



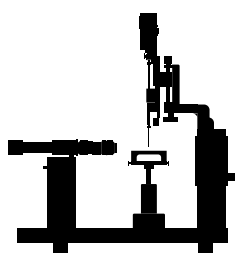
Application Note

High-precision droplet dosing for wettability analysis on small structures using the FDDS FlexDrop dosing system

The characterisation of surface wettability on modern materials often requires the analysis of **very small and delicate structures**, such as microelectronic components, medical devices, precision mechanical parts, and coated functional surfaces. Conventional syringe-based dosing systems operating in the microlitre range often produce droplets that are too large, resulting in inaccurate or non-representative contact angle measurements. To overcome these issues, the controlled dosing of **extremely small droplets** is essential. The **FDDS FlexDrop dosing system**, a module for the contact angle measuring devices of the **OCA series from DataPhysics Instruments^[1]**, enables the reproducible generation of droplets **down to 25 pL**. This allows **precise dosing of individual droplets for accurate contact angle measurements and advanced wetting analysis**. In addition, practical challenges such as cross-contamination, handling of different liquids, and efficient workflows must be addressed. The FDDS dosing system meets these requirements through the use of easily exchangeable cartridges, eliminating cleaning steps and ensuring reliable, contamination-free operation. Furthermore, the capability for simultaneous dosing of two droplets enables efficient and accurate surface energy determination, improving both measurement speed and reproducibility.

Measurement device

Optical contact angle measuring and contour analysis systems – OCA series



Measurement method

Optical contour analysis systems

Measured quantities

Contact angle

Environmental conditions

Room temperature

Industries

Semiconductor
Printed electronics
Precision manufacturing
Surface coatings
Medical devices



Fig. 1: The FDDS FlexDrop dosing system is available in three variants. The FDDS Nano and FDDS Double Nano can dose one or two liquid drops with a minimum volume of 2 nL and the FDDS Pico can dose one liquid drop with a minimum volume of 25 pL.

Increasing droplet volume increases the droplet footprint, with the effect becoming especially critical on hydrophilic surfaces, where droplets spread more strongly. For example, assuming a 45° contact angle, a square test area, and a recommended side length of approximately $2 \times$ droplet diameter, the required dosing technology can be selected according to the available test area:

- $0.20 \times 0.20 \text{ mm}^2$ test area: maximum drop diameter $\approx 100 \text{ }\mu\text{m}$, corresponding to about 100 pL $\rightarrow$ FDDS Pico
- $1 \times 1 \text{ mm}^2$ test area: maximum drop diameter $\approx 0.5 \text{ mm}$, corresponding to about 10 nL $\rightarrow$ FDDS Nano
- $5 \times 5 \text{ mm}^2$ test area: maximum drop diameter $\approx 2.5 \text{ mm}$, corresponding to about $1.3 \text{ }\mu\text{L}$ $\rightarrow$ conventional dosing system

FDDS Dosing System Overview^[2]

The FDDS FlexDrop dosing system is a flexible module for OCA optical contour analysis systems^[3], enabling the precise and reproducible dosing of nanolitre and picolitre droplets for accurate wettability analysis on small or structured surfaces. It can be equipped with one or two dosing heads, allowing single or simultaneous dual-liquid dosing for one-click surface energy determination in a single measurement. Further details can be found in the [FDDS brochure](#).

The FDDS dosing systems operate based on an inertia-driven droplet generation principle without continuous pressure on the liquid reservoir. As illustrated in Fig. 2, the liquid inside the cartridge remains at ambient pressure, ensuring a stable meniscus at the nozzle.

Droplet generation is triggered by a short, controlled mechanical actuation, which induces inertia in the liquid and causes a defined droplet to shear off from the nozzle. This principle offers several advantages:

- High reproducibility, independent of pressure fluctuations
- Precise droplet size control, defined by nozzle geometry and actuation
- Stable, contactless dosing, minimising disturbance to the sample.

Choosing the Right Dosing System

In contact angle measurements, the drop base diameter must always remain smaller than the available test area to ensure accurate results. Otherwise, interactions with edges or surrounding structures can lead to distorted results.

As shown in Fig. 3, the drop diameter strongly depends on two key parameters:

- Drop volume: Larger volumes result in significantly larger base diameters
- Contact angle: Lower contact angles (better wetting) increase droplet spreading

