What's the difference between surface tension and surface energy?

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What is surface tension?
Surface tension is a phenomenon whereby a liquid can resist an external force and minimises its surface area. For example, a metal needle can float on the surface of water. Despite being denser than water, the surface tension of the water seems to create a "skin" that supports the weight of the needle. This phenomenon is achieved through the power of friendship! Or at least the power of cohesion.

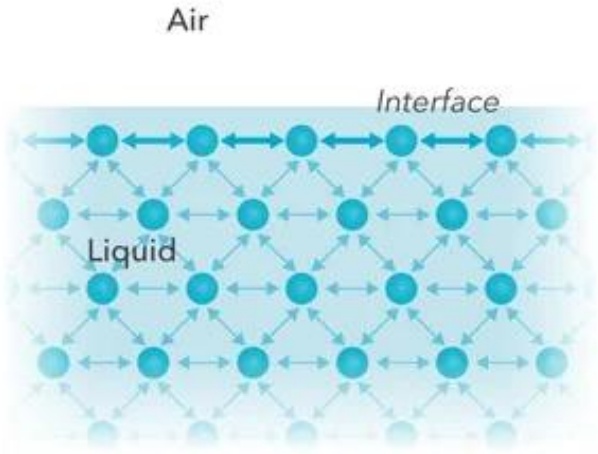

Figure 1 – Molecules at the interface are subject to unbalanced forces

Figure 1 illustrates where the lack of friends causes tension. Cohesion is the force between molecules of the same type. Inside the liquid, these molecules have balanced cohesive forces, friends on all sides, meaning they are stable; however, at the surface of the liquid (in this case the interface between the liquid and the air), the cohesive forces between the molecules are unbalanced. They experience cohesive forces below them and adjacent to them but not above them (where they lack friends!). The sum of these forces at the surface is directed inwards. This imbalance creates instability, creating surface tension.

Surface tension results in the liquid attempting to minimise its surface area. You can see this when water collects on a surface, like on your waxed car bonnet, as it forms spherical droplets instead of spreading out flat. You can also see it in the zero gravity of space, when water forms a perfect sphere.



Figure 2 - NASA astronaut Chris Cassidy, Expedition 36 flight engineer, watches a water bubble float freely between him and the camera, showing his image refracted, in the Unity node of the International Space Station.

Surface tension is commonly measured in mN/m (millinewtons per meter), mJ/m² (millijoules per meter squared), or dyne/cm – often known as “Dynes".

Surface tension can be measured in a variety of ways, and in the past has traditionally been done through the use of force tensiometers, with either a Du Noüy ring or a Wilhelmy plate. It can also be determined with an optical tensiometer through pendant drop methods or using a bubble tensiometer and the bubble pressure method.



Figure 3 - A Sigma 702ET force tensiometer measures surface tension with a Du Noüy ring or Wilhelmy plate

Surface tension plays a big part in wettability; the lower the surface tension, the more dispersive the liquid, and the more willing it is to spread out.

What is surface energy?
Surface energy, sometimes called surface free energy, is surface tension for a solid as opposed to a liquid. Surface energy and surface tension are physically equivalent and are measured in the same units. The “free" in the term *surface free energy* refers to the free energy available to do work at the surface of the material, or how the atoms or molecules at a surface have unrealised bond energy.

Atoms in the bulk solid (not at surface) are more stable, with balanced cohesive forces. Surface free energy tends to increase when the material's internal cohesive forces are stronger, as molecules at the surface experience a stronger inward pull from neighbouring molecules in the bulk. This creates a higher energy state for surface molecules compared to those in the interior. Metal is typically a good example of a material with high surface energy.

Surface energy can be determined using contact angle analysis using optical tensiometer. This method usually requires two liquids, one polar and one non-polar, such as water and diiodomethane. The optical tensiometer dispenses microliter-sized droplets of each test liquid onto the surface and captures high-resolution images of the droplets.

