Droplet Lab

The Practical Guide to Surface Science for the Biotech Industry

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INTRODUCTION

Contact angle, surface energy, and surface tension measurements play a crucial role in the biotech industry. These measurements are used to evaluate the wettability and surface properties of materials, which have significant implications for various applications, including drug delivery systems, biomaterials, tissue engineering, and diagnostic devices. Understanding the interfacial behavior and surface characteristics is vital for **optimizing performance, reliability, and biocompatibility** of biotech products.

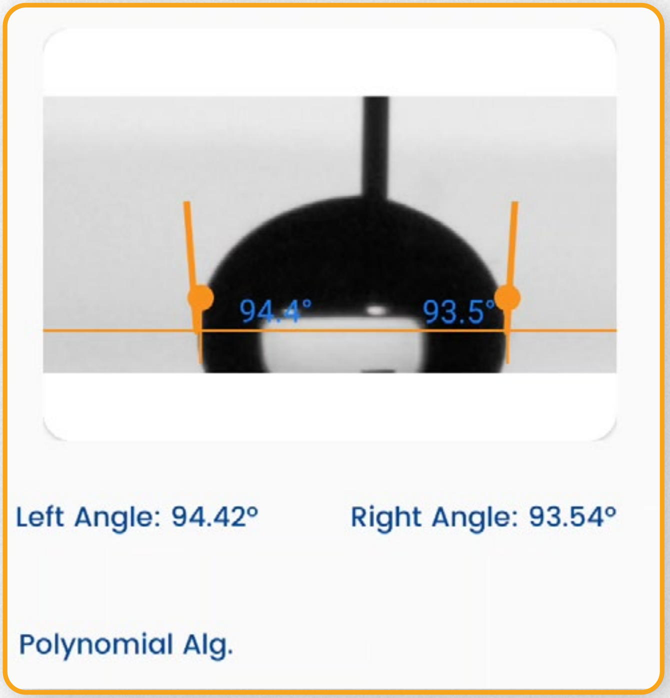
Optimizing Performance

Reliability

Biocompatibility

Contact Angle Measurement

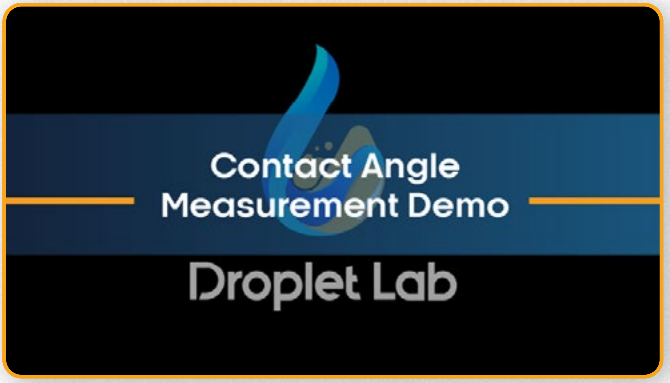
Contact angle quantifies the wettability of a surface, representing the angle between the surface of a liquid and a solid surface. The wettability of a surface affects how cells, proteins, and other biomolecules interact with the material. For example, measuring the contact angle of a biomaterial can provide information on whether it will elicit an unfavorable response when exposed to a tissue.



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 liquid 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, such as 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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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 biotechnology, materials science, and paints in designing effective surfaces and optimizing processes.