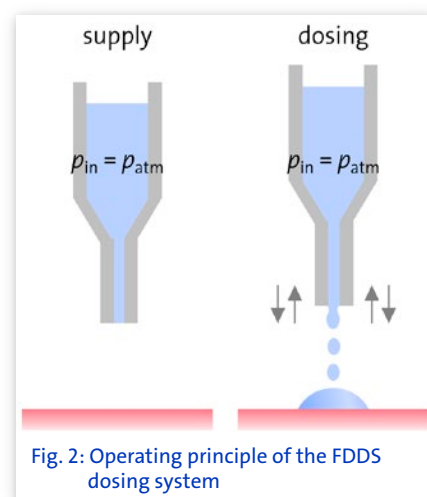


Fig. 2: Operating principle of the FDDS dosing system

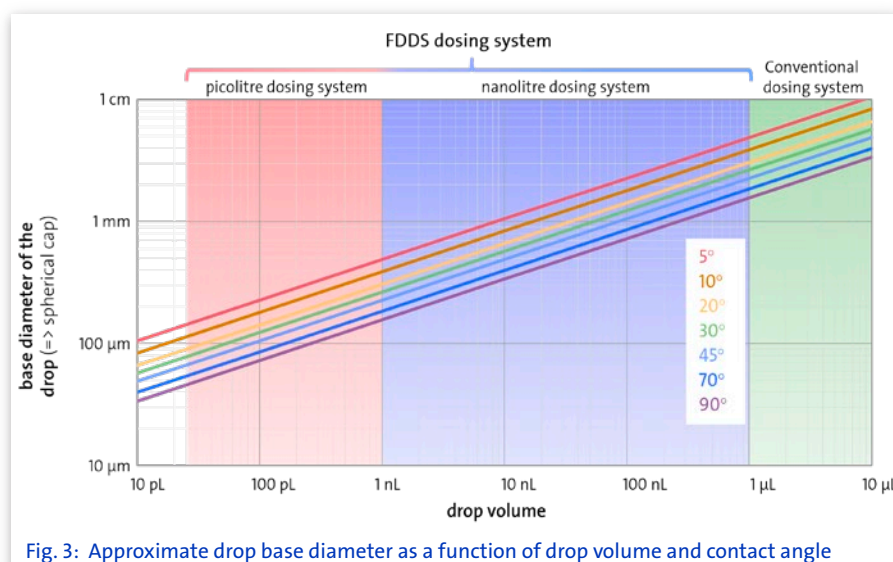


Fig. 3: Approximate drop base diameter as a function of drop volume and contact angle

This illustrates a key point: **the smaller the available test area, the more important precise low-volume dosing becomes.** Conventional micro-litre droplets can quickly exceed the available surface area, making reliable contact-angle measurements difficult or impossible.

The FDDS dosing system directly addresses this requirement by enabling the precise and reproducible generation of nanolitre and picolitre droplets. By minimising droplet volume, the base diameter is reduced, ensuring that:

- The droplet remains fully within the test area
- Edge effects are avoided
- Reliable and representative contact angle measurements are achieved

The FDDS dosing system expands the accessible application range to micro-structured, patterned, coated, or otherwise area-limited samples where conventional dosing systems reach their practical limits.

Experiment

Experiments were conducted to investigate the influence of orifice size and droplet size of different test liquids on contact angle measurements, and to verify the reliability and reproducibility of the FDDS dosing system for picolitre- and nanolitre-scale wettability analysis.

Measurements were performed using an OCA series contact angle measuring system equipped with the FDDS dosing system from DataPhysics Instruments. Different FDDS cartridges were used, including DC Pico 30 with a 30 μm orifice, DC Pico 70 with a 70 μm orifice, and DC Nano 150 with a 150 μm orifice. These cartridges were used to generate droplets of selected test liquids, including water, dimethyl sulfoxide (DMSO), and diiodomethane (DIM). The droplets were deposited onto clean, homogeneous solid surfaces, under ambient laboratory conditions.

The selected liquids cover a broad range of polarities and are commonly used for surface energy characterisation. For each liquid and cartridge combination, the power factor in the FDDS dosing system was individually optimised to ensure stable and reproducible droplet generation. The droplets were deposited directly onto the sample surface and recorded immediately using the high-speed OCA camera system. Contact angles were subsequently determined by Circle fitting using dpiMAX software.

Results & Discussion

To investigate the influences of the cartridge orifice size on the contact angle result, measurements were performed with water, diiodomethane, and DMSO using three different FDDS cartridge orifice sizes: 30 μm , 70 μm , and 150 μm .

As shown in Fig. 4, comparable contact angles were obtained for all three test liquids regardless of the selected orifice. Water exhibited contact angles between 79° and 82°, diiodomethane between 28° and 32°, and DMSO between 40° and 42°. No systematic increase or decrease in contact angle was observed with increasing orifice size, demonstrating that comparable wettability results can be obtained with the different FDDS dosing system configurations under the investigated conditions.

At the same time, the orifice size provides an effective means of controlling

the droplet footprint. As shown in Fig. 5, for water under the standard dosing parameters, increasing the cartridge orifice size from 30 μm to 70 μm and 150 μm increased the droplet volume from approximately 70 pL to 250 pL and 1900 pL, respectively. Correspondingly, the droplet diameter increased from approximately 75 μm to 110 μm and 220 μm . Thus, the FDDS dosing systems allow the droplet size to be tailored to the available test area while maintaining comparable contact-angle results. Smaller droplets are particularly advantageous for narrow, delicate, or microstructured surfaces, whereas larger droplets can be used when sufficient homogeneous measurement area is available.

