Importance of Baseline Determination for Contact Angle Measurements

Application Note #242e

by:

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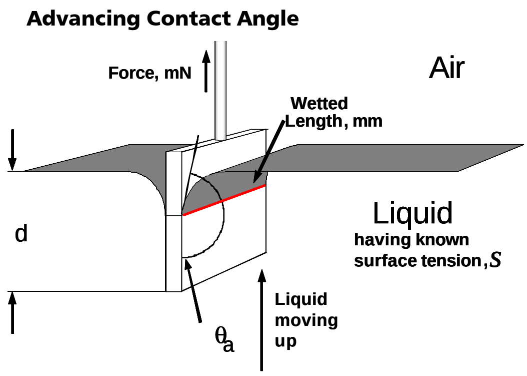
Abstract

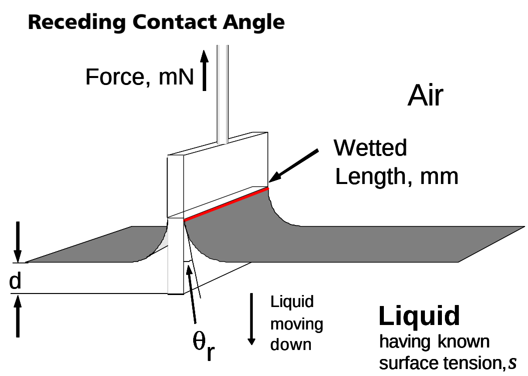
When determining the contact angle of a liquid drop on a solid surface, many factors can influence the outcome of the result. Poor lighting, improper drop deposition, and poor fit routines are but a few. All of these can be properly controlled with proper training, automated syringes, and high quality/mathematically sound software. The most important variable in determining an accurate contact angle is most often the placement of the drop baseline. The DSA software has the capability to determine an automatic baseline, taking much of the variability from the measurement. However, to get an accurate measurement for drops on curved surfaces, a curved or "curvable" baseline is the only option that will allow for accurate results.

Introduction to Contact Angle

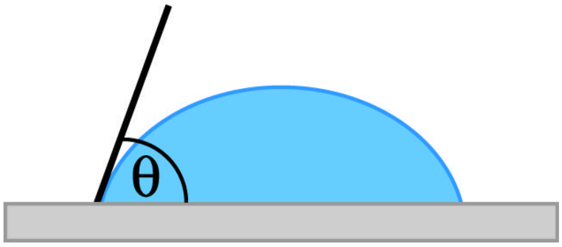
Contact angle has become increasingly important in many fields such as semiconductor layering and cleanliness, coatings research, pharmaceutical research, polymer science, and many more disciplines. The determination of contact angle can be purely for the sake of determining wettability or can be used for determining an even more general measure of the surface and its coatability, the surface energy. For flat, reflective surfaces, contact angle determination can be very simple. In fact, for the measurement of such simple surfaces the user can choose between measurement by either optical or gravimetric methods. For gravimetric measurement, the sample is placed into a clip and dipped into the liquid of interest. The contact angle is then determined automatically through the Wilhelmy equation as described below:

$$\cos\theta = \frac{F - F_b}{l\sigma}$$





If a sample has one side different from the other or comes as an odd shape (e.g. a car part, sunglasses, cell phone casing, etc.) contact angle by an optical method may be the only choice for the investigator.

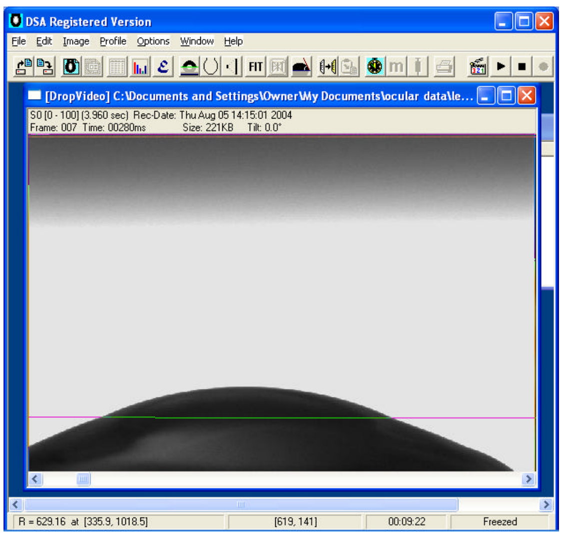


Again, for flat surfaces the measurement and baseline determination is fairly simple. However, for curved surfaces, a proper, curved baseline must be determined to provide an accurate contact angle.

Contact Angle determination on a contact lens

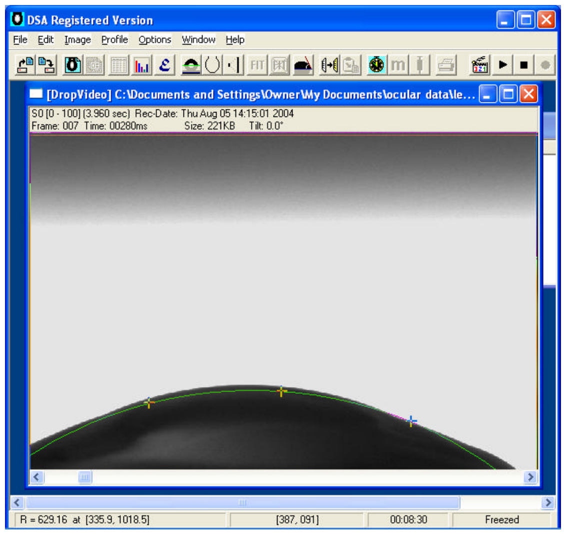
Contact angle was determined on a contact lens with a small radius of curvature (approximately 1.5 cm). The dynamic contact angle was determined for a drop spreading on a pre-wetted contact lens surface. A drop of approximately 6 µl was applied to the lens and a movie was captured at 25 frames per second. The movie was subsequently analyzed for contact angle among other properties with and without a curved baseline.

