Examining and Optimizing the Performance of the Microfluidic Electrokinetic Sample Holder (MESH)

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Introduction

The Microfluidic Electrokinetic Sample Holder (MESH) is a system capable of producing ultrathin jets (nano-scale) which are often used as a convenient sample delivery method for serial crystallography at LCLS. It works by charging free ions within a sample, passing it through a capillary, and forcing it out onto a grounded plate.

Under the right conditions, the fluid will form a Taylor cone at the end of the capillary and produce a jet (**Figure 1**).

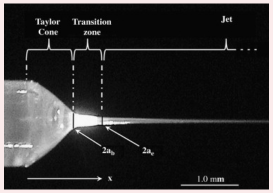

Figure 1: T. Han, A. L. Yarin, and D. H. Reneker, Polymer 49, 1651 (2008).

Ref: Sierra RG, Weierstall U, Oberthuer D, Sugahara M, Nango E, Iwata S & Meents A (2018) Sample delivery techniques for serial crystallography. In *X-ray Free Electron Lasers* (S Boutet, P Fromme & M Hunter, eds), pp. 109– 184. Springer, Cham.

Improving the MESH

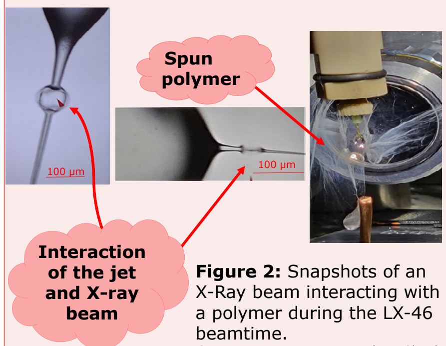

Figure 2: Snapshots of an X-Ray beam interacting with a polymer during the LX-46 beamtime.
Courtesy Dr. Meng Liang and Dr. Claudiu Stan

A stable and straight jet will yield the most amicable environment for data collection. Therefore, it is important to understand and quantify which factors inhibit or improve performance.

Objectives

- Investigate how variables such as conductivity, capillary size, and position of charging contact can influence jet formation and performance.
- Explore what modifications to the design will improve performance

Experimental Set-Up

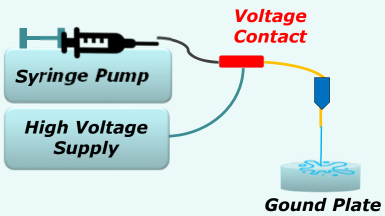

Figure 3: Basic MESH Set-Up.
The testing fluid leaves the syringe and travels towards the voltage contact where it is charged and pushed through a capillary towards the outlet.
During most experiments, a pressurized metal reservoir is used instead of a syringe pump

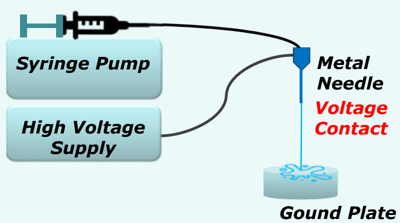

Figure 4: SprayBase Set-Up.

Spraybase is a commercial electro-spray/spin system where the testing fluid leaves the syringe and travels towards the needle which is connected to a voltage contact; the fluid is charged and pushed out of the end of the needle.

Performance of both set-ups was compared in order to determine whether charging at or near the tip improves jet stability or provides any benefit to the sample delivery.

Results

Table 1: Comparing testing fluids with varying conductivities (utilizing SprayBase).

Sample	Min. Voltage to Achieve a Jet
NaAc 0.1 Molar	4.5 KV
NaAc 0.05 Molar	4.6 KV
Deioinized Water	4.5 KV

Table 2: Comparing MESH set-up with varying capillary length using sodium acetate (NaAc) at .1M.

Capillary Length	Min. Voltage to Achieve a Jet
50 cm	3.9 KV
80 cm	3.7 KV
100 cm	3.8 KV

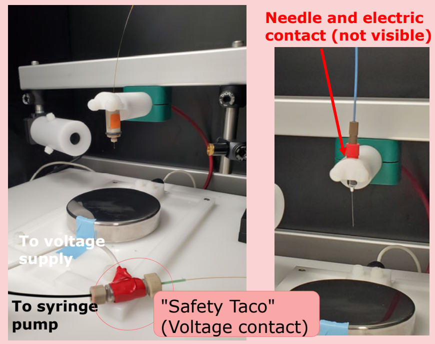

Figure 5: Images of experimental set-up. *Left,* experiment configuration as shown in Fig. 3. *Right,* experiment configuration as shown in Fig. 4

Table 3: Comparing different sizes of capillaries at the same length using NaAc at .1M.

Capillary Outer Diameter (OD)	Capillary Inner Diameter (ID)	Min. Voltage to Achieve a Jet
360 μm	50 μm	Jet never stabilized
360 μm	150 μm	3.8 KV
360 μm	100 μm	3.7 KV
160 μm	100 μm	3.2 KV

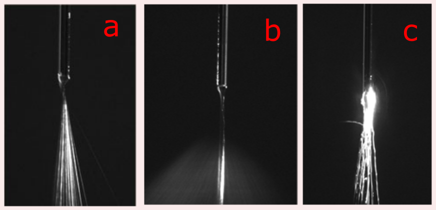

Figure 6: Pictures of jets from capillaries with varying inner diameters a) 50μm b) 100 μm and c) 180 μm

*Same outer diameter of 360 μm for all

Conclusions

Based on the results, OD has the most significant impact on the jet, requiring a lower voltage than the rest. Instead of using a thinner capillary, which is fragile, it is also possible to polish down the tip to achieve a similar effect.

For aqueous NaAc the optimal ID range was 100 μm to 150 μm, however, for more viscous fluids we would likely see different results.

It is still unclear whether charging at the tip is more efficient than charging prior to the capillary since there are most likely charge leakages within SprayBase that were not accounted for. However, capillary length did not seem to have a significant impact.

Topics for future investigation: Viscosity effects; polished capillaries; using a cone-shaped ground.

Acknowledgments

Special Thank You to: **Dr. Raymond Sierra** for being an amazing mentor**; Dr. Meng Liang** for allowing me to participate in a real LCLS experiment; **Prof. Richard Kirian** and his students **Roberto Alvarez & Kosta Karpos** for hosting me at their lab; **Stella Lisova** for her insight and support.

"Funding for YL and RGS was provided by the Linac Coherent Light Source (LCLS), SLAC National Accelerator Laboratory, supported by the US Department of Energy, Office of Science, Office of Basic Energy Sciences under Contract No. DE-AC02-76SF00515"