Investigating the plasma-liquid interface using a 2-D bubble in a modified Hele-Shaw cell: First results

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The interaction of plasmas with liquid water is the basis of a number of new and exciting technologies. These technologies range from novel water purification methods to non-equilibrium chemical processing and plasma medicine. At the heart of the plasma-liquid interaction is the interface. Key physical processes that ultimately "activate" the liquid are believed to occur at this interface. The discharge plasma subjects the interface to energetic particle bombardment, UV radiation, locally high electric fields, electrolysis, and high temperature gradients. Indeed, it is this interaction that creates an active boundary layer. The active boundary layer itself is conjectured to be a thin region adjacent to the plasma-liquid interface that acts as a transfer vehicle—imparting energy and information from the plasma to the surrounding liquid. The key question is how do the physical processes occurring in this boundary layer give rise to large-scale changes in the bulk liquid. Physical processes known to occur at the interface and boundary layer include the production of radicals, species transfer, evaporation, fluid dynamical instabilities and gas-liquid mixing. Quantifying these processes is key to understanding the interplay between the plasma kinetics in the gas phase incident on the interface and the resulting multiphase processes occurring in the boundary layer and beyond.

Particularly problematic in the quest to understand the physical processes taking place at the interface is that unlike the gas phase there is a paucity of liquid phase diagnostics tailored to interrogate the plasma liquid interaction. The chief problem is that the intervening liquid precludes the use of electrostatic probes or optical methods. We are currently investigating the use of a modified Hele-Shaw cell for the purpose of reducing the dimensionality of the plasma interface problem, essentially interrogating a cross sectional plane of the plasma-liquid interaction.[1] This method reduces the thickness of intervening fluid thereby making the interfacial region accessible to optical interrogation. To date, we have demonstrated the functionality of the cell as shown in Fig. 1. Stable confinement of the bubble and plasma formation within the bubble has been demonstrated. We have also observed 2-d decolorization of momodel solutions induced by the local plasma discharge. The chemical probes will be used to directly study the activity of the boundary layer and to serve as a contrast agent to determine the spatial extent of the boundary layer. Ultimately the cell will be used to make absorption spectroscopy measurements so that we can directly measure radicals in the multiphase region around the bubble.

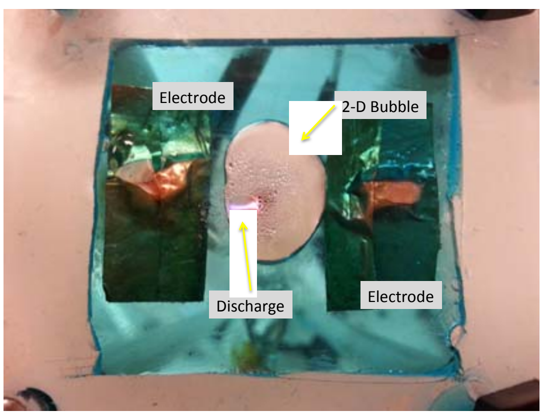


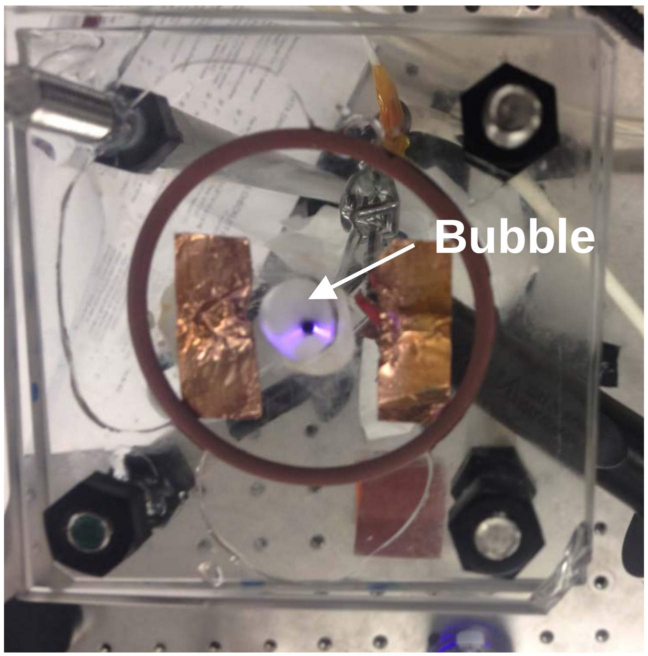
Figure 1 – 2-D bubble with plasma decolorization of Methylene Blue solution.

References

[1] C. G. Baig, et al, Korean J. Chem. Eng. **17**,169 (2000).