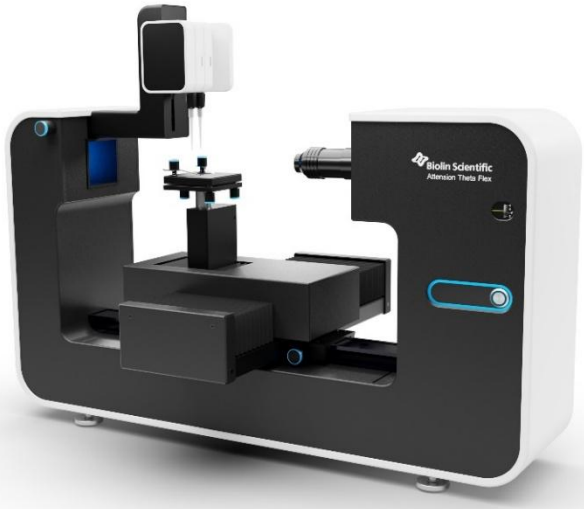

Figure 4 – An example of an optical tensiometer, which can be used to measure contact angle

Contact angle and wettability
The optical tensiometer analyses the shape of the droplet on the surface to determine the contact angle (θ). The contact angle is the angle formed between a liquid droplet and the solid surface, indicating how well the liquid spreads. A low contact angle (< 30°) indicates high surface energy (good wettability). A high contact angle (> 90°) indicates low surface energy (poor wettability).

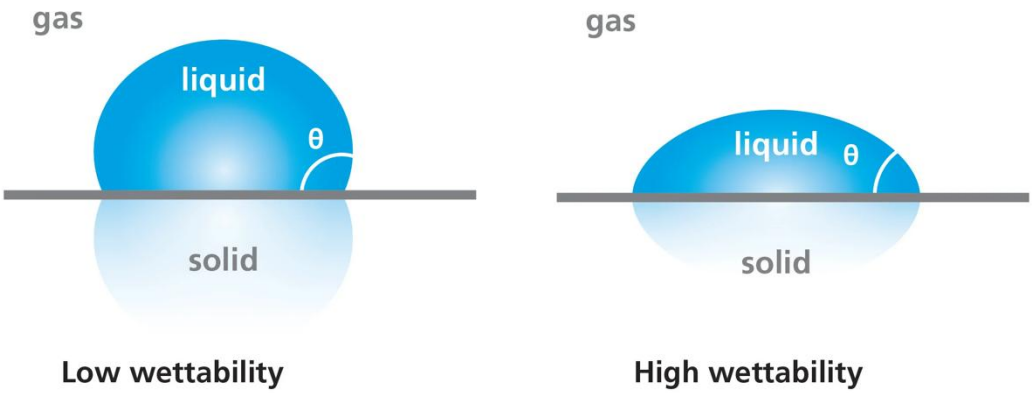

Figure 5 – High and low contact angles

Using the contact angle measurements, the software calculates the surface energy of the solid using with one of several different mathematical models; the Owens-Wendt-Rabel-Kaelble (OWRK) method being the most common.

Other measuring methods
Another method for determining surface energy is through the use of Dyne inks. These inks come in a range of surface tensions and are commonly available in an application pen. When a Dyne pen is applied to a substrate, the ink will either form a continuous film on the surface or pull back into small droplets. If the Dyne pen ink forms a continuous film which is stable for three seconds, it indicates that the surface energy of the substrate is at least as high as the ink value. This method is not as precise as an optical tensiometer and is often destructive; however, it is very quick and easy.



Figure 6 – Dyne Pens showing the ink wetting and non-wetting at different Dyne levels

How do surface tension and surface energy apply to adhesion?
Wetting describes how easily a liquid spreads on a solid surface. For wetting to take place, surface energy of the solid must be greater than or equal to the surface tension of the liquid; enough to overcome the liquid's surface tension and the solid-liquid interfacial

energy. Surfaces with low surface energy will have poor wetting and high contact angles, because it is not energetically favourable for a liquid to spread across the surface. Remember: minimum surface area is the lowest energy and most stable state for a liquid, while having a covered surface is the lowest energy and most stable state for a solid.

Wetting is a prerequisite for adhesion. You can imagine that a liquid adhesive or ink which has balled up on a surface is unlikely to form great adhesion.

In an application where adhesion is required (printing, bonding, sealing, painting, coating, etc), understanding the surface tension and the surface energy of the components – and, crucially, the difference between them – can be very useful in determining material choices, the development of the process, the reliability and robustness of that process, and quality control of the process.

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We support you with your material choice, process development, ongoing production, and product supply, whether it's the adhesives, coatings and sealants themselves or the equipment you need for application, curing, surface preparation and measurement.

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