Droplet Lab

The Practical Guide to Surface Science for the Plastics Industry

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TABLE OF CONTENTS

INTRODUCTION

Plastics are polymers that are used in variety of fields such as packaging, automotive, medical devices, electronics, textiles etc. A well-known problem in plastic industry is the adhesion between different polymeric phases. It may be in the form of unwanted adhesion or insufficient adhesion [1]. To deal with these problems, knowledge about surface properties and interfacial properties can be very crucial. Analysis of surface properties like contact angle, sliding angle, surface energy and surface tension is always very helpful in determining how plastics interact with their environment and other materials. With the help of these parameters one can easily evaluate adhesion, wetting behavior, coating, printing, and overall product performance.

Adhesion

Wetting Behavior

Coating

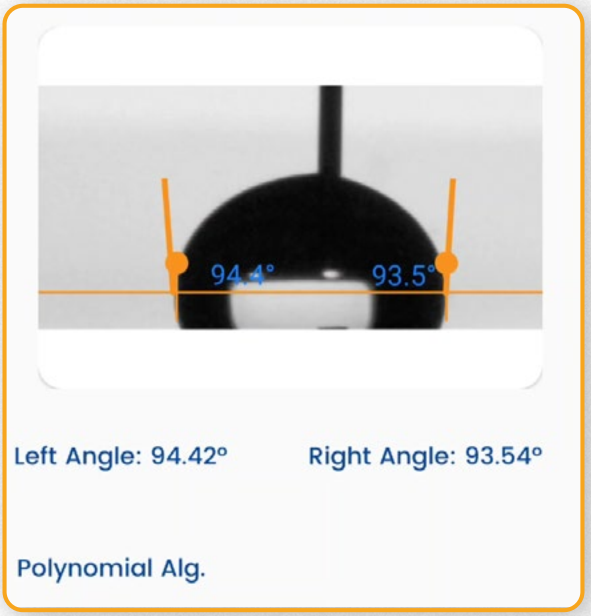
Printing

Overall Product Performance

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

Contact Angle Measurement

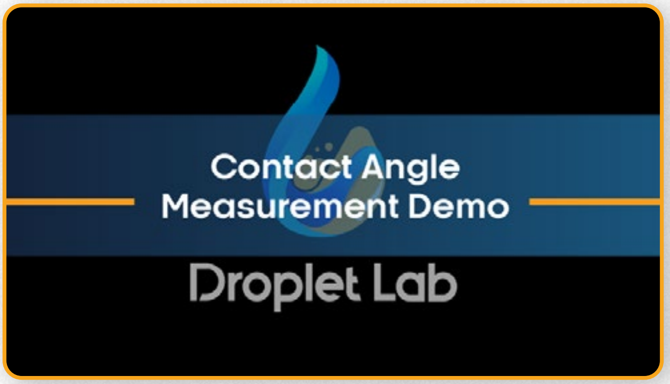
Contact angle quantifies the wettability of a surface, representing the angle between the surface of a liquid and a solid surface. In the automotive industry, plastic components like dashboards and panels often need to be securely bonded together. By measuring the contact angle of adhesives on different plastic surfaces, engineers can select adhesives with optimal wetting properties. Higher contact angles may indicate poor adhesive wetting, leading to weak bonds. Choosing adhesives with appropriate contact angles enhances the strength and longevity of bonded components.



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.

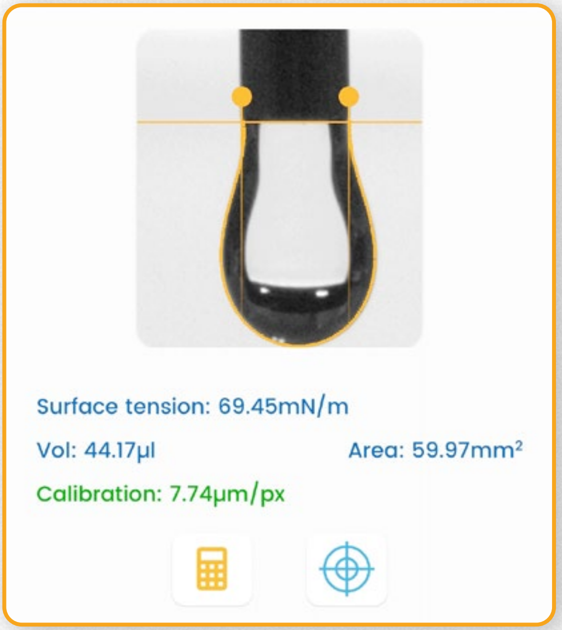
This insight is crucial for real-world surfaces with variations, roughness, and dynamics, aiding industries like plastics, materials science, and biotechnology in designing effective surfaces and optimizing processes.

