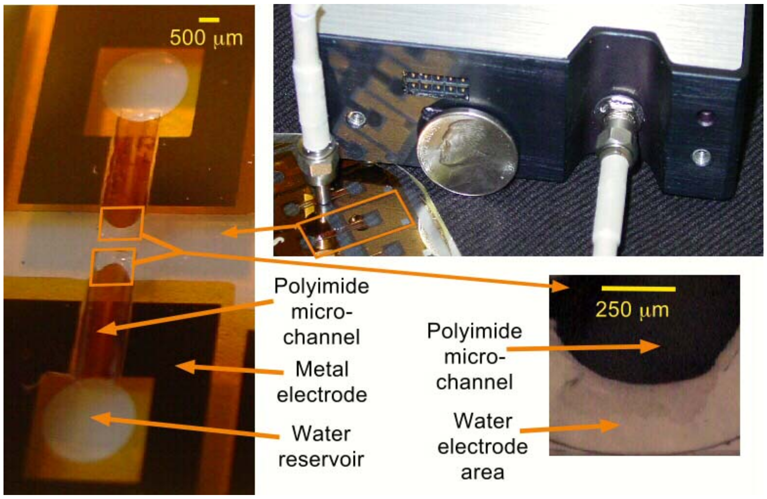

Fig. 1 Optical viewgraph of system and close-up view of the LEd-SpEC.

The optical spectrum from a sodium sample can be seen in Figure 2.

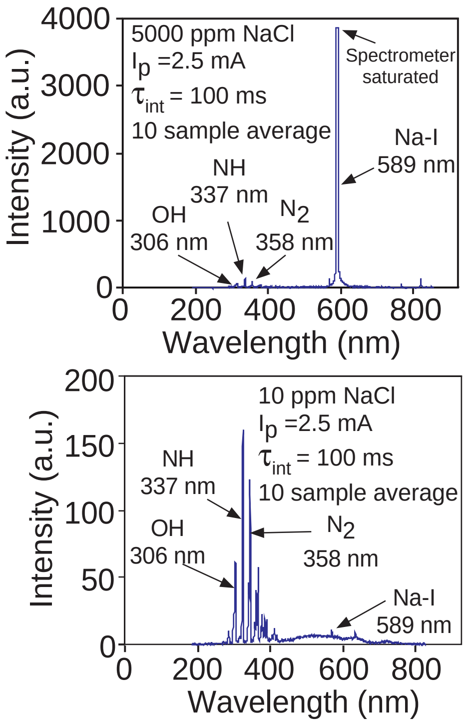

Fig. 2: Spectra for NaCl samples with concentrations of (a-upper) 5000 ppm, and (b-lower) 10 ppm.

We were able to develop a linear calibration curve for this system as shown in Figure 3. While these concentrations are not representative of very low ppb levels in real waters the results thus far are extremely promising. We are now in the process of further optimizing this system.

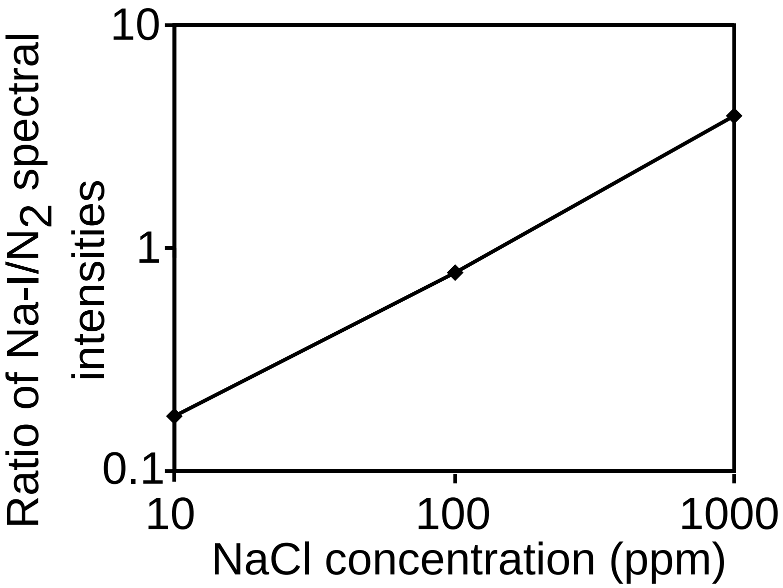

Fig. 3: Ratio of Na to N_2 spectral intensities as a function of NaCl concentration.

Optimization of system will include looking at the electrode configurations to determine proper spacing. Examining new wicking electrodes that will help in the further miniaturization of this system. We also need to increase sensitivities such that detection limits can be lowered. We also want to work with other metal species to determine if the device is also responding linearly with respect to concentration to other species. In addition, we would like to see if there are other contaminating species such as mixed electrolytes which would interfere with spectral interpretation. Lastly, we would like to move to the development of an on-board optical detector that would obviate the need to have a separate external fiber optic based detector.

We continued to be encouraged about our progress and believe that it will indeed be possible to develop a microscaled plasma detection system that will greatly reduce the costs associated with the field analysis of heavy metals. While we still have a long way to go in this pursuit our initial results are highly encouraging particularly with respect to the stability of the electrodes and the ability to sputter the sample from the cathode into the plasma without the need of a fancier nebulizer system. This would have complicated the structure of our final device.