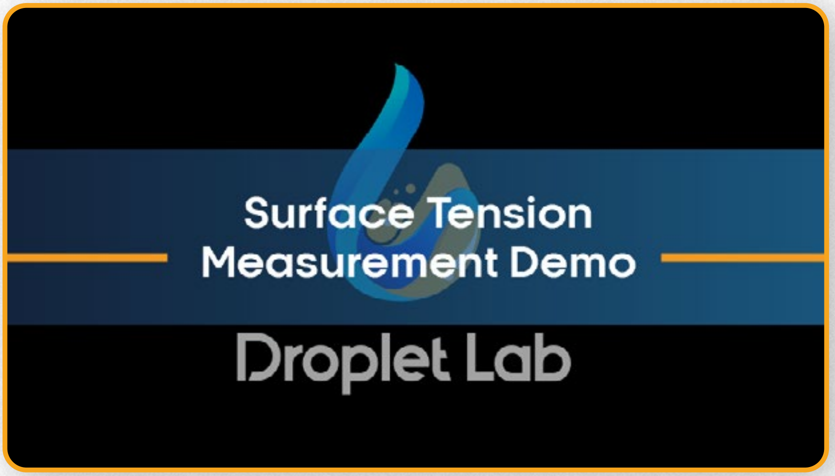
To improve the data quality of your contact angle measurements, we recommend you read up on the best practices in the below referenced paper.

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. Surface tension measurements are essential to predict the interaction between cell culture media and biomaterial surfaces.

Sample Image taken from Droplet Lab Tensiometer



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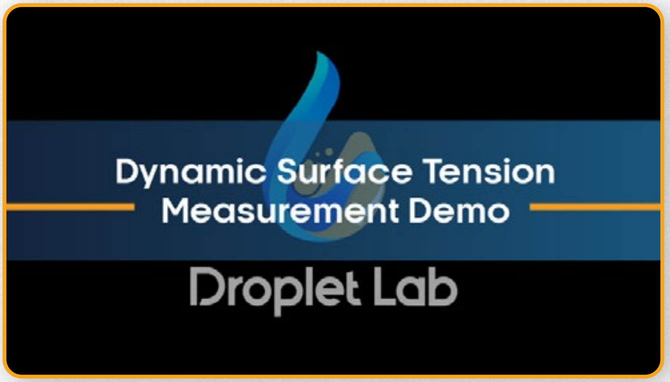
[Learn How Surface Tension measurement is done on our Tensiometer]

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 considers the kinetics of changes at the interface. These changes could be the presence temperature, pressure, and/or compositional changes at the interface.



Watch us on:

[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 often measured by analyzing the shape of a hanging droplet over time.

As such, dynamic surface tension has applications in various industries, including biotechnology, 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:

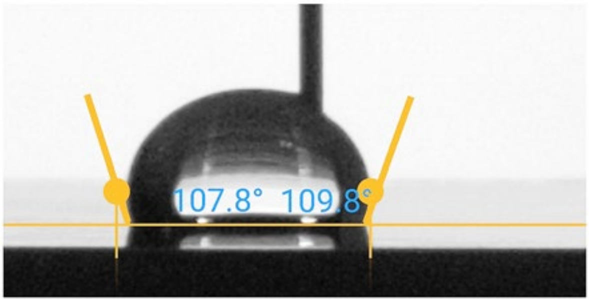
Accuracy and reliability are the cornerstones of any scientific instrument, and concerns regarding the precision of our setup are both understood and acknowledged. While our state-of-the-art tech lays the foundation, it's our unwavering commitment to validation that sets us apart.

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

Surface energy refers to the energy required to create a unit area of a new surface.



Theta L: 107.81°

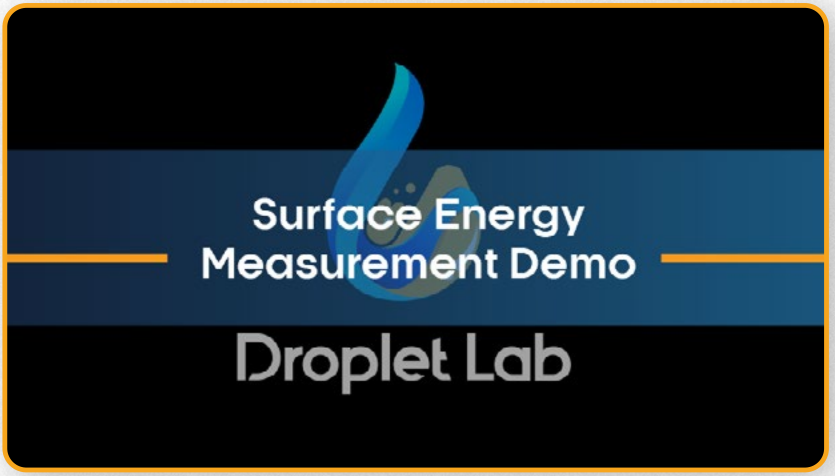
Theta R: 109.83°

Surface energy:

