FTÅ4000 Small Drop Dispense

November 8, 2000

The FTÅ4000 contains a piezo pressure pump which provides the user with the control to dispense very small volumes using special tips. A small hemispherical droplet is prepared at the end of the tip and then lowered until the liquid just touches the surface, at which point a certain amount will detach and form a sessile drop. The volume of the sessile drop will be controlled by the size of the initial drop on the tip, the contact angle of the sessile drop (i.e., the interfacial tensions of the materials) and, to a degree, the characteristics of the tip. Thus some experimentation is involved to find the recipe for any particular volume.

Laplace's Equation

Our goal here is to dispense nanoliter and picoliter drops. Laplace's equation comes into play in this regime, unlike the normal microliter, millimeter-sized drops we commonly see. For spherical drops, the equation expresses the pressure difference ΔP as one goes across an interface of radius of curvature R with interfacial tension γ:

$$\Delta P = 2\,\gamma / R$$

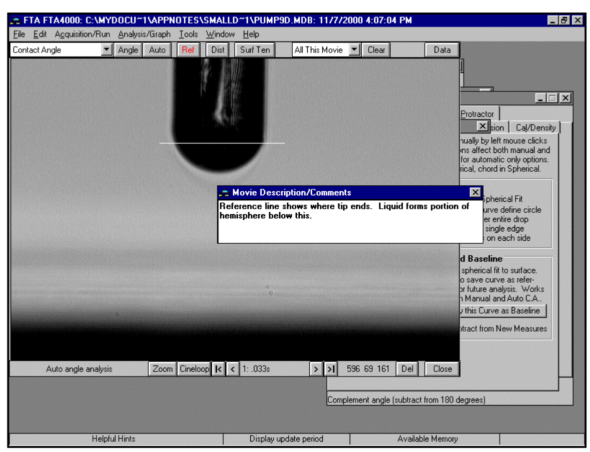
For small R, the pressure becomes significant and acts to keep liquid *inside* the tip. It turns out the radius of curvature is smallest when the drop radius is just equal to the wetted tip radius. For R = 10µm and γ = 73 for water, ΔP = 14,600 Pascals, or roughly 15% of an atmosphere. This is a significant pressure within a syringe pump, and the entire pump must be pressurized to this level to make the liquid fully emerge from the tip and form a classical pendant drop. Unfortunately once the radius of the drop becomes larger than that of the tip, its radius of curvature *decreases* rapidly and lowers the retarding pressure ΔP, with the consequence that a large volume (relative to what we want) rapidly flows; we want to prevent this.

Tips

Two tip types are offered. Fused silica tips are constant diameter tubes with a polyimide coating. Glass capillary tips are tapered down to almost any desired diameter. While glass capillaries are offered in more and smaller sizes, they do not have as effective hydrophobic coatings (even when silanized) and they are more subject to cracking. The trade-off becomes the ease of use of fused silica versus the smaller sizes of drawn glass capillaries. The fused silica tip in this work has a 20µm ID and 90µm OD.

Example

The figure below shows this tip with liquid ready to dispense. The reference line marks the end of the tip; the volume is ≈100pl.



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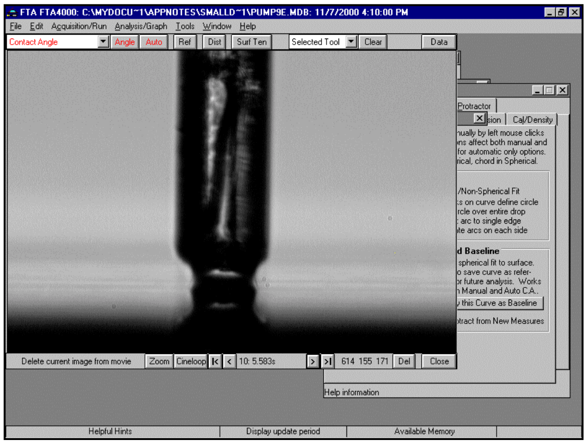
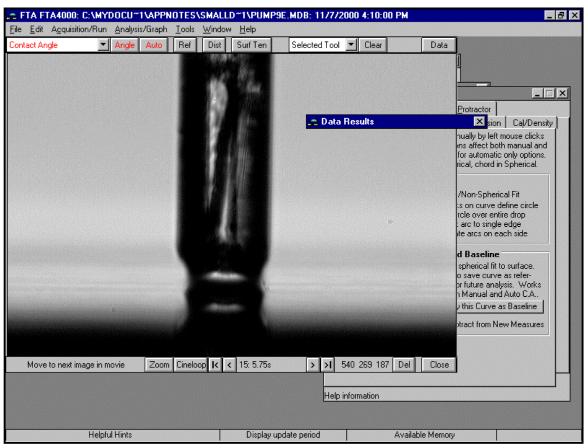
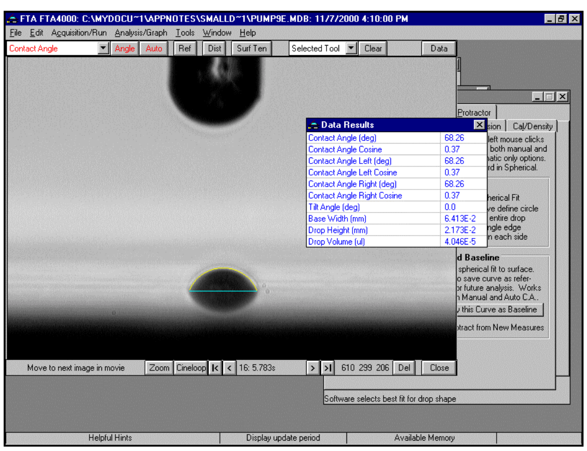
It is touched off in the following images. When the liquid touches the surface, it forms a complex capillary between the surface and the tip, with a small radius of curvature so no great pressure drop occurs and no flow results. The period the tip is low if 0.167s, from the first to the second image. The capillary remains essentially constant.







Notice that as the tip rises in the third image, the original hemisphere on the tip bottom appears intact. This illustrates an important fact. The entire volume of liquid in the pump is pressurized prior to touch-off, so sufficient flow will occur down the tip to fill the sessile drop as the tip retracts and also to make a new hemisphere. In other words, the pressure in the syringe is little changed by dispensing an infinitesimal volume, 40pl in this example (the syringe volume is ≈500µl, or ≈ ×10,000,000). *All of the shapes and volumes are pressure driven*. Detailed analysis shows the sessile drop receives an excess of liquid as the capillary detaches, which ensures the sessile drop exhibits an advancing contact angle.

Five drops were placed on the anodized aluminum sample. The table lists the sessile drop volume and the initial contact angle. These drops are so small they evaporate in less than 1 second. The contact angles are consistent with microliter sized drop angles placed on the same sample.

Volume (picoliters)	Contact Angle (°)
40	68.3
62	69.2
63	62.2
89	66.8
49	73.3

This example concentrated on easily made small drops, but larger drops can be made by pulsing pressure after the tip is low. Using only a simple touch-off, a 75µm ID, 144µm OD silica tip dispenses 2nl, while a 20µm ID, 40µm OD glass tip will be below 50pl. Low surface tension liquids, e.g., 70% IPA, work well as long as the same partial hemisphere is used (a full pendant drop will climb the tip).