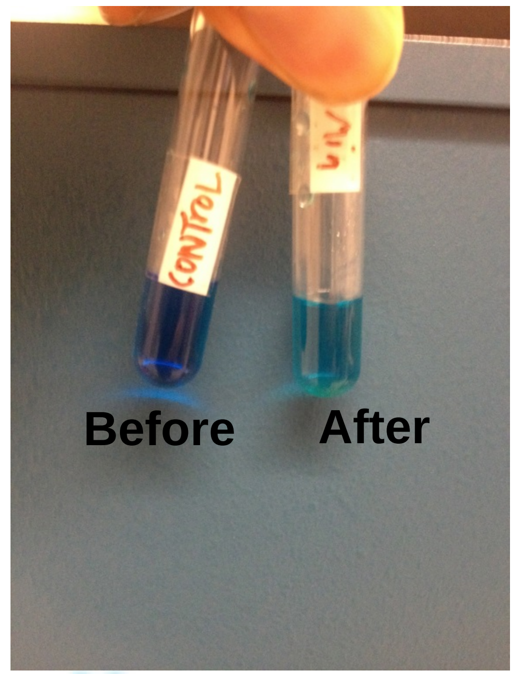
INVESTIGATING PLASMA-LIQUID INTERFACES USING A 2-D BUBBLE IN A HELE-SHAW CELL: FIRST RESULTS

- A Hele-Shaw cell is used to confine a 2-D bubble to investigate the plasma liquid boundary layer
- Plasma was formed in a "2-D" bubble using both a ns pulser and a low frequency sine wave source, producing streamer discharges in both cases and validating functionality
- Plasma in 2-D bubble successfully decolorized surrounding deionized water demonstrating the prospect for the use of chemical probes as contrast agents so that the active interfacial region can be imaged and spatial extent quantified.



- Discharge confined to 2-D bubble in deionized Water

- 2-D bubble modification to Contrast Agent



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Construction and First Results of an Atmospheric Pressure Plasma Jet Source Interacting with a Surface

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We have constructed and successfully operated an atmospheric pressure plasma jet. An image of the discharge operating in He is in Fig. 1. The jet emerging from the plasma is impinging on a quartz window in open air. The plasma engulfs the surface of the quartz window. An optical fiber (not shown) was placed behind the window (not shown) and light emitted along the axis of the jet was collected by the fiber, coupled to medium resolution spectrometers. A preliminary UV-visible optical emission spectrum was recorded, as shown in Fig. 2. The spectrum contains strong emission lines from He, as expected, as well as emissions from OH, N_2, H, and O. In future experiments, this source will be installed in a chamber in which the ambient pressure and composition, substrate temperature, and other parameters can be carefully controlled. Substrates, including MgF_2, coated with layers of H_2O and organic films, will be investigated with a focus on plasma surface interactions and VUV emissions (λ > 110 nm).

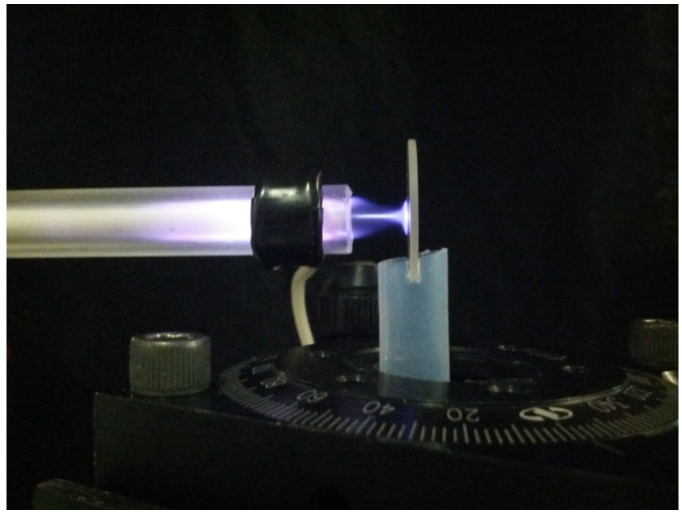

Figure 1 - Photograph of an atmospheric pressure He plasma jet impinging on a quartz substrate in open air.