An example of an image of the drop resting on the lens approximated with a straight baseline is shown below:

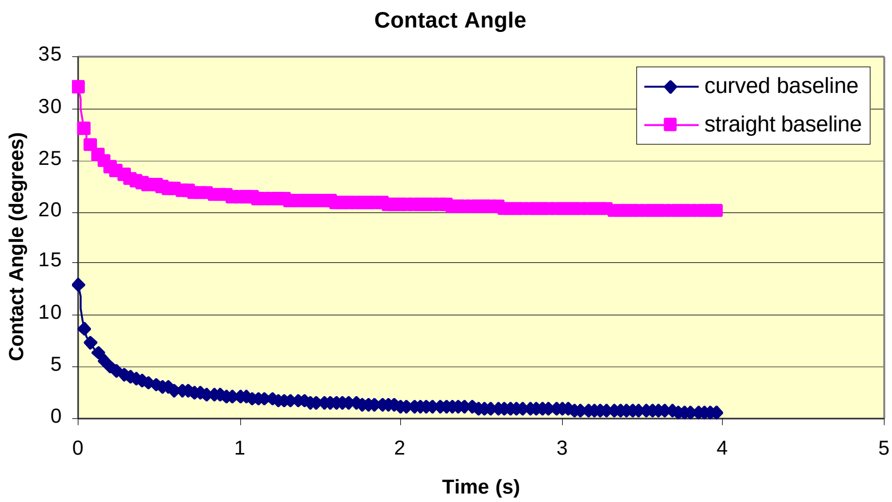


Although it may be difficult to see with the straight baseline in the image, the drop does exist in the image above. The drop edges are approximately where the baseline in the image crosses the sample. A simple circle fit was used to provide contact angle values. The drop shape above looks reasonable and gives reasonable data for the sample.

When you compare this to the image below with a curved baseline fit to the sample, one can immediately see that the results will be quite different.

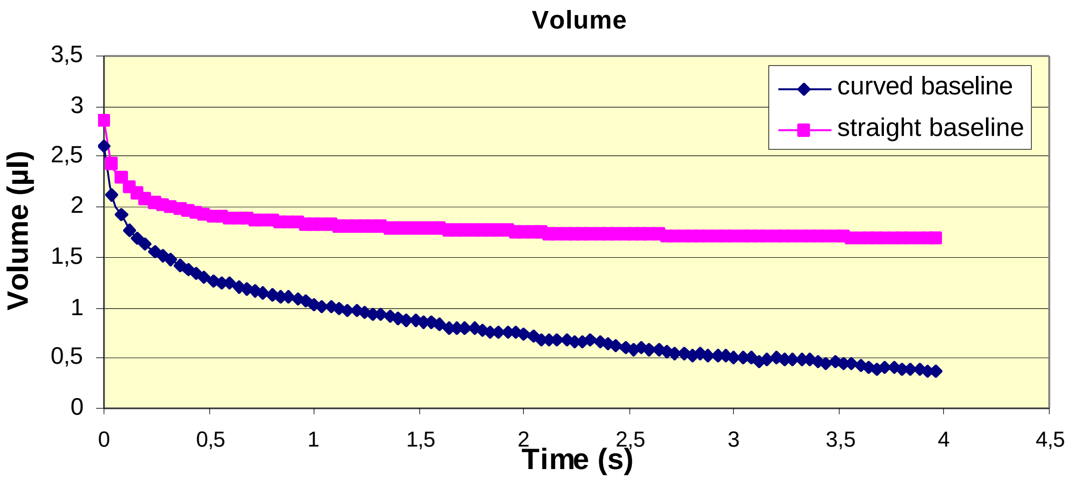


This image is the same as that shown for the straight baseline earlier. One can see how difficult it might be to see such an image without the baseline present. The baseline was fit in this image by fitting it to a sample with no drop present. Then the baseline remains in the same place on the image for subsequent drop contact angle analysis. Contact angle for the same set of images and same drop are shown below with and without the curved baseline fit.



The contact angle for the straight baseline is shown to be 20 degrees too high as compared to the accurate value shown by the analysis with a curved baseline. Theoretically, this could be determined by subtracting the angle of incidence between the baseline and the drop from every measurement to give the correct angle. However, if the edges of the drop did not remain in the same place during the measurement, this would not be accurate either, since the angle of incidence would change along the surface of the substrate.

Even more importantly, further information about the drop would be incorrect due to an improper, straight baseline. For instance, one can tell that the calculated volume would be much greater for the straight baseline, since a part of that volume is actually occupied by the substrate itself and not by the drop. A comparison of the volume over time for a spreading drop is shown in the plot below:



It can easily be seen that the uncorrected volume cannot be simply corrected or even approximated by subtracting off a constant volume in a linear fashion as might have been achievable with a reasonable approximation for the contact angle itself.

Summary

For straightforward, flat samples, at least two methods are available for contact angle determination, optical methods and the Wilhelmy, or gravimetric, method. For samples with an odd shape, as in the contact lens above, there is no reasonable way to measure the sample without destroying it. Many samples are similar in that their shape or size may not allow for the measurement via the Wilhelmy method, yet they still require contact angle and surface energy analysis. For these samples, only contact angle determination via optical analysis is available.

For such odd shaped samples, curves are often a necessary evil that cannot be escaped during the measurement. However, with the appropriate software and tools, such curves can easily be accommodated. The Kruss DSA software can accommodate for these curves with a simple curved baseline routine that can fit almost any sample provided to the system for analysis. With the curved baseline, contact angles and other data can then be correctly determined.