Application Note
C-215

# Bundle fiber handling technique

*Thermo Fisher Scientific, Process Instruments, Newington, USA*

Surface properties of liquid and solid materials can be measured by many different techniques. Among those surface properties, surface tension of liquid, surface free energy of solid, liquid-liquid and solid-liquid interaction characteristics are of most interest.

Thermo Scientific Dynamic Contact Angle analyzers (DCA) are instruments that are using the Wilhelmy plate theory to obtain the above information about solid, liquid, and solid-liquid characteristics. With the highly integrated and sophisticated hardware and software, Thermo Scientific DCAs offers a powerful, and versatile approach to the comprehensive understanding of the complex interactions at liquid-liquid and liquid-solid surfaces.

As the application of fiber materials expands, the need to understand the surface properties of the fiber materials is increasing. Equipped with the well-known Thermo Scientific high-sensitivity balance, DCA 322 has the capability of handling single-fiber samples, down to 1 mm in diameter, for measuring its surface properties. However, there are occasions that the customer would like to obtain the surface properties of a bundle of fibers.

No matter what kind of techniques will be used to handle bundle of fibers, the Wilhelmy plate theory can no longer be applied. Due to the inter-fiber structure and possible pore structure among the fiber, a bundle of fibers is best described and studied by Washburn theory. [1-6] It will then be used to obtain the contact angle between the bundle of fibers and the liquid. The Washburn theory can be expressed in the following equation:

$$\cos\theta = \frac{w^2}{t} \times \frac{\eta}{\rho^2 \times \gamma \times C}$$

Where θ is the liquid-solid-vapor contact angle, w is the weight of the liquid absorbed by sample, t is time, and η γ, and ρ are the viscosity, surface tension and density of the liquid, respectively. C is the dimension constant which is related to the packing and structure of the samples.

From the above equation, it can be seen that the sample's weight change as a function of time needs to be measured. This wicking information can be easily performed on Thermo Scientific DCA systems. Under the wicking experiments, the sample's weight change was monitored as a function of time right after the sample touched the liquid's surface.

From this, the $\frac{w^2}{t}$ can be obtained.

With $\frac{w^2}{t}$ value, in order to find out the contact angle, θ, it is then necessary to obtain the value of C first. Therefore, it is necessary to use a standard liquid, which has a known contact angle against the sample. In most cases, a liquid with low surface tension will be used, assuming it will result in a 0° contact angle, or $\cos\theta = 1$.

Therefore, for each fiber bundle sample, at least two DCA wicking experiments are necessary in order to use the Washburn equation to obtain the contact angle value for a given liquid. One run should be made using a standard liquid, which will result in 0° contact angle between the fiber bundle sample and the liquid. This will result in the dimension constant value, C. Another run should be performed against the test liquid. Analysis of this data, by using the Washburn equation, will produce the contact angle value of the sample against the test liquid.

It's necessary to mention that all of the physical constants of the liquids, η γ, and ρ, should be known. Following is just a small list of the liquids that are commonly used:

To measure the surface properties of a bundle of fibers, there are two different sample handling techniques. One is called "Tube" method to handle flexible fibers that are continuous for longer than 2 inches. For shorter and non-continuous fibers, the fibers can be considered as powder samples and the Thermo Scientific Powder Accessory [7] can then be applied.

The "Tube" method is discussed here. Figure 1 shows the procedure to prepare the bundle fiber samples. Full description is as follow:

1. Run a thin flexible wire through a small piece of thin-wall tubing (the "Tube") to form a loop. Lay a bundle of fibers through the loop and underneath the "Tube".
2. Pull the wire so that the fibers are forced into the tube. Make sure the fiber entered the "Tube" fully, and seen on the top. Correct amount of fibers and internal diameter of the "Tube" should

| Liquid name | Viscosity (mPs) | Density (g/cm$^3$) | Surface Tension (mN/m) |
|---|---|---|---|
| Hexane | 0.3 | 0.6594 | 18.4 |
| Acetone | 0.306 | 0.792 | 23.7 |
| Toluene | 0.56 | 0.866 | 28.4 |
| Ethylene glycol | 16.1 | 1.1088 | 48.3 |
| Distilled water | 1.002 | 0.998 | 72.8 |
| Ethanol | 1.41 | 0.816 | 22.3 |

be used to ensure good packing. Trim the fibers evenly at the bottom end of the "Tube". Leave less than 1 mm of fibers exposed.