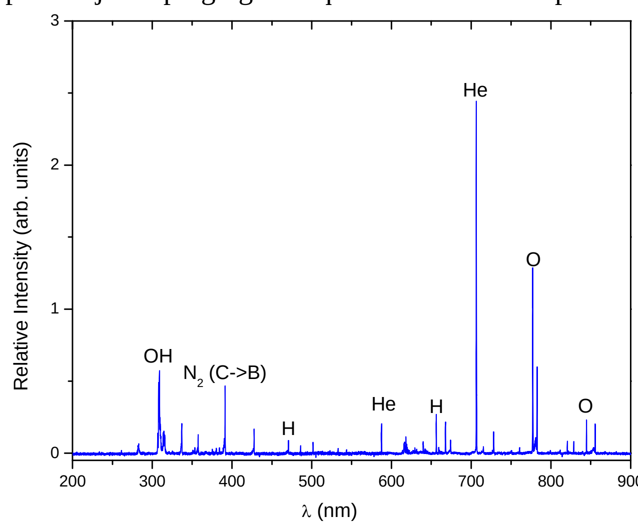

Figure 2 - Optical emission spectrum of a He plasma jet in open air impinging on a quartz window. The spectrum was recorded through the window at an angle of 90^{o} with respect to the surface, sampling the whole plasma.

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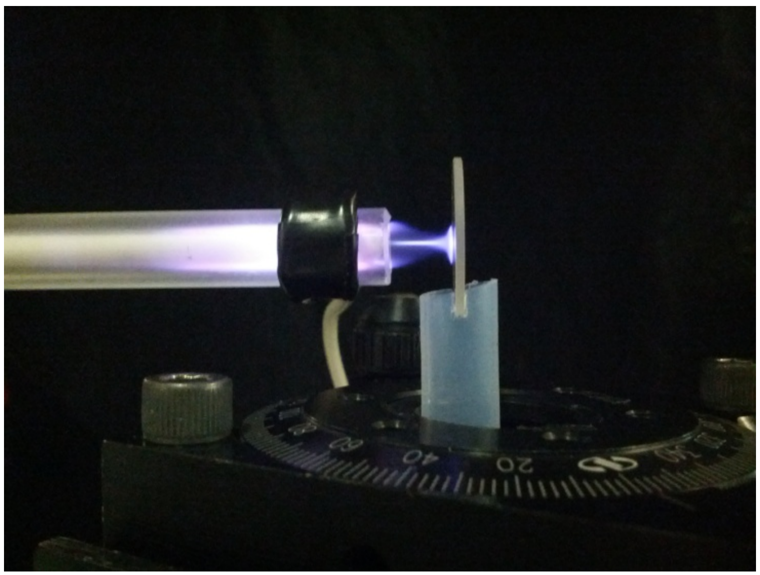
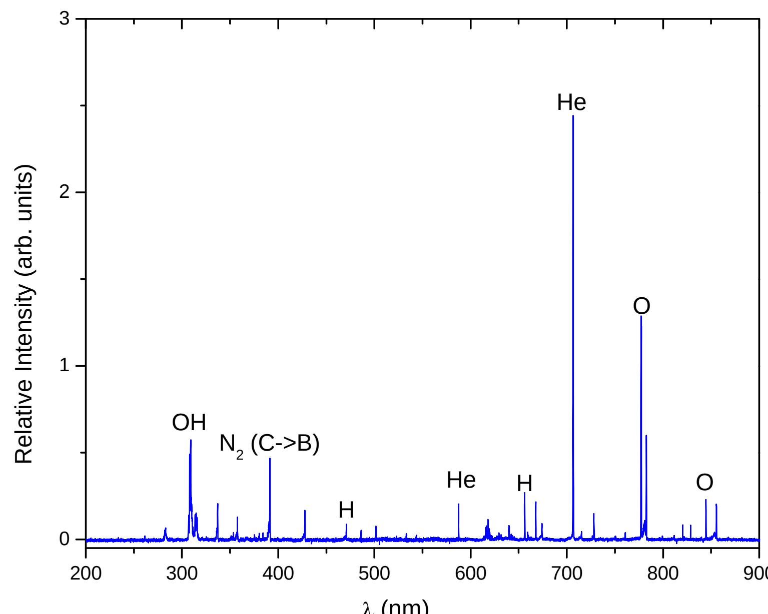
CONSTRUCTION AND FIRST RESULTS OF AN ATMOSPHERIC PRESSURE PLASMA JET SOURCE INTERACTING WITH A SURFACE

- **Constructed and operated a He atmospheric pressure plasma jet, impinging on a quartz window in open air.**
- **First UV-visible optical emission spectrum (OES) for light observed through the window contained emission lines from He, OH, N_2, H, and O.**
- **Future studies will focus on plasma surface interactions and VUV emissions in a controlled ambient with adsorbed water layers and organic films.**



- **Atmospheric pressure He plasma jet impinging on quartz in air.**



- **OES of He plasma jet in air on a quartz window, recorded through the window.**

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HIGHLIGHT

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