Droplet Lab

The Practical Guide to Surface Science for the Medical Device Industry

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INTRODUCTION

Choice of materials and their interaction within the device and with surroundings is very important for efficient and reliable functioning of medical devices. For example, it is desired that materials will have good strength, be durable as well as they will have minimum issue of corrosion resistance etc. In this regard, different surface properties (contact angle, sliding angle, surface energy and surface tension) play a key role in their performance and safety. These properties can affect the **biocompatibility, adhesion, wear resistance, and antifouling properties** of medical devices.

Biocompatibility

Adhesion

Wear Resistance

Antifouling Properties

Some of the important surface properties that are used to understand the behavior of medical devices and for their quality improvement are:

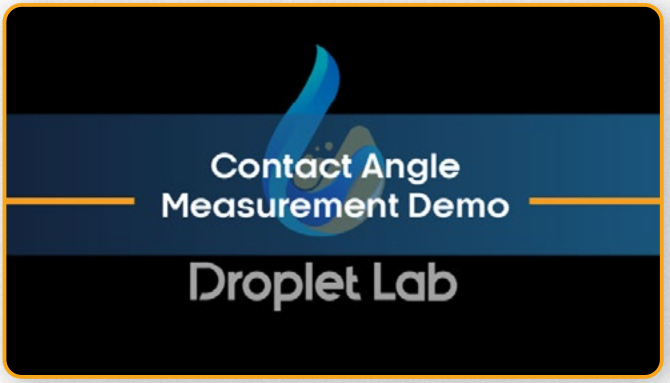
Contact Angle Measurement

Contact angle quantifies the wettability of a surface, representing the angle between the surface of a liquid and a solid surface. Hydrophilic surfaces allows better bacterial adhesion. A high contact angle is direct indicator of low wettability or hydrophobic surface. Enhanced wettability results in better biocompatibility. By measuring the contact angle, manufacturers can ensure good biocompatibility for example in dental implants [1].

Sample Image taken from Droplet Lab Tensiometer

Droplet Lab offers both Young-laplace and Polynomial methods in our Tensiometer.

Young - Laplace Method	Polynomial Method
Uses the whole drop profile to calculate the contact angle value	Uses only a certain percentage of the drop profile to calculate the contact angle value.
Only compatible with an axisymmetric drop. This is not always seen in practice, as a needle is typically inserted into the drop to increase/decrease the drop volume.	Compatible with both axisymmetric and non-axisymmetric drops.
Measurement results are more consistent compared to the polynomial fitting method.	Measurement results are less consistent, as they are affected by local surface imperfections.



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Learn how Contact Angle measurement is done on our Tensiometer

Dynamic Contact Angle

Ideally, when a drop is placed on a solid surface, a unique angle exists between the liquid and the solid surface. The value of this ideal contact angle (the so-called Young's contact angle) can be calculated using Young's equation.

In practice, due to the surface geometry, roughness, heterogeneity, contamination, and deformation, the value of the contact angle on a surface is not necessarily a unique value but falls in a range. The upper and lower limits of this range are called the advancing contact angle and the receding contact angle, respectively.

The value of Advancing and receding for a solid surface is also very sensitive and can be affected by many parameters, e.g., temperature, humidity, homogeneity, and minute contamination of the surface and liquid. For example, the advancing and receding contact angles of a surface at different locations can be different.

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[Learn how Dynamic Contact Angle measurement is done on our Tensiometer]

Dynamic Contact Angle versus Static Contact Angle

Practical surfaces and coatings naturally show contact angle hysteresis, indicating a range of equilibrium values. Measuring static contact angles provides a single value within this range. Solely relying on static measurements poses problems, like poor repeatability and incomplete surface assessment regarding adhesion, cleanliness, roughness, and homogeneity.

Practical applications require understanding a surface's liquid spreading ease (advancing angle) and removal ease (receding angle), such as in painting and cleaning. Measuring advancing and receding angles offers a holistic view of liquid-solid interaction, unlike static measurements, which yield an arbitrary value within the range.

This insight is crucial for real-world surfaces with variations, roughness, and dynamics, aiding industries like medical devices, materials science, and biotechnology in designing effective surfaces and optimizing processes.

