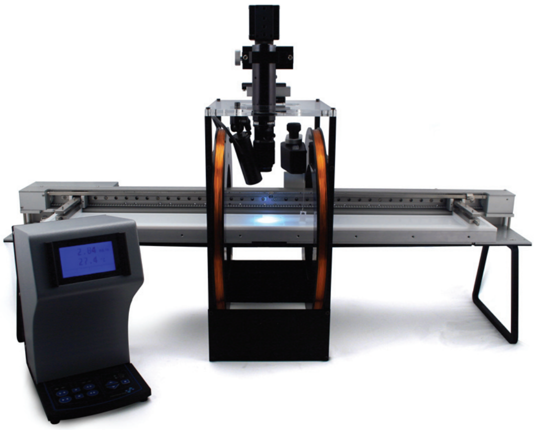
KSV ISR 400

Interfacial Shear Rheometer

The KSV Interfacial Shear Rheometer (KSV ISR 400) is a unique instrument that provides, for the first time, an accurate and quantitative method to measure the shear properties of fluid interfaces (gas/liquid or liquid/liquid). The method marks a quantum leap in technology from the traditional rotational rheometers that lack the sensitivity to probe many of the phenomena occurring within a thickness range of a few nanometers. The ISR400 can be combined with a standard KSV Langmuir trough, allowing measurement on both soluble and insoluble films.



KSV ISR 400 + KSV Langmuir trough

The instrument can be mounted onto standard KSV troughs for insoluble monolayers, or it can be used with normal sample dishes for soluble systems. Measurements can simply be performed either at the air/water or oil/water interface.

Measuring with KSV ISR 400

Shear rheological properties

This unique instrument reports the full range of shear rheological properties of thin films:

- Interfacial viscosity
- Elastic (storage) modulus
- Viscous (loss) modulus
- Compliance
- Relaxation times

Applications

KSV ISR 400 enables number of applications such as:

- Prediction of emulsion, froth and foam stability
- Determination of thin film structure
- Examination of phase transitions
- Monitoring surface gelation and network formation in real time
- Continuous monitoring of protein adsorption and denaturation
- Detection of entanglements and hydrogen bonding in thin films

Specifications

Dynamic moduli lower limit: 0.001 mN/m
Frequency range: 0.01 to 10 rad/s
Strain range: 3×10^{-4} to 1

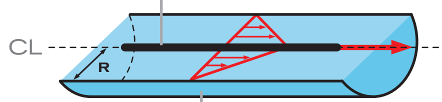
Software

LabView-based software allows the user to control the applied stress or strain. Real-time measurements of the surface rheological properties are presented.

Rheological Properties of Thin Films

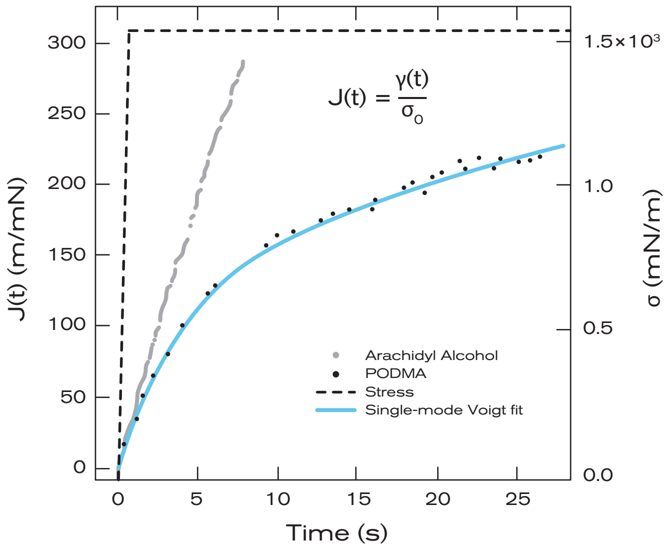
When a stress is applied to a thin film, it will deform. The relationship between stresses and deformation defines the rheological properties of the film. Most systems encountered in industry and in biology are viscoelastic films where these relationships are nonlinear and intermediate between purely viscous and purely elastic responses. An important example would be a protein monolayer at an oil/water interface where the protein has denatured and formed a two-dimensional network.

The KSV ISR400 applies a controlled stress, σ, to an interface by creating a magnetic field gradient onto a slender rod at the interface, causing it to glide on the surface. This induces a simple shearing deformation of the interface (see figure below). The resulting strain, γ, is measured in real time by imaging the position of the rod onto a CCD detector. The KSV ISR 400 can be operated in two different modes: creep compliance where a steady stress is applied and dynamic testing where sinusoidal stresses at variable frequencies, ω, are applied.



Creep compliance (J(t))

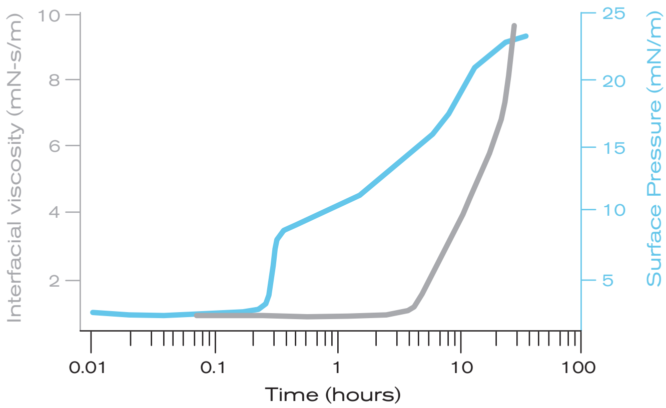
In this test, the instrument produces the surface viscosity, μs, the storage modulus, G', and the relaxation time, τ, of the film. The graph below shows two curves of compliance are plotted as functions of time. The straight, gray line is the linear response of a Newtonian phase of arachidyl alcohol. The inverse of the slope of the curve is the surface viscosity of the layer. The yellow line is the nonlinear response of a monolayer of the amphiphilic polymer Poly(octadecyl methacrylate), which shows a highly viscoelastic and non-Newtonian response.



Dynamic testing

In a dynamic test, the instrument delivers the interfacial moduli, G'(ω) and G"(ω). These are the elastic (storage) and viscous (loss) moduli, respectively. The relative magnitudes of these two properties immediately provide a measure of the tendency of a film to behave more like an elastic membrane or a viscous, fluid film. These quantities can be converted to the dynamic, interfacial viscosity, η*.

The graph opposite illustrates the time evolution of the interfacial viscosity of a monolayer of the protein lysozyme residing between water and decane is plotted as a function of time. Also plotted is the surface pressure of the layer. These data show the evolution of the adsorption and crosslinking of the protein as a viscoelastic "skin" develops at the interface as a function of time.



Comparison with Alternative Methods

While several commercial rheometers can be fitted with special probes to study interfacial shear rheology, the mechanical connection between the probe and the rheometer greatly limits their sensitivity. The absence of any physical connection between probe and rheometer in the ISR 400 instantly improves sensitivity by several orders of magnitude compared with standard rheometers. This is clearly of advantage in systems where small changes in surface rheology are of critical importance. Rather than directly competing with standard rotational rheometers, the ISR 400 compliments them by opening up several orders of magnitude of measurable shear strain.

Interfacial rheological properties can also be accessed by dilating the interface (i.e. changing it's area) and following the change in surface tension. This can be done either by drop profile analysis, where the drop volume is altered, or in a Langmuir trough, where the area is varied. It should however, be understood that dilational and shear deformation cannot be directly compared. A great advantage of the shear measurement is that the interfacial area is held constant. Changing the area of the interface in the dilational measurement introduces the complication that the concentration of surface-active material at the interface often does not remain constant. The rate of change of surface tension is therefore not only dependent on the viscoelastic behaviour of the monolayer, but also on the solubility and adsorption/desorption rate of the surface-active material. A further advantage of the ISR 400 is that the open architecture allows simultaneous application of optical and Brewster angle microscopy.

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