3. Cut the extra thin flexible wire and make it into a hook to put the prepared bundle fiber sample to the DCA.

With DCA equipment and software, the wicking experiments can be performed on the bundle of fibers. The wicking data can then be treated by the available applications software, which uses the Washburn theory, to obtain the wettability of bundle of fibers against a certain liquid.

While the "Tube" method can provide the contact angle information between a bundle of fibers and a liquid, there are a few things that need to be noted:

1. 90° Limitation
   The Washburn theory is based up on the assumption that the liquid will be absorbed into the solid sample matrix. In other words, the liquid has to wet the solid, or the contact angle between the solid and the liquid has to be less than 90°.

2. Advancing contact angle only
   Since the liquid will advance into the dry solid surfaces, and that process can be reversed, the contact angle obtained is advancing contact angle only.

It's also worthwhile to mention that Thermo Scientific DCA RADIAN 322 can perform contact angle measurement not only on single fiber, but also on the bundle of fibers. Such a method of measuring the surface properties of fibers can also be utilized on a Thermo Scientific DCA RADIAN 315.

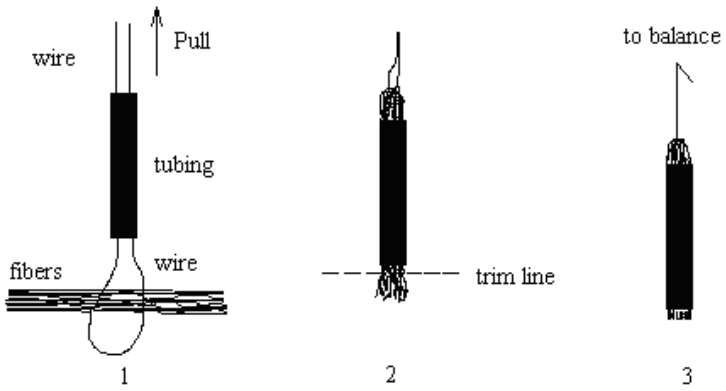


*Figure 1: Steps in using the Tube fiber bundling method.*

**Reference:**


*[1] D. J. Gardner, N. C. Generalla, et al, Langmuir, Vol 7(11), 1991, pp 2498-2502.*

*[2] K. T. Hodgson and J. C. Berg, J. of Colloid and Interface Science, 121(1), 1988, pp 22 - 31.*

*[3] J. Domingue, The Relationship of Wettability to Absorbency Thermo Scientific 1989.*

*[4] K. T. Hodgson and J. C. Berg, Wood and Fiber Science, Vol.20(1), 1988, pp 3 – 17.*

*[5] R. Lucas, Kolloid-Z, 3, 1918, 15-22.*

*[6] E. W. Washburn, Physics Review, 17(3), 1921, 273-282.*

*[7] Dun Chen, Measuring the Wettability of Porous Materials, Thermo Scientific, Inc., 1998.*



**Thermo Fisher Scientific Process Instruments**

**International/Germany**
Dieselstr. 4,
76227 Karlsruhe
Tel. +49(0)721 40 94-444
info.mc.de@thermofisher.com

**Benelux**
Tel. +31 (0) 76 5 87 98 88
info.mc.nl@thermofisher.com

**China**
Tel. +86 (21) 68 65 45 88
info.mc.china@thermofisher.com

**France**
Tel. +33 (0) 1 60 92 48 00
info.mc.fr@thermofisher.com

**India**
Tel. +91 (22) 27 78 11 06
info.mc.in@thermofisher.com

**United Kingdom**
Tel. +44 (0) 1785 81 36 48
info.mc.uk@thermofisher.com

**USA**
Tel. 603 436 9444
info.mc.us@thermofisher.com

**www.thermo.com/mc**



C215_13.08.2008