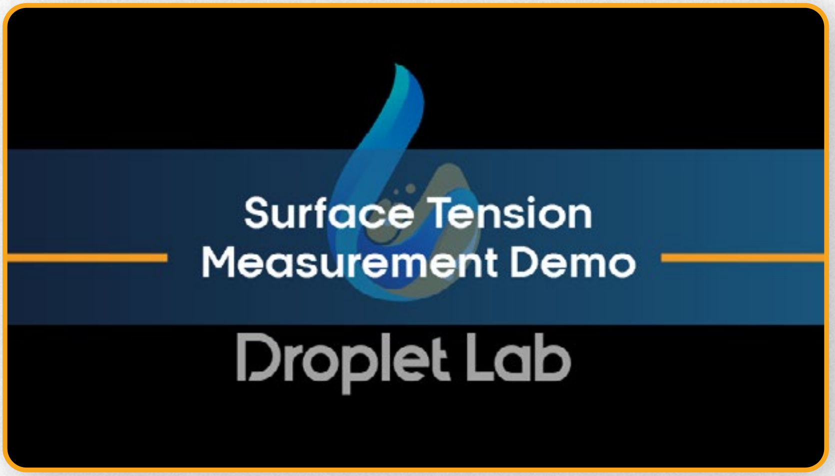
To improve the data quality of your contact angle measurements we recommend you read up on the best practices in the below referenced paper.

Guidelines to measurements of reproducible contact angles using a sessile-drop technique

Surface Tension Measurement

This property measures the force acting on the surface of a liquid, aiming to minimize its surface area. medical devices like catheters, stents, and orthopaedic implants interacts with biological fluids through protein-surface interaction. Protein adsorption can change the surface properties that can result into preventing or enabling attachment of bacteria, or other surface-active species. In such scenario, the knowledge of surface tensions can be helpful [2].

Sample Image taken from Droplet Lab Tensiometer



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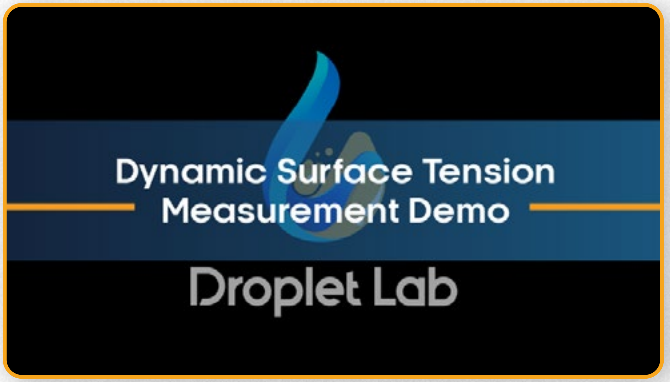
[Learn How Surface Tension measurement is done on our Tensiometer]

Dynamic Surface Tension

Dynamic surface tension is different from static surface tension, which refers to the surface energy per unit area (or force acting per unit length along the edge of a liquid surface).

Static surface tension characterizes the equilibrium state of the liquid interface, while dynamic surface tension takes into account the kinetics of changes at the interface. These changes could be the presence of surfactants, additives, or temperature, pressure, and/or compositional changes at the interface.



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Learn how dynamic surface tension measurement is done on our Tensiometer

When to use Dynamic Surface Tension Measurement

Dynamic surface tension is particularly important when dealing with processes that involve rapid changes at the liquid-gas or liquid-liquid interface, such as droplet and bubble formation or coalescence (change of surface area), behavior of foams, and drying of paints (change of composition, e.g. evaporation of solvent). It is measured by analyzing the shape of a hanging droplet over time.

Dynamic surface tension has applications in various industries, including medical devices, coating, pharmaceuticals, cosmetics, food and beverage, and industrial processes where understanding and controlling the behavior of liquid interfaces is essential for product quality and process efficiency.