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

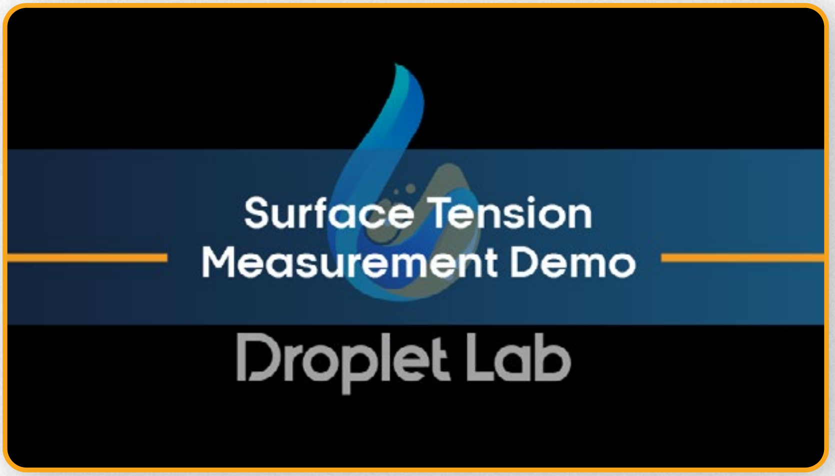
Guidelines to measurements of reproducible contact angles using a sessile-drop technique

Surface Tension Measurement

This property measures the force acting on the surface of a liquid, aiming to minimize its surface area. In industries like electronics and automotive manufacturing, plastic parts often undergo electrostatic painting. Surface tension plays a key role in determining how paint evenly coats the plastic surface. By measuring surface tension, manufacturers can adjust paint formulations and application methods to achieve uniform coverage. This ensures consistent color and finish quality on plastic parts.



Sample Image taken from Droplet Lab Tensiometer



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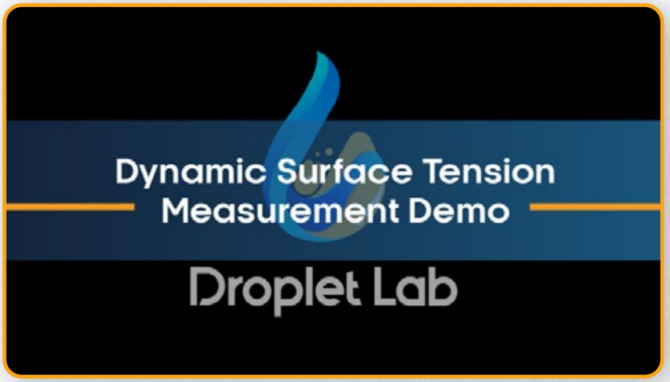
[Learn How Surface Tension measurement is done on our Tensiometer]

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 plastics, 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:

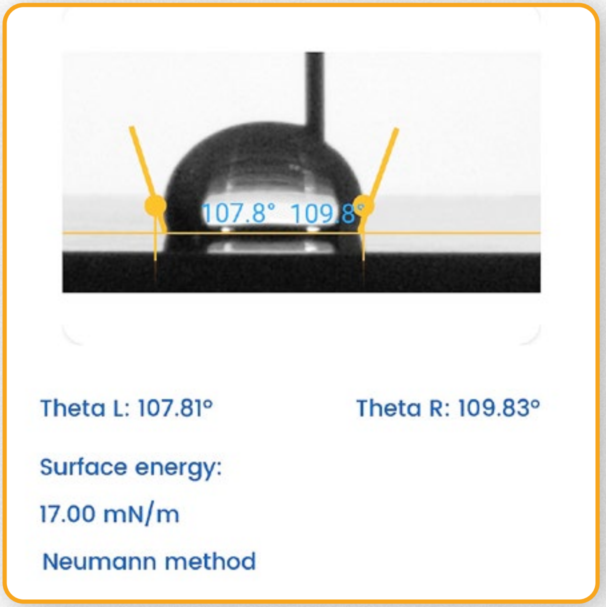
Accuracy and reliability are the cornerstones of any scientific instrument, and concerns regarding the precision of our setup are both understood and acknowledged. While our state-of-the-art tech lays the foundation, it's our unwavering commitment to validation that sets us apart.

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

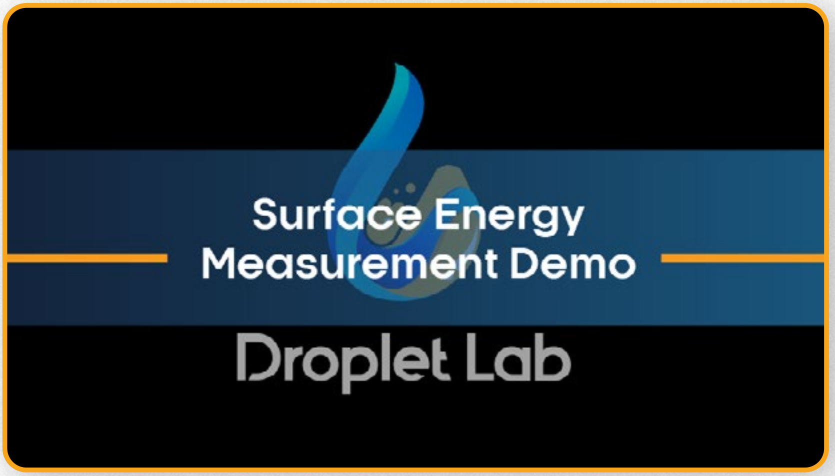
1. Review of Scientific Instruments
2. Colloids & Surfaces A

Surface Energy Measurement

Surface energy refers to the energy required to create a unit area of a new surface. In the packaging industry, plastic films and containers require printing of labels, logos, and other information. The surface energy of plastics directly influences the adhesion of inks and coatings. High surface energy plastics allow better ink spreading and adherence, resulting in sharper and more vibrant prints. Surface energy measurements guide material selection, ensuring that packaging materials are compatible with printing processes.



Sample Image taken from
Droplet Lab Tensiometer



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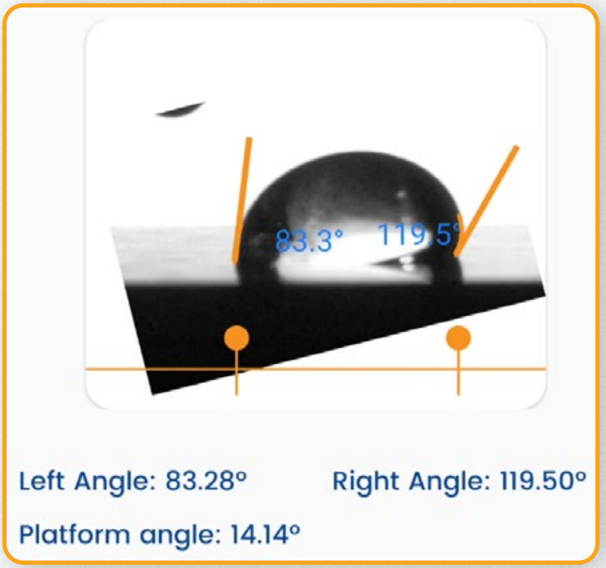
Learn how Surface Energy measurement is done on our Tensiometer

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. Plastic surfaces used in outdoor equipment, such as solar panels and signage, need to repel water and dirt to maintain functionality. By measuring the sliding angle of water droplets on these surfaces, manufacturers can design materials with low sliding angles, ensuring that rainwater easily washes away dust and debris. This self-cleaning property reduces maintenance efforts and extends the life of outdoor equipment.



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

Real-World Implications
Case Studies

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

Presented below are a few illustrative instances:

1 Improving Packaging Performance

Scenario: A packaging company experiences issues with poor ink adhesion on their plastic containers, resulting in label smudging and reduced shelf appeal.

Application: The company performs surface energy measurements to resolve this. It reveals that the plastic used for the containers had a low surface energy and could not be easily wet, leading to poor ink adhesion. Therefore, the company decided to modify the surface chemistry through plasma treatment to increase the surface energy. Surface energy is increased, and thus ink adhesion is improved, and packaging appearance is enhanced.

2 Enhancing Biocompatibility in Medical Devices

Scenario: A medical device manufacturer wants to develop a plastic catheter with improved biocompatibility to prevent clot formation. This manufacturer knows that biocompatibility is related to the surface property of the device.

Application: They apply surface energy and contact angle measurements to optimize the catheter material's surface energy. He applied a hydrophilic coating, and the surface energy was increased, reducing the risk of clot formation and improving the device's biocompatibility.

3 Hydrophobic Microplastic Part Production with Micro-UPM

Scenario: Hydrophobic surfaces with microstructures are widely used for the purpose of self-cleaning and drag reduction.

Application: A manufacturer sought to create hydrophobic microplastic parts and to achieve this, they employed the micro ultrasonic powder molding (micro-UPM) technique. They meticulously linked key parameters including ultrasonic energy, welding pressure, pressure holding time, and replication rate to the surface contact angle in order to attain the desired hydrophobic properties. The results demonstrated that the micro-UPM method offered an efficient and rapid approach to producing hydrophobic microplastic components.

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

- **ISO 8296:2003 Plastics - Film and sheeting — Determination of wetting tension:**

  This standard provides a method of determination of the wetting tension of plastic film surfaces and sheeting in contact with drops of specific test solutions. Evaluation of surface tension can be quite useful in different surface-treatment techniques to improve the ability of plastic films to retain inks, coatings, adhesives, etc. [2]

- **ASTM D5946-17 - Standard Test Method for Corona-Treated Polymer Films Using Water Contact Angle Measurements [3]:**

  This standard provides the guidelines for surface treatments which are applicable where the ability of polymer films to retain inks, coatings, adhesives, etc. is being explored. The contact angle of water can be used as a guiding factor to define the effectiveness of surface treatments on polymer films. The water contact angle is measured by capturing an image of a liquid drop placed on a solid and then analysing it [4]. As per the standard, a guiding contact angle range to define the level of surface treatments is given as follows:

Marginal or no treatment	>90°
Low treatment	85 to 90°
Medium treatment	78 to 84°
High treatment	71 to 77°
Very high treatment	<71°

- **ISO 15989:2004 Plastics - Film and sheeting — Measurement of water-contact angle of coronatreated films:**

  This standard also provides the details for the measurement of the contact angle of water droplets on corona treated polymer film surfaces and in this way determining the wetting tension of the film. As per this standard, surface energy can be defined as energy that is associated with the intermolecular forces at the interface between two surfaces and it is measured as free energy per unit area. Also static contact angles is defined as an angle between a plane solid surface and the tangent drawn in the vertical plane at the interface between the plane solid surface and the surface of a droplet of liquid resting on the surface [5].

Sources

[1] 289–280 ,(5)4 ,"Surface Properties of Plastic Materials in Relation to Their Adhering Performance“, 2002.

[2] https://www.iso.org/obp/ui/en/#iso:std:iso:8296:ed-2:v1:en

[3] https://www.astm.org/d5946-17.html.

[4] https://www.dataphysics-instruments.com/Downloads/ApplicationNote-OCA-Treated-Polymer-Films- ASTM-D5946.pdf?v=1.0.

[5] https://www.iso.org/obp/ui/en/#iso:std:iso:15989:ed-1:v1:en.