17.00 mN/m

Neumann method

Sample Image taken from Droplet Lab Tensiometer



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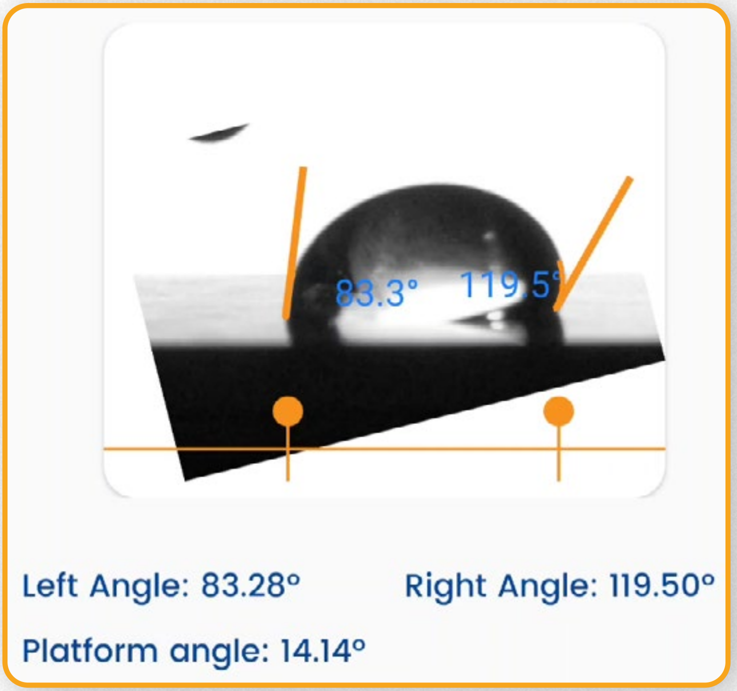
[Learn how Surface Energy measurement is done on our Tensiometer]

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, and it can be related to the cell adhesion properties of a biomaterial.



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, manufacturers can continually improve their products' quality and meet the evolving needs of their customers.

Real-World Implications
Case Studies

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

Presented below are a few illustrative instances:

1 The Dance of Dissolved Oxygen Sensors in Fermentation

Enter the glycolipid biosurfactants from yeast—a sustainable twist in chemical production. [1]

These surfactants are essential in various industries, from food to cosmetics. But more importantly, the role of dissolved oxygen in their synthesis can't be understated. Not only does it provide these microorganisms with enough oxygen, but it also ensures they have the right kind of environment for proper growth. [2]

As such, the membranes used to monitor dissolved oxygen levels should strike the right balance: They need to be hydrophobic enough to repel cell debris—and not so hydrophobic that they trap air bubbles. [3]

Using tools like the tensiometer developed by Droplet Lab, researchers can gauge the surface properties of these membranes and the fermentation solution to create a seamless (and precise) production process.

2 Creating Life with Surface Coatings

Medical implants, scaffolds, biosensors—these words might sound like science fiction, but they're quickly becoming our everyday reality.

