TRACKER™

DROP TENSIOMETERS & INTERFACIAL RHEOMETERS

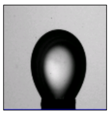
A Complete Range of Measuring Instruments
For Surface Tension & Interfacial Rheology Study

Surface tension and interfacial tension play an important role in our everyday life. Numbers of industrial applications are utilizing interfacial tension phenomenon and require to characterize dispersed systems such as foams and emulsions as well as the surface energy of solids.

TRACKER™ automatic drop tensiometers, helps you characterize, easily and precisely, the properties of the interfaces between 2 immiscible fluids. Measurements provide valuable data, saving time and money in formulating products.

Measuring Principle

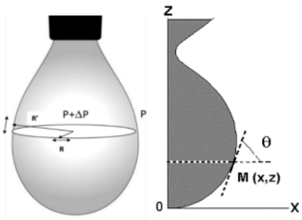
TRACKER™ determines the dynamic interfacial tension between two immiscible fluids by performing a numerical analysis of the shape of a drop or bubble. Two different configurations are possible:



Rising Drop/Bubble: when the density of the fluid inside the drop is lower than the one inside the cuvette.

Pendant Drop/Bubble: when the density of the fluid inside the drop is higher than the one inside the cuvette.

TRACKER™ software uses algorithms to analyze the drop's profile and to fit it with models based on the Young-Laplace equation in order to determine surface tension, interfacial tension or contact angle.



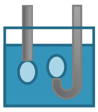
$$\Delta P = \gamma \cdot \left(\frac{1}{R} + \frac{1}{R'} \right)$$

the pressure difference caused by the curvature of the surface is proportional to the average curvature, the proportionality coefficient being precisely the interfacial tension

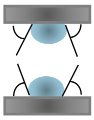
TRACKER™ software controls the variations in volume or area of the drop in both frequency and amplitude. Therefore, it makes possible to study the rheological properties of the interfaces.

The automated regulation guarantees precise and reproducible measurements. Up to 60 frames per second can be recorded. The software calculates the measurements in real time.

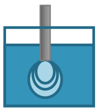
Range of Measurements



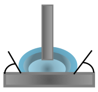
Surface Tension measurement at Liquid/Gas **or interfacial Tension** measurement at Liquid/Liquid interface.



Contact Angle measurement at Liquid/solid interface. The measurement determines the wettability of the solid and the deduction of the surface energy of the solid.



Interfacial Rheology measures the evolution of surface or interfacial tension on a drop / bubble whose volume varies in sinusoidal cycles.



Dynamic Contact Angle : measures the advancing and receding contact angle when the volume of the drop varies.

Data & Measurements

- Tension vs time (accuracy 0,01 mN/m)
- Contact angle
- Temperature: up to 200°C
- Pressure: up to 700bars
- Drop volume / area
- Viscoelastic modulus: Elastic component (real part) & Viscous component (imaginary part)
- Coefficient of rigidity
- Bond number
- Critical Micellar Concentration

Examples of Applications…

Crude oil: emulsion stability for separation, influence of surfactants for oil recovery, dynamic contact angle crude oil/rock/liquid phases.

Cosmetics: emulsion stability, physical-chemical formulation, dynamic contact angle container/emulsion.

Food: Food packaging, stability of emulsion before getting frozen (ice cream), influence of proteins, sugar or alcohol on the bubble size.

Bitumen: wettability, emulsion properties at different temperatures, dynamic contact angle.

Fuel formulation: characterization of the coalescence of an emulsion, wettability.

Lubricant: contact angle (lubricant/material), influence of surfactants on the wettability

TRACKER™ HIGH PRESSURE

designed to characterize surface & interfacial properties in demanding conditions

TRACKER™, automatic single drop Tensiometer, is designed to measure surface / interfacial tension, contact angle, and study interfacial rheology.

Thanks to its smart modular design, TRACKER™ is adaptable to many applications and allows you to choose the instrument that matches your application choosing one or more modules and options:

- Phase exchange
- Piezoelectric cell for higher frequency drop oscillation
- Pressure sensor to measure Laplace pressure
- Automatic CMC module
- Pressure Cell 200°C/200bar

Optical System

TRACKER™ is equipped with a monochrome CCD camera with a resolution of 640x480 pixels and a tele-centric lens. The camera records up to 60 frames per second (fps) covering most applications. When very fast phenomena are studied, a fast camera (up to 600 fps) is provided.