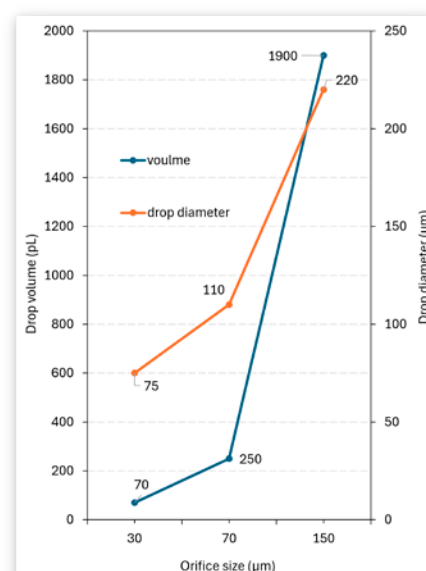


Fig. 5: Influence of FDDS cartridge orifice size on droplet footprint, using water as a test liquid.

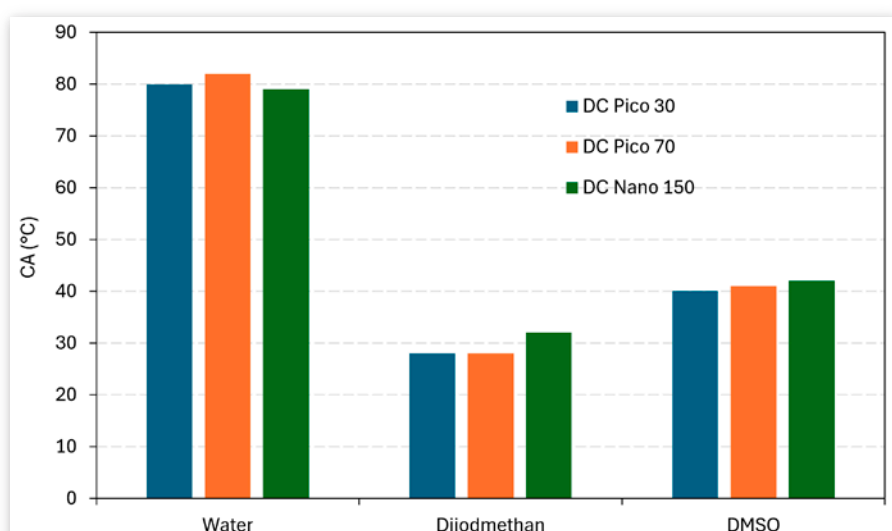


Fig. 4: Comparison of contact angles of liquid drops generated by different cartridges

Table 1: Recommended minimum test areas by cartridge type for water, DMSO and diiodomethane as representative test liquids.

Cartridge	Orifice size	Drop volume range [pL]	Drop diameter range [μm]	Maximum observed drop diameter [μm]	Recommended minimum square test area side[mm]*
DC Pico 30	30 μm	35–80	75–110	110	0.22
DC Pico 70	70 μm	120–250	110–140	140	0.28
DC Nano 150	150 μm	600–1900	220–250	250	0.5

*Recommended minimum square test area side length is estimated as approximately 2× the maximum observed drop diameter determined using the representative test liquids water, DMSO, and diiodomethane.

Furthermore, as summarized in Table 1, the expected droplet footprint—and therefore the required test area—can be estimated from the droplet volume and contact angle. This provides a practical basis for selecting the most appropriate FDDS cartridge orifice size for a given sample geometry.

For example, under the test conditions in this note, a square test area with a side length of approximately 0.25 mm would favour an FDDS cartridge with a 30 μm orifice. For a larger square test area with approximately 0.4 mm side length, either a 30 μm or 70 μm orifice may be suitable, depending on the desired droplet volume. As the available test area increases, bigger orifice sizes can be selected to generate larger droplets while still maintaining sufficient clearance from the sample edges, which may allow to use FDDS Nano dosing system.

By matching the droplet size to the available homogeneous test area, the FDDS dosing systems enable reliable contact angle measurements even on very small surface areas.

Summary

The FDDS dosing systems enable reliable contact angle measurements on very small and spatially limited sample areas by generating droplets in the picolitre to nanolitre range. By selecting the appropriate FDDS dosing system, the droplet volume and resulting footprint can be adapted to the available test area. The presented results show that the contact angle results from the cartridges with different orifice sizes are comparable. This is particularly advantageous for microstructured surfaces, small components, narrow tracks, coated areas, and other applications with only a limited homogeneous test area.

Reference

- [1] www.dataphysics-instruments.com/
- [2] www.dataphysics-instruments.com/fdds-promo-video/
- [3] www.dataphysics-instruments.com/products/oca/

We will find a tailor-made solution for your surface science use case and will be pleased to provide you with an obligation-free quotation for the system that fits your needs. For more information, please contact us.

DataPhysics Instruments GmbH • Raiffeisenstraße 34 • 70794 Filderstadt, Germany
phone +49 (0)711 770556-0
sales@dataphysics-instruments.com • www.dataphysics-instruments.com

Your sales partner: