Droplet Lab

The Practical Guide to Surface Science for the Paint Industry

Alidad Amirfazli

Department of Mechanical Engineering,
York University , Toronto, Canada

Amit Singh

PhD, Delhi University,
Post Doc - AIST Japan

647-490-4644

abhandankar@dropletlab.com

www.dropletlab.com

98 Major Wm Sharpe Dr Brampton,
ON L6X 3V1, Canada

TABLE OF CONTENTS

INTRODUCTION

Determining the adhesion, durability, and appearance of paint is a crucial objective in the paint industry [1]. This is undertaken to enhance the quality of paint materials. Paint manufacturers employ surface property measurements as a means to improve the performance of their products and ensure they meet the demands of their customers.

These measurements offer numerous advantages to manufacturers, such as:

Improved Adhesion

Enhanced Durability

Superior Appearance

Cost Reduction

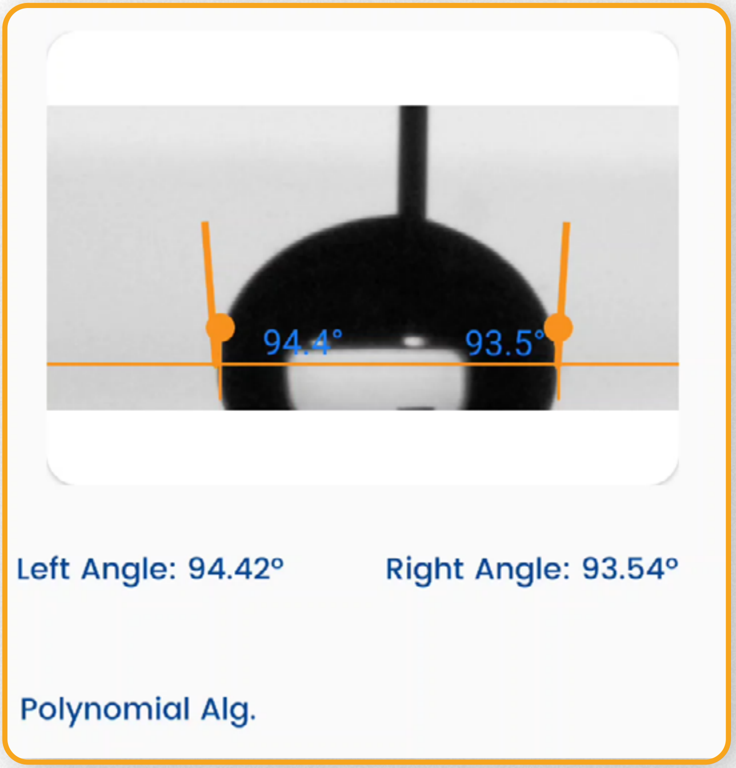
Enhanced Product Development

Increased Customer Satisfaction

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

Contact Angle Measurement

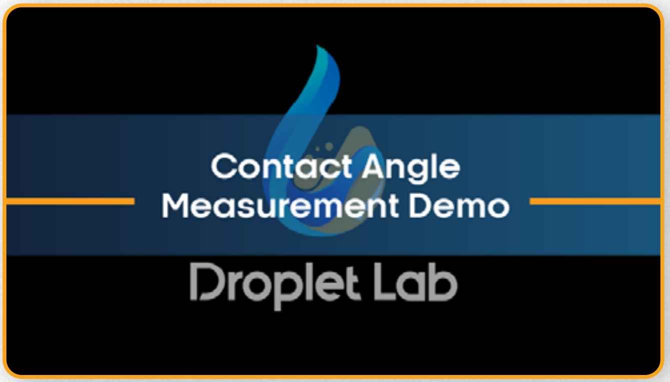
Contact angle quantifies the wettability of a surface, representing the angle between the liquid interface and the solid interface. By measuring the contact angle, manufacturers can ensure that their paints achieve optimal surface wetting [2].



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 v/s 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 paint formulation, materials science, and biotechnology in designing effective surfaces and optimizing processes.

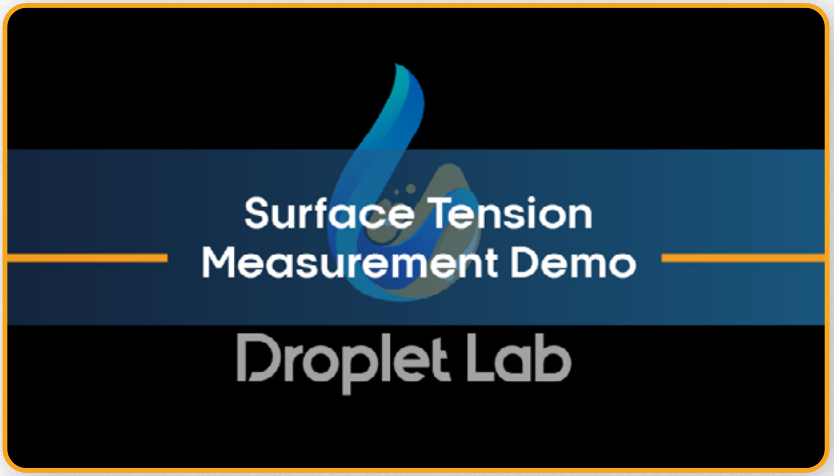
To improve the data quality of your contact angle measurements we recommend you read up on the best practices in the below referenced paper.