A distortion correction, stored in the software, is used to correct the acquired image for maximum measurement accuracy. Therefore, resolutions lower than pixel (0.2 px) are obtained.

A light source illuminates the sample in a homogeneous and constant manner. The grayscale variation of one pixel only varies by ± 10 grayscales out of 256. The light source has 2 luminous intensities to adapt to solutions with higher optical density.

Measurement device

TRACKER™ is equipped with a cuvette surrounded with a thermostatic envelop. A magnetic stirrer is integrated into the base of the supporting plate to mix samples if solution concentration is changed during experiment.

Temperature can be controlled up to 90°C for both the cuvette and the syringe by using a circulating bath. A temperature-sensing probe is provided to record temperature of the sample or sample jacket (accuracy ± 0.2°C).

Data from the temperature probe are automatically recorded in the software along with sample results. Thus density values can be adjusted with the actual temperature.

TRACKER™ is equipped with a removable platform which allows the horizontality to be adjusted in order to measure the static or dynamic contact angle between a liquid and a solid.

TRACKER™ can be provided in a protective box that prevent from light when operating experiments and protects the instrument from dust.

Data & Measurements

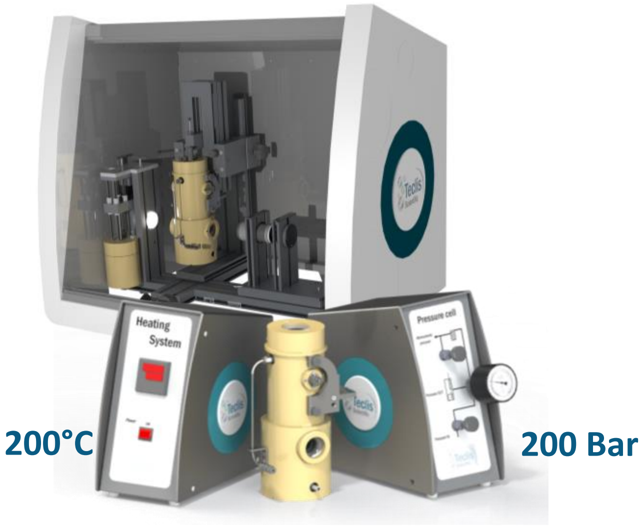
• Surface Tension (liquid/gas)
• Interfacial Tension (liquid/liquid)
• Contact angle & Surface Energy (liquid/solid)
• Advancing and receding Contact angle
• Interfacial rheology – Viscoelastic modulus
    ✓ Surface Elasticity
    ✓ Surface Viscosity
• Coefficient of rigidity
• Critical Micelle Concentration (CMC)
• Temperature

Applications

- Surfactant characterization
- Efficiency/Effectiveness of the surfactants
- Quantity of surfactant to saturate the surface
- Surfactant behavior on the surface
- Wettability of the surface
- Properties of biological surfactants (protein, lipids ...)
- Competition of surfactants...

TRACKER™ H - *Pressure Cell 200bar*

TRACKER™H is standard automatic drop Tensiometer, equipped **with a removable pressure cell** that allows to measure superficial/interfacial tension and contact angle up to **200 bar and 200°C .**



The pressure cell is easily attached to the TRACKER™. It encloses the syringe and the cuvette for handling the sample under a controlled atmosphere.

TRACKER™H is designed to measure gas/liquid or liquid/liquid or solid/liquid interfaces with both configurations, pendant drop or rising drop**.** Thanks to the rotative platform, several drops can be successively placed on or beneath a solid to make several contact angle measurements under pressure without opening the pressure cell.

The syringe piston is accessible from outside the cell and can be automatically controlled. The cell is connected to a pressure network, a gas cylinder or a compressor via the gas control box.

A separated thermocouple measures temperature of liquid inside the cell. Temperature control is driven by using an external circulating bath or electric resistances. A control unit supplies power to electrical heaters and displays set and actual temperature of the environmental chamber jacket.

The module has been designed to be easily dismantled for cleaning.

Drop shape analysis is made through sapphire windows (diam300mm). Both temperature and pressure parameters as well as measurement set up are controlled by the software. Data are calculated in real time.

Measuring devices

Data & Measurements
• Surface Tension (liquid/gas) • Interfacial Tension (liquid/liquid) • Contact angle & Surface Energy (liquid/solid) • Advancing and receding Contact angle • Interfacial rheology – Viscoelastic modulus • Coefficient of rigidity • Temperature / Pressure

Applications

- Supercritical CO^2
- Petroleum, bitumen experiments
- Smelt polymer
- Contact angle under pressure
- Compatible with methane

Technical specifications	
Pressure / T°	Up to 200bar / 200°C
Gas	Supercritical CO^2, nitrogen, argon, air, CO_2 …
Connectors	Stainless steel tube (1/8”OD, 1m length) to connect pressure cell to the gas box

Software

The interfacial tension can be calculated from the profile of a drop which exhibits a revolution symmetry.

The actual shape of the drop results from the interactions between the interfacial tension and the effects of gravity. The interfacial tension gives the drop a spherical shape, whereas gravity elongates it, so that it becomes pear-shaped, or flattened in the case of a sessile drop. If these antagonistic effects have absolute values of the same order, it is possible to determine the shape of the resulting profile, as well as the contact angles between the drop and its support.

The calculation is based on 2 fundamental equations :

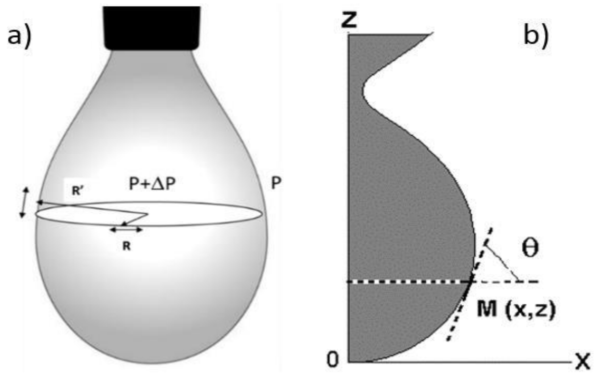


Figure 1.a/Surface curvature of the drop.
b/Coordinates of a point M of the drop surface

- The Laplace-Young equation expresses the fact that the difference in pressure resulting from the surface curvature is proportional to the average curvature, the coefficient of proportionality being equal to the interfacial tension:

$$\Delta P = \gamma \cdot \left(\frac{1}{R} + \frac{1}{R'} \right)$$

R et R' are the main radii
ΔP is the pressure variation across the interface
(Figure 1.a).

- The second equation is based on the equilibrium of the forces across any horizontal plane:

$$2\pi \cdot x \cdot \gamma \cdot \sin\theta = V \cdot (\rho_1 - \rho_2) \cdot g + \pi \cdot x^2 \cdot p$$

p is the pressure exerted on the surface of the drop
γ is the interfacial tension
R et R' are the main drop surface curvature radii
x is the abscissa of the meridian point having z as its ordinate
θ is the polar angle of the tangent to M(s) with axis Ox
V is the volume of the fluid beneath the plane
ρ_1 et ρ_2 are the densities of fluids
g is the acceleration of gravity
(Figure 1.b).

The shape of a drop depends only on the non-dimensioned shape factor named the shape factor or Bond number:

$$Bo = \frac{g\Delta\rho}{\gamma b^2} = \frac{c}{b^2}$$

Δρ is the density difference between the two fluids
g is the acceleration of gravity
b is the inverse of the radius of curvature at the apex
γ is the interfacial tension
c the capillary constant $c = \frac{g\Delta\rho}{\gamma}$

The lower *Bo* is, the more spherical is the drop and the less accurate the measurement (Figure 2-3). To increase *Bo*, it is necessary to increase the radius of curvature at the apex of the drop and thus increase the volume of the drop. The more pear-shaped the drop, the better the measurement.

The value of the Bond number can also be affected by errors due to the optical distortion of the camera lenses and the verticality of the drop.

A good indicator for a precise measurement of the drop's shape is *Bo* higher than 0.1.