Scientific Validation of our Instrument:

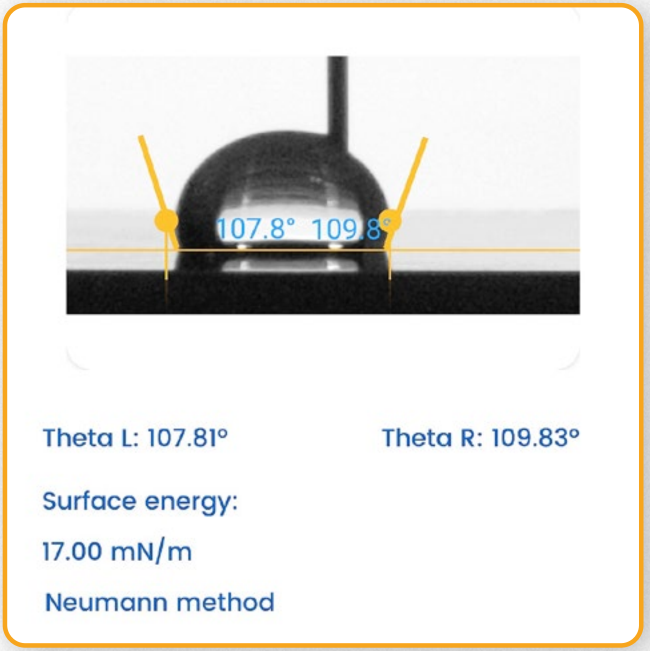
Accuracy and reliability are the cornerstones of any scientific instrument, and concerns regarding the precision of our setup are both understood and acknowledged. While our state-of-the-art tech lays the foundation, it's our unwavering commitment to validation that sets us apart.

This promise of transparency and scientific rigor is supported by two peer-reviewed papers that thoroughly detail and validate the performance of our instrument:

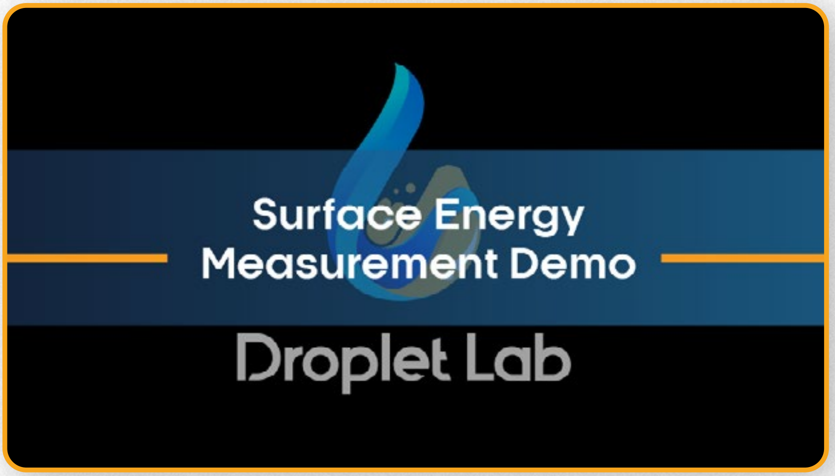
1. Review of Scientific Instruments
2. Colloids & Surfaces A

Surface Energy Measurement

To evaluate the desired properties of coatings in medical devices like catheters, stents, and orthopaedic implants, manufacturer regularly performs surface characterization for which the analysis of surface energy of the coatings on bacterial adhesion and protein adsorption is very critical to the performance of these devices. Surface energy refers to the energy required to create a unit area of a new surface.



Sample Image taken from Droplet Lab Tensiometer



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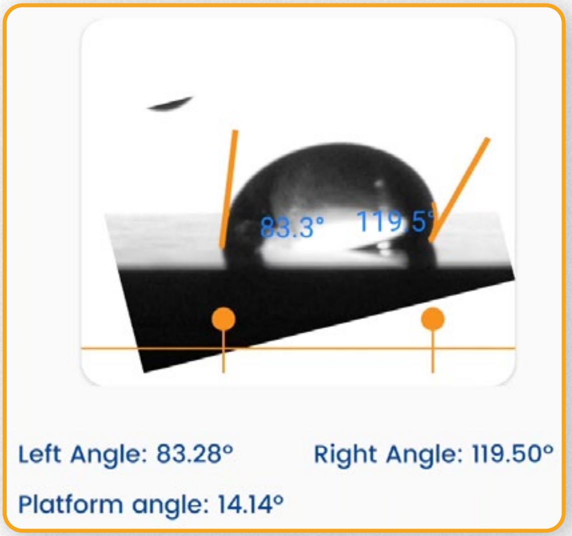
[Learn how Surface Energy measurement is done on our Tensiometer]