Every biomaterial surface has a different interaction with hydrophilicity or hydrophobicity. Knowing these differences is essential, as it influences everything from cell adhesion to tissue regeneration. [4,5]

For instance, tweaking the surface energy and roughness of a substrate can amplify cell growth. [6] Surface tension is important in the fabrication of hybrid materials where 3D printed polymers are combined with cell-laden hydrogels to fabricate biocompatible, full 3D structure of living tissues. This innovative approach taps into surface wetting forces to suspend liquid films across the fenestrations of a reticulated mesh that can be transformed subsequently into a solid coating or hydrogel [7]

3 Nano Magic: Targeting Treatment

It's easy to write off nanoparticles as insignificant due to their petite size—but looks can be deceiving. In reality, these minuscule particles are powerhouses in the biotech sector thanks to their impressive adaptability.

Their large surface area relative to their volume—combined with a tunable surface chemistry, makes them ideal for drug delivery systems—Take, for example, the treatment of eye conditions like glaucoma. The effectiveness of its treatment depends on both the medicine and how it's delivered. With the help of contact angle measurements, researchers can gauge how drugloaded microparticles interact with the eye's surface.

The result? Optimized formulations that improve patient outcomes and ensure medications are delivered efficiently to remain effective for longer.[8]

4 Bioprocess Purification: Where Precision Meets Efficacy

The evolution of modern bioprocesses is intriguing, to say the least. While the end product could be a life-saving drug or a vital enzyme, its initial form is often as inclusion bodies or crystals. Furthermore, the liquid phase in these bioprocesses is a melting pot of bioparticles—ranging from cell debris and whole cells to particulate biocatalysts and by-products.

As such, separating these precious entities from the collection of other particles present is no small feat with the contact angle of bioparticles assuming a significant role in this purification process[9]

Surface properties play a leading role in this process, as a particle's surface dictates how it interacts with its surroundings. And this is where our tools come into play, providing detailed insights that ensure the purification process is as efficient as possible.

Consider, for instance, the challenges of drying and re-dispersing these particles. Without an understanding of the capillary forces at play—forces directly influenced by surface tension—it's easy for particles to aggregate or for films to crack. But by providing precise measurements, we can help researchers avoid these pitfalls and produce the highest product quality possible.[10]

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

In the tightly regulated biotech industry, numerous standards and guidelines are established to ensure that products meet stringent quality requirements. Monitoring and maintaining specific values for surface tension and wettability is crucial for quality control in biotech manufacturing. Variations in these properties can affect the reproducibility and efficacy of processes and products.

The American Society for Testing and Materials (ASTM) technical standards on surface property measurement are relevant to the biotech industry when the specifications of a product depend on its surface properties. For example:

- **D7541-11(2022)- Standard Practice for Estimating Critical Surface Tensions:**

  This standard is applicable to measure the critical surface tension of substrates, primers, and other coatings. The measurements are based on the observation of wetting and de-wetting of different liquids applied to the targeted surface. [11]

- **D7334-08(2022) - Standard Practice for Surface Wettability of Coatings, Substrates, and Pigments by Advancing Contact Angle Measurement**

  It provides a procedure for the characterization of wettability of surfaces by applying contact angle measurements.[12]

The International Organization for Standardization (ISO) develops and publishes international standards that are also relevant to the quality and reproducibility of biotechnology processes, for example:

- **ISO 9101:1987 Surface active agents** — Determination of interfacial tension — Drop volume method. It provides a method to measure the interfacial tension between two liquids. Interfacial tension is essential for formulating stable emulsions and suspensions of drugs and other bioactive compounds, as well as affecting cell culture processes, especially in bioreactor systems.[13]

- **ISO 17025:2005—Testing and calibration laboratories.** The purpose of this standard is to establish broad criteria that ensure the quality of measurement processes, resulting in precise and reliable readings. It also provides general guidelines for the appropriate training of personnel involved in measurements. It should be noted that this standard does not specify specific acceptable tolerances. Instead, its primary focus is to assist laboratories in developing and implementing quality processes by emphasizing critical factors necessary for accurate measurements and promoting effective training practices for personnel involved in taking measurements.[14]

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[13] https://www.iso.org/standard/16696.html

[14] https://www.iso.org/ISO-IEC-17025-testing-and-calibration-laboratories.html