New account of wetting phenomena at the nanoscale

Can you think of any very smooth surface in nature or in the man-made objects surrounding you? How about a glass window? Glass is smooth, right? very smooth? Well in reality standard glass substrates, and any other material that we commonly consider to be smooth, present some level of roughness when we look at them at a very small scale with the help of powerful microscopes. The small grooves, bumps, pore or other features that can then be observed are of the order of hundreds or maybe tens of nanometres, which are a million time smaller than a millimetre. Yet, these very small surface nanofeatures strongly affect how a surface behave in contact with water or other fluids, such as oils, water or blood. In combination with the surface intrinsic chemistry, that is the nature of the superficial atoms, nanofeatures can confer materials amazing properties such as water repellency, non-stick behaviour, or, to the opposite, strong absorbance capacity or adhesive character. In recent years, a new kind of technology was developed which provides ways to modify and make surfaces with controlled nanoscale topography.