Sliding Angle Measurement

The sliding angle measures the angle at which a liquid film slides over a solid surface. It is commonly employed to assess the slip resistance of a surface. Catheters is blood-contacting medical device that is commonly used in clinical medicine to treat different kind of diseases, forexample, cardiovascular diseases. There is always a danger of device failure due to thromboembolic complications and therefore, Catheters are coated with an antithrombotic, omniphobic lubricant-infused coating to make them less thrombogenic [3]. To achieve the coating with efficient results, sliding angle measurements are very helpful.



Sample Image taken from Droplet Lab Tensiometer

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Learn How Sliding Angle Measurement is done on our Tensiometer

By carefully considering and measuring these surface properties, medical device manufacturers can continually improve their products' quality and meet the evolving needs of their customers.

Real-World Implications
Case Studies

Within the medical device industry, several case studies exemplify the advantages derived from conducting surface property measurements.

Presented below are a few illustrative instances:

1 Creating Safer Implantable Medical Devices

Scenario: Imagine a group of experts dedicated to crafting medical devices, like stents or catheters, that can be implanted inside the human body. They understand that the surface properties of these devices can make a big difference in preventing itnfections.

Application: By carefully studying how liquids interact with the surface, they can design surfaces that proteins find less inviting to stick to. This meticulous attention to detail ensures that patients undergoing these procedures have a lower risk of equipment failure, which is vital for their recovery.

2 Refining Drug Delivery for Better Patient Care

Scenario: Consider a team working on advanced drug delivery systems, such as,patches that administer medication or implants that gradually release drugs. The secret weapon for making these systems efficient is the measurement of surface properties.

Application: By analyzing the behavior of liquids on the surface, they can finetune the design to ensure precise drug release and absorption. This innovation leads to increased treatment effectiveness and enhances patient well-being.

3 Healing Harmony in Biodegradable Medical Materials

Scenario: Picture a team focused on developing biodegradable materials for medical use, such as sutures or wound dressings. These materials need to blend seamlessly with the body's natural processes.

Application: By studying how liquids interact with the surface, they can tweak thematerials to promote healing and minimize any negative responses. This thoughtful approach results in medical solutions that aid recovery while naturally breaking down over time.

We are your partners all the way in solving your Business & Technological challenges

If you are interested in implementing these or any other applications you can send an email to us at **abhandankar@dropletlab.com**

We would also be interested to hear from you if you face any sample related difficulties. Book a call with our engineer to discuss the same with the below link **https://calendly.com/gsaini-ob4**

Standards and Guidelines

- **ASTM C813-20 - Standard Test Method for Hydrophobic Contamination on Glass by Contact Angle Measurement:**

  This method provides the procedure of hydrophobic contamination removal with the help of contact angle measurements. This standard is more effective in smooth surfaces and it may not work well in rough or porous surfaces [4].

- **ISO 13485:2016(en) - Medical devices — Quality management systems — Requirements for regulatory purposes:**

  This International Standard sets requirements of a quality management system for regulatory purposes. As per this standard, an organization should demonstrate its ability to provide medical devices and related services that regularly meet customer and applicable regulatory requirements [5].

Sources

[1] “Surface Testing of Dental Biomaterials—Determination of Contact Angle and Surface Free Energy”, Materials 2021, 14, 2716. https://doi.org/10.3390/ma14112716.

[2] “Enhanced anti-biofilm and anti-protein adsorption properties of liquid-infused silver-poly tetra fluoroethylene coatings”, Applied Surface Science 616 (2023) 156463.

[3] “An omniphobic lubricant-infused coating produced by chemical vapor deposition of hydrophobic organosilanes attenuates clotting on catheter surfaces”, Sci. Reports, 7: 11639. doi:10.1038/ s41598-017-12149-1.

[4] https://www.astm.org/c0813-20.html.

[5] https://www.iso.org/obp/ui/en/#iso:std:iso:13485:ed-3:v1:en.