Hydrophilic surfaces and air humidity

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The surface tension of a material, depends on how many H_2O molecules are located at the surface. The wetting properties and contact angle (*CA*) thus depends on the water content of the material. The water content of a material of course depends on how much water it has been in contact with and for how long, and on drying and temperature etc. Less obvious is the humidity of the surrounding air, but this has a significant impact on surface tension and contact angle.

A **hydrophobic material** become less hydrophobic when there is a lot of water in the material. This makes intuitively sense, because water itself is very hydrophilic. When water is added to a hydrophobic material, it should become more hydrophilic ie. less hydrophobic.
Example: A solid hydrophobic material (*CA*=100°) has 5% water (*CA*=0°) added. Simple *CA* averaging gives *CA*=95° for the moist material.
One cannot use averaging of contact angles or averaging of surface tension, and expect to get an accurate result of a mixture of materials. However, this example demonstrates that a hydrophobic material the behavior is as intuitively expected.

However, a **hydrophilic material** becomes less hydrophilic when water is added, and this makes no intuitive sense.
Example: A solid hydrophilic material (*CA*=10°) has 5% water (*CA*=0°) added. Simple *CA* averaging gives *CA*=9.5° for the moist material. However, this is completely wrong because the contact angle increases to ~50°.

This is exactly what we observe when a hydrophilic material, or hydrophilic coating, is in contact with humid air, it becomes less hydrophilic and the contact angle increases.

What is going on?

A hydrophilic surface "likes" to be in contact with water. In more scientific terms; the total surface energy is lower when the hydrophilic material is in contact with water, than when it is in contact with air.
A hydrophilic surface is hydrophilic because it has unbalanced surface charges. The highly polar H_2O molecules favorably binds to the unbalanced surface charges, and thus lower the total surface energy. This is illustrated in figure 1. The strong attractive interaction between water and the surface, is what makes the surface hydrophilic.

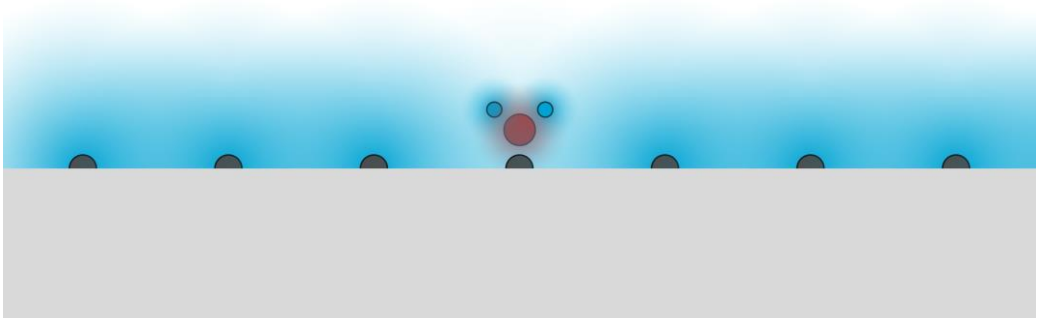

Figure 1. A hydrophilic material (grey) with unbalanced surface charges (black), and the associated electric field (blue). A water molecule is bound to one of the charge sites, thereby partly balancing the charge and thus reducing the field and field energy.

The complication is that the hydrophilic surface likes to be in contact with H_2O molecules, irrespective of where the molecules come from. The H_2O molecules can come from liquid water, but also from humid air.
When a surface charge site binds a H_2O molecule, it cannot bind more, and thus the surface becomes less hydrophilic. For this reason, a hydrophilic surface must be kept dry to maintain its hydrophilicity. Contact with liquid water or humidity in the air, will make the surface less hydrophilic. This is illustrated in figure 2.

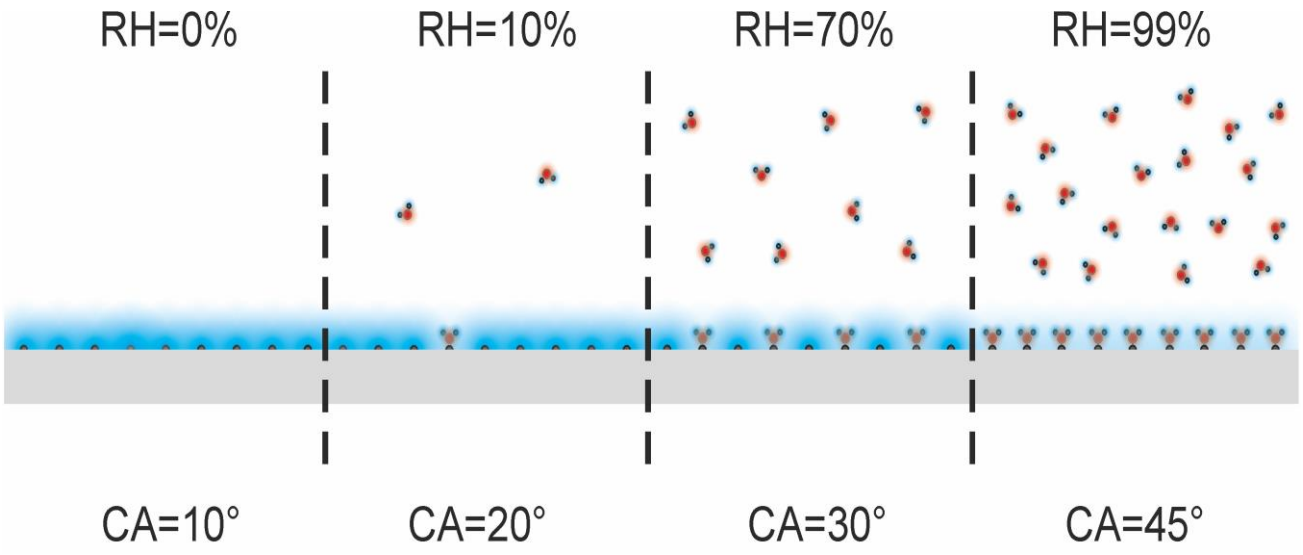

Figure 2. A hydrophilic surface exposed to air with different relative humidity. The higher humidity, the more water molecules will bind at the charge sites, and the higher the contact angle will be. The relative humidities and contact angles in this figure, are only for illustrative purposes, and does not describe a specific material.

Recommended storage of hydrophilic devices

The contact angle of a hydrophilic surface, is thus dependent on the humidity in which the device has been stored. How much the contact angle can change by exposure to humid air, depends on the hydrophilic material. Some hydrophilic materials change a lot, and others very little.
If you want to be safe, then produce and store a hydrophilic device in a dry atmosphere. This ensures that the surface is as hydrophilic as it can be, and ensures a minor variability in the hydrophilic surface property.

If a hydrophilic device has been exposed to humid air

If your hydrophilic device has been exposed to humid air, then it will be less hydrophilic than before the exposure. However, there are a few positive things:

1. The increase in contact angle is normally quite slow (hours to days).
2. Even when fully humidified, the surface will still be hydrophilic, just less than when dry.
3. The humidity does not destroy the hydrophilic material, it just makes it less hydrophilic.
4. The increase in contact angle is reversible by drying. Drying can be done by; dry air, heat and vacuum. Or even better, a combination of these conditions. Drying will slowly remove the H_2O molecules from the charge sites, and thus restore the hydrophilic characteristics.