FTÅ4000 Liquid Dispense Methods and Capabilities

September 13, 2000

The FTÅ4000 uses a combination of pumping techniques to dispense drops. Laplace's interfacial tension versus radii of curvature rule is the governing rule. Any surface (like the surface of a small drop) can be described by two radii of curvature R1 and R2. For a formal definition, see Adamson, *Physical Chemistry of Surfaces*, ISBN 0-471-61019-4, but for a sphere, or hemisphere, R1 = R2 = ordinary radius of sphere. Laplace's equation says the pressure across the interface, ΔP, is given by the interfacial tension (surface tension) γ and R1 and R2:

$$\Delta P = \gamma\,(1/R1 + 1/R2)$$

When dispensing liquids through tips a millimeter or so in diameter, the pressure inside the drop is higher than outside the drop by ΔP, but the difference is so small as to not be noticeable compared to, say, the effects of viscosity. As one wishes to dispense smaller drops however, smaller tip diameters are used and the Laplace pressure becomes important as the drop emerges from the tip. For tips of 10 microns in diameter, the drop pressures may approach 30KPa, or roughly 1/3 of an atmosphere. This interfacial pressure is a strong function of drop diameter (the radii refer to the drop diameter, not the tip diameter), and is of such magnitude, that control of drop volume is difficult.

A second issue is that small drops will not fall off the dispense tip. The adhesion of the liquid to the tip is too great compared to the very small mass of a small drop.

These two factors lead to the two practical dispense methods for small drops:

- ejection of drops from a nozzle. A more-or-less fixed size drop is ejected with velocity and hence momentum. This is the ink jet printer approach. Typical ink jet volumes are about 50 picoliters, and typical velocities are of the order of 1 meter per second. The fluid types which can be handled are basically restricted to the inks for which the mechanism was developed, but more specifically alcohol-water solutions.

- pendant drop formation on a tip. Microliter sized drops can be formed with traditional syringe pump control. If the drop becomes large enough, typically several microliters, it will fall off from its own weight. Nanoliter and picoliter sized drops are formed in the FTÅ approach by having a second pump, a piezo-driven pressure pump in series with the syringe pump. The piezo pump can control a total volume of about 500 nanoliters, and it can respond very quickly. Basically it squeezes the liquid through the tip, then once the pendant drop is formed, reduces the pressure to keep the drop from growing large. These drops must be detached by having them touch the substrate. When they touch, the adhesion of the liquid to the substrate literally pulls the drop off the tip.

465 Dinwiddie Street • Portsmouth, Virginia 23704 • 1.757.393.1584 Fax: 1.757.393.3708
http://www.firsttenangstroms.com

Important Points

- The FTÄ4000 has a motorized Z axis on the pump as standard equipment, so the tip can be lowered to the sample and touch off the drop. The Z movements can be setup in advance and then done automatically.

- All nanoliter sized drops are made by letting the drop first emerge from the tip, at which time it will be larger than desired, then pulling liquid back in to achieve the desired volume. This is necessary because of the way Laplace's rule affects volume versus pressure inside the pump. The instantaneous volume can be measured so the user can "drive" the drop to the desired size.

- Viscosity affects drop formation at nanoliter volumes because of the small tip diameters. Therefore it is important to experimentally verify drop formation capabilities (how much trouble? how long?)

- Heating the syringe affects the pressure inside the syringe, just like the piezo pump does. Therefore it is important that temperature be stabilized before small volume dispense is attempted.

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