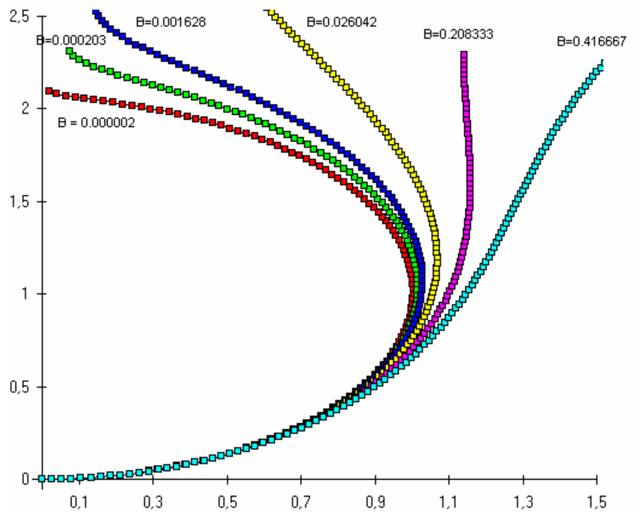


Figure 2 Drop profiles for different Bond numbers

	Bo = 0.1	Bo = 0.01
Gaussian noise (mm)	Relative error	Relative error
0.001	0.25 %	2.3 %
0.005	1.7 %	**12.15 %**
0.009	2.2 %	**28.6 %**
0.013	2.7 %	**27.6 %**
0.017	2.4 %	**42.0 %**
0.021	**5.0 %**	**53.7 %**

Figure 3 Relative error given by the Laplacian profile of the drop according to the Gaussian noise for 2 values of *Bo*

TRACKER™ is automated to perform accurate measurements, produce reliable results and perform reproducible manipulations.

Contact angle measurement allows to determine the wettability of a liquid and the surface energy of a solid. Contact angle measurement can be made on drops deposited manually or automatically driven by the software (option). Contact angle can be calculated from a liquid drop placed on or beneath a solid surface. Measurement begins as soon as the drop detaches from the needle and contacts the solid.

Surface and Interfacial Tension measurements are made with both rising or pendant liquid drops or gas bubbles depending on the density of the fluids.

Measuring over the time (Ex1) makes it possible to determine both the surface tension at equilibrium and the kinetics of adsorption of surfactant molecules.

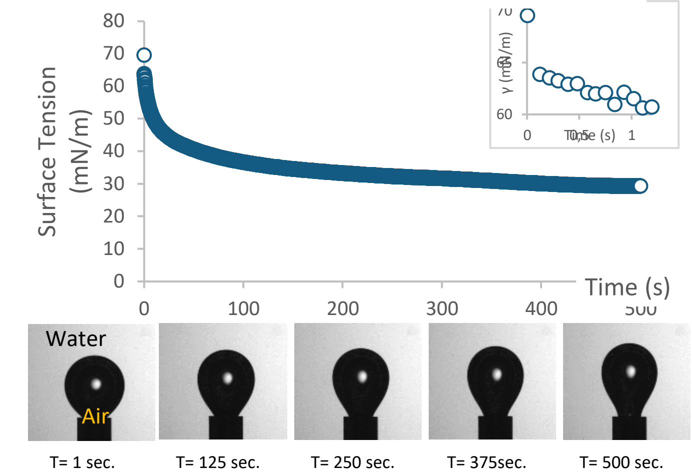
Interfacial rheology (Ex2) measures the viscoelastic modulus often correlated with the stability of foams or emulsions. Interfacial rheology provides a better understanding of the properties of insoluble surfactants, soluble surfactants, soluble surfactants with irreversible adsorption and their reactions at the interface.

TRACKER™ software controls drop volume or area in order to:

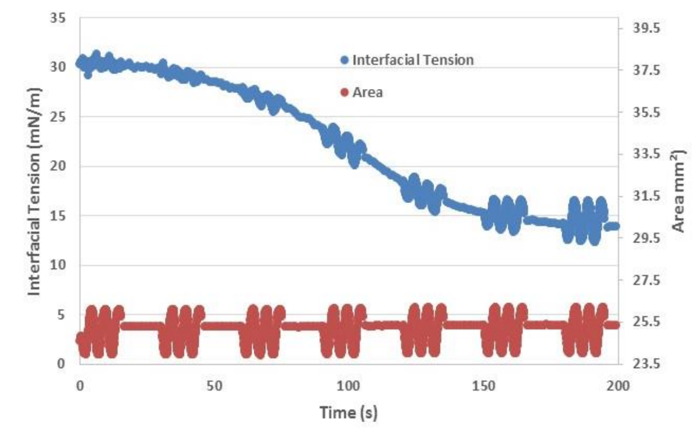
- maintain constant Volume/Area Drop along experiment
- provide a sinusoidal variation whose frequency and amplitude are programmable by the user. These experiments are used to determine the dilatational viscoelastic modulus
- provide linear regimes with sudden variations: pulses.