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

Surface Tension Measurement

Surface Tension measures the force acting on the surface of a liquid minimizing its surface area. It directly affects the flow and spreading of paint. Manufacturers rely on surface tension measurements to guarantee that their paints possess the appropriate flow and spreading properties.

Sample Image taken from Droplet Lab Tensiometer



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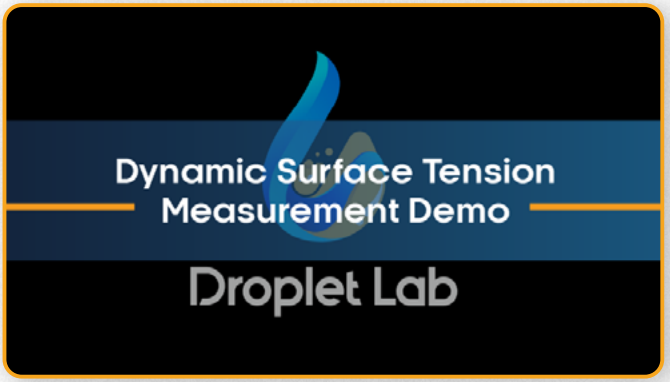
[Learn How Surface Tension measurement is done on our Tensiometer]

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 paint, 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:

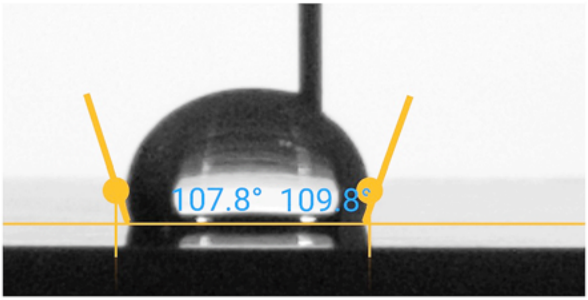
Accuracy and reliability are the cornerstones of any scientific instrument, and concerns regarding the precision of our setup are both understood and acknowledged. While our state-of-the-art tech lays the foundation, it's our unwavering commitment to validation that sets us apart.

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

The interaction between paint and a solid surface is influenced by the surface energy of the solid. Surface energy refers to the energy required to create a unit area of a new surface.



Theta L: 107.81°

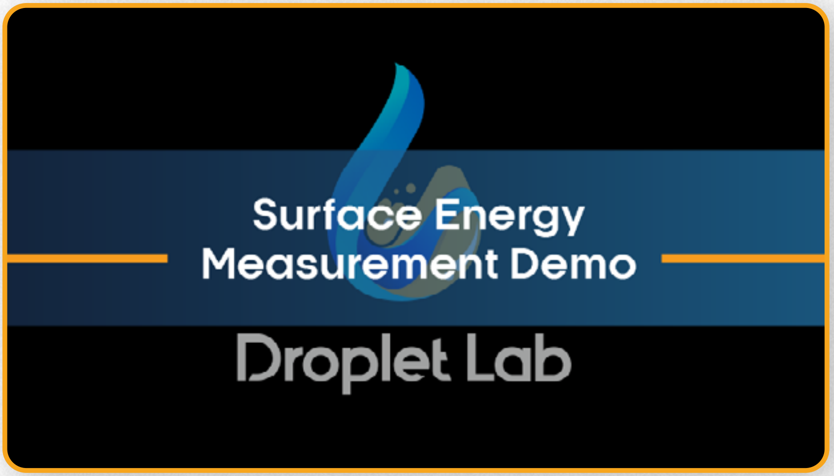
Theta R: 109.83°

Surface energy:

17.00 mN/m

Neumann method

Sample Image taken from Droplet Lab Tensiometer



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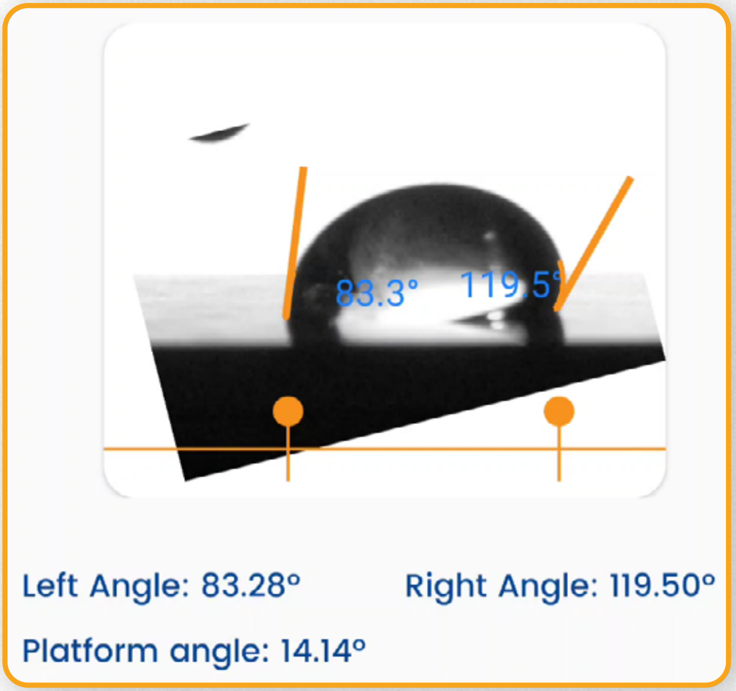
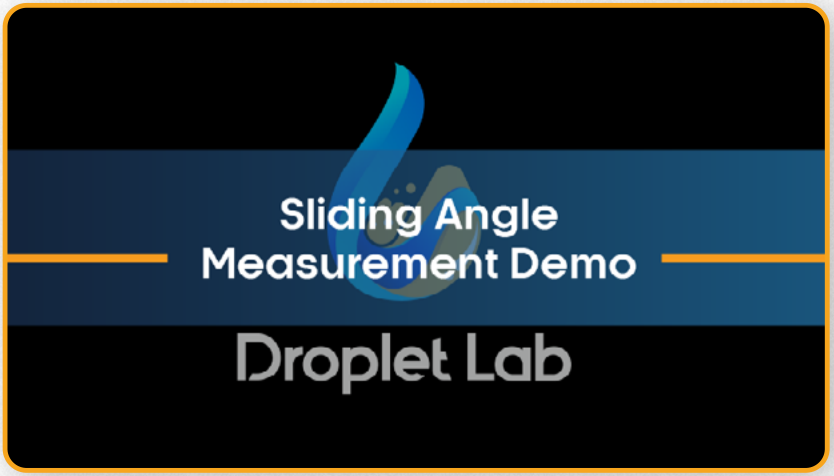
[Learn how Surface Energy measurement is done on our Tensiometer]

Sliding Angle Measurement

The sliding angle measures the angle at which a droplet slides over a solid surface. It is commonly employed to assess the slip resistance of a surface. By measuring the sliding angle, manufacturers can determine if their paints provide sufficient slip resistance.



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 the above 4 surface properties, paint manufacturers can continually improve their products' quality and meet the evolving needs of their customers.

Real-World Implications
Case Studies

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

Presented below are a few illustrative instances:

1 The Metal Dilemma
From Peeling to Perfect Adhesion

Imagine this: a paint manufacturer ventures into coating metal surfaces. They expect durability, but what they get is the opposite – paint that peels away after just a few months.

The issue? A disconnect in surface energies.

After thorough surface tension and wettability evaluations, the culprit was clear– the metal's low surface energy. Not one to back down, the manufacturer remodeled the paint formula, amplifying its surface energy.

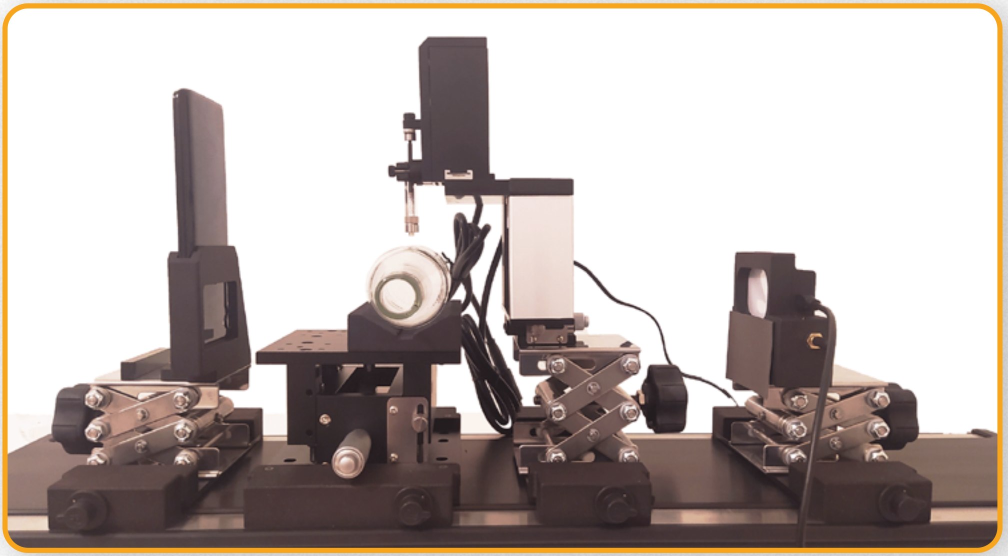
The outcome? Paint that clung to the metal, as if they were always meant to be together.

2 Glass Goals Fogging No More

A manufacturer dreamed of a paint tailor-made for glass — one that would resist the unsightly issues of fogging and streaking. With aspirations sky-high, they embarked on a journey of surface property discovery.

The revelation? The paint's high surface tension was the mischief maker.

With a touch of ingenuity, they tweaked the formula to greatly diminish its surface tension. The result was nothing short of magic: paint that flowed on glass, free from fog and streaks.



Custom instrument designed by Droplet Lab for glass bottle samples

3 Concrete Conquests Crafting Durability

Finally, there was the concrete challenge. For a manufacturer, the vision was clear: paint that would endure, standing tall against wear and tear. Their quest for answers led them to surface property investigations.

The discovery? Concrete's low surface energy was the secret adversary.

With innovation on their side, they introduced a silane coupling agent into the mix, therefore upping the paint's surface energy. This resulted in paint that not only bonded with concrete but also promised longevity thanks to its durable nature.

Custom Instrument designed by Droplet Lab for Benchtop measurements like concrete

At the heart of these tales is a common thread: the undeniable power of surface property measurements. When wielded with precision and insight, they transform challenges into success stories, ensuring that paints do more than just color surfaces; but also interact, adhere, and last.

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 an industry where precision reigns supreme, where does one turn to ensure that their paints can survive this scrutiny? The answer lies in standards and guidelines — the compass that guides paint manufacturers through the complex maze of quality and performance.

The American Society for Testing and Materials (ASTM) technical standards on surface property measurement are widely used to ensure the quality of paints [3]. 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 dewetting of different liquids applied to the targeted surface [4].

- **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 the contact angle measurements. An excellent wetting has been defined by low contact angle in the range of 10 to 20 0 [5].

- **D2578-23** - **Standard Test Method for Wetting Tension of Polyethylene and Polypropylene Films:**

As the title suggests this method is applicable to Polyethylene and Polypropylene Films and provides the measurement of the wetting tension of the film surface which is in contact with drops of specific test solutions in the presence of air [6].

So, the above standard can be used to ensure that paints will adhere properly to surfaces.

The International Organization for Standardization (ISO) evelops and publishes international standards that are also relevant to the quality of paints [7]. ISO has a number of standards and guidelines on surface property measurement, including:

- **ISO 19403-1:2022 -** Paints and varnishes — Wettability — Part 1: Terminology and general principles. General terms, definitions and general principles for wettability can be utilized with the help of this standard [8].

- **ISO 19403-2:2017 -** Paints and varnishes — Wettability — Part 2: Determination of the surface free energy of solid surfaces by measuring the contact angle: This test method specifies the measurement of contact angle to determine the surface energy of solid surfaces. This method is applicable to both substrates and coatings [9].

- **ISO 19403-6:2017 -** Paints and varnishes — Wettability — Part 6: Measurement of dynamic contact angle— It provides the method for the measurement of dynamic contact angle using optical method. Dynamic contact angle can be either advancing angle when volume is increasing at liquid-solid interface or receding angle when volume is decreasing [10].

Sources

[1] "Effects of automotive paint spray technology on the paint transfer efficiency – a review", *Proc IMechE Part D:J Automobile Engineering 1–20.*

[2] "Surface modifications to enhance dropwise condensation", *Surfaces and Interfaces, Volume 25, August 2021, 101143.* Doi: https://doi.org/10.1016/j.surfin.2021.101143.

[3] https://www.astm.org/products-services/standards-and-publications/standards/paint-standards-and-related-coating-standards.html.

[4] https://www.astm.org/d7541-11r22.html.

[5] https://www.astm.org/d7334-08r22.html.

[6] https://www.astm.org/d2578-23.html.

[7] https://www.iso.org/home.html.

[8] https://www.iso.org/standard/81414.html.

[9] https://www.iso.org/standard/64809.html.

[10] https://www.iso.org/obp/ui/en/#iso:std:iso:19403:-6:ed-1:v1:en.