Data obtained are treated in real time (up to 60 images/s). Setup data, images and results are stored in ITC files and are unalterable.
All measurement results are comparable directly within the software.
The recorded images can be recalculated in post-processing.

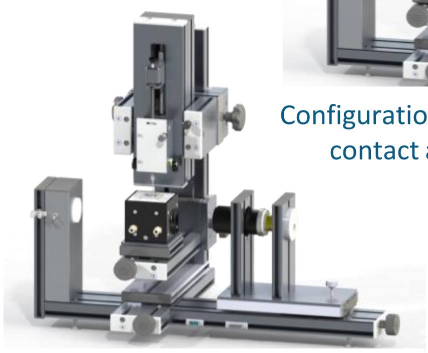
Ex1: Tension at Air/Soap liquid Interface



Ex2: surfactant adsorption at oil/water interface



Configuration for static and dynamic contact angle measurement



Configuration for Surface and Interfacial Tension measurement

Interfacial Dilatational rheology represents a powerful tool to investigate equilibrium and dynamic properties of simple and more complex interfacial layers containing surfactants, proteins, polymers or micro–nano sized particles.

Interfacial rheology allows a better understanding of the properties of surfactants, proteins, polymers or micro–nano sized particles at the interface. Moreover, it enables the **study of adsorption-desorption** phenomena as well as interactions that can take place at the interface. That can reveal crucial information on interfacial dynamics and the contribution of the structure to formulation properties.

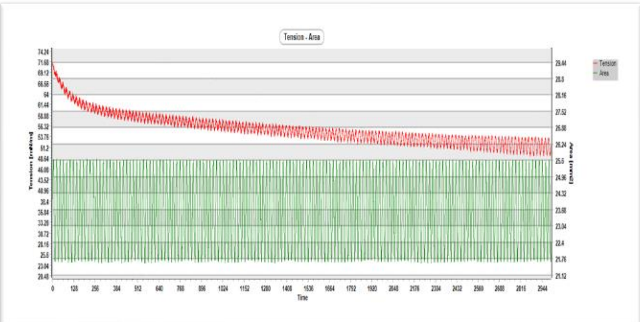
The calculation of the viscoelastic modulus gives a better understanding of how elasticity and viscosity properties of interfaces can be modified and correlated with the stability of foams and emulsions.

Interfacial Rheology by TRACKER™

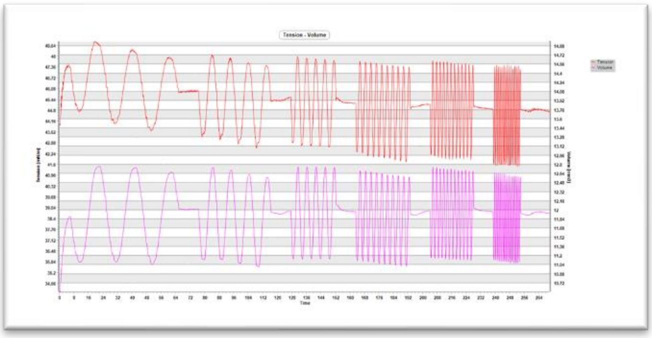
TRACKER™ software enables to precisely control the drop/bubble volume or area and to perform at the same time a sinusoidal variation whose frequency and amplitude is determined by the user. From the basic single-frequency oscillation to complex scenarios including several oscillation steps, all measurement parameters can be set or changed independently, even during measurement:

- Oscillating frequency: from 0.001Hz to 2Hz and up to 10Hz with Piezoelectric module
- Drop volume variation: from +/- 0.1 µl to +/- 100 µl and up to +/- 4 µl with Piezoelectric module
- Volume variation Speed min : 0.01 µl/s
- Volume variation Speed max : 20 µl/s
- Time: drop or bubble area remains constant during oscillations for several hours including at a gas-liquid interface

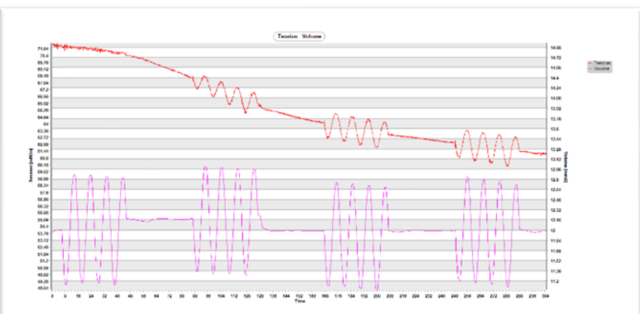
Interfacial rheology measurement examples with TRACKER™



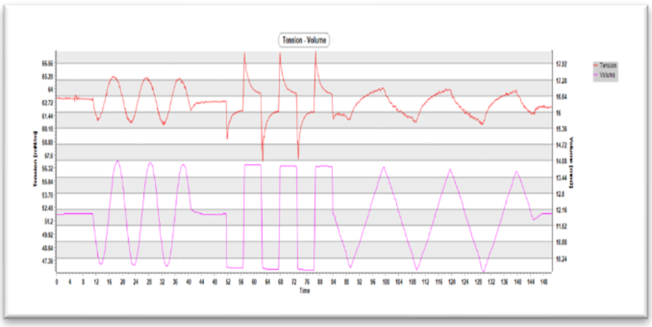
Ex 1: Area regulation during adsorption kinetics



Ex 2: Volume regulation with frequency sweep



Ex 3: Volume regulation with and without oscillation periods



Ex 4: Volume regulation with amplitude sweep

VISCOLEASTIC MODULUS

Viscoelasticity calculation can be performed during the measurement.

$$E = d\gamma/(dA/A)$$

Raw data are recorded, either as drop images or measurements. They can be opened later for re-analyzing and/or reevaluation.

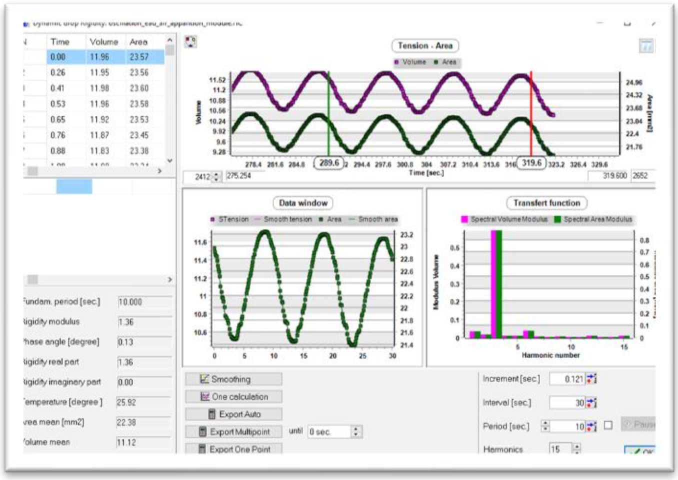
Example of Viscoelastic modulus Calculation

RIGIDITY MODULUS

The calculation of the modulus of rigidity can be performed during the measurement.

$$\text{Rigidity} = (dV/V) / (dA/A)$$

It enables to highlight the appearance of membrane on surfaces.



Example of Rigidity modulus Calculation

Compression & dilatation Interfacial rheology

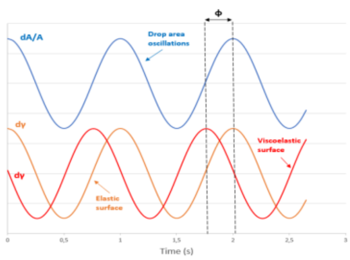
Interface deformation consists of a variation in the interfacial area A (compression & dilatation).

The response of the interface to such deformation is manifested by a variation in surface tension γ.
A viscoelastic modulus can be defined as the increase in surface tension as a function of surface deformation.

$$E = d\gamma/(dA/A) = d\gamma/d\ln(A)$$

The viscoelastic modulus in compression/dilatation is therefore the coefficient of proportionality between a deformation (dA/A) and a surface stress (in N/m), surface tension.

If the deformation varies over time, the ratio between stress and deformation speed with the corresponding surface viscosities can be calculated. If a surface is sinusoidally dilated and compressed at a frequency ω and an amplitude ΔA, and for a viscoelastic surface, a phase shift θ may occur between the change in strain ($\Delta A/A_0$) and the surface tension.



The viscoelastic modulus E becomes a complex number, with a real part E', representing the stored and recoverable energy, and an imaginary part E'', corresponding to the mechanisms that dissipate mechanical energy.

$$E = |E|\cos(\theta) + i|E|\sin(\theta)$$

$$E' = |E|\cos(\theta)$$

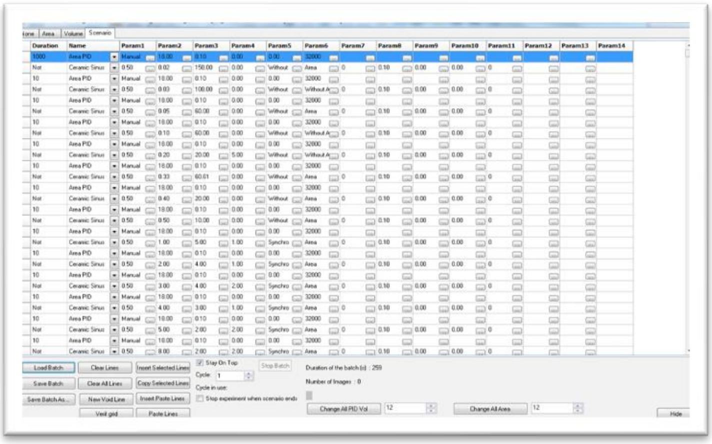
$$E'' = |E|\sin(\theta)$$

BATCH: SCENARIO MANAGEMENT

Batch function enables to write a scenario with an unlimited number of steps or actions to be carried out on the droplet/bubble during the measurement.

All measurement parameters can be set or changed independently, even during measurement:

- Area/volume regulation
- Oscillating frequency
- Oscillation amplitude
- periods
- Time

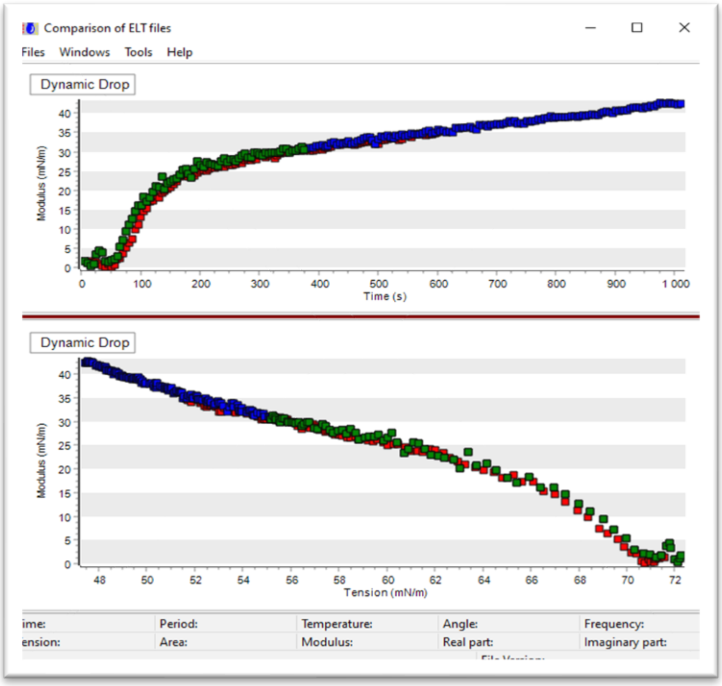


Example of Batch settings

RESULTS COMPARISON

Raw data are recorded, either as drop images or measurements. They can be opened and compared in the software directly. Drop images and measurement data can also be opened later for re-analyzing.

Viscoelastic and Rigidity Modulus Results can also be compared directly in the software without prior data export.



Example of Modulus comparison

About US

TECLIS Scientific is a French company specializes in measuring instruments and services for Interface Science for more than 25 years.

TECLIS Scientific designs and markets analytical equipment and provides scientific expertise to characterize dispersed systems such as foams and emulsions and to characterize solids surface energy. .

An advanced technology software based on image analysis is applied in all instruments. A complete range of measuring instruments has been developed to study and understand interfaces properties of liquid/liquid, solid/liquid and gas/liquid interfaces.

TECLIS Scientific uses innovative engineering to create efficient instruments and software solutions which are easy to use for researchers.

Measuring Instruments for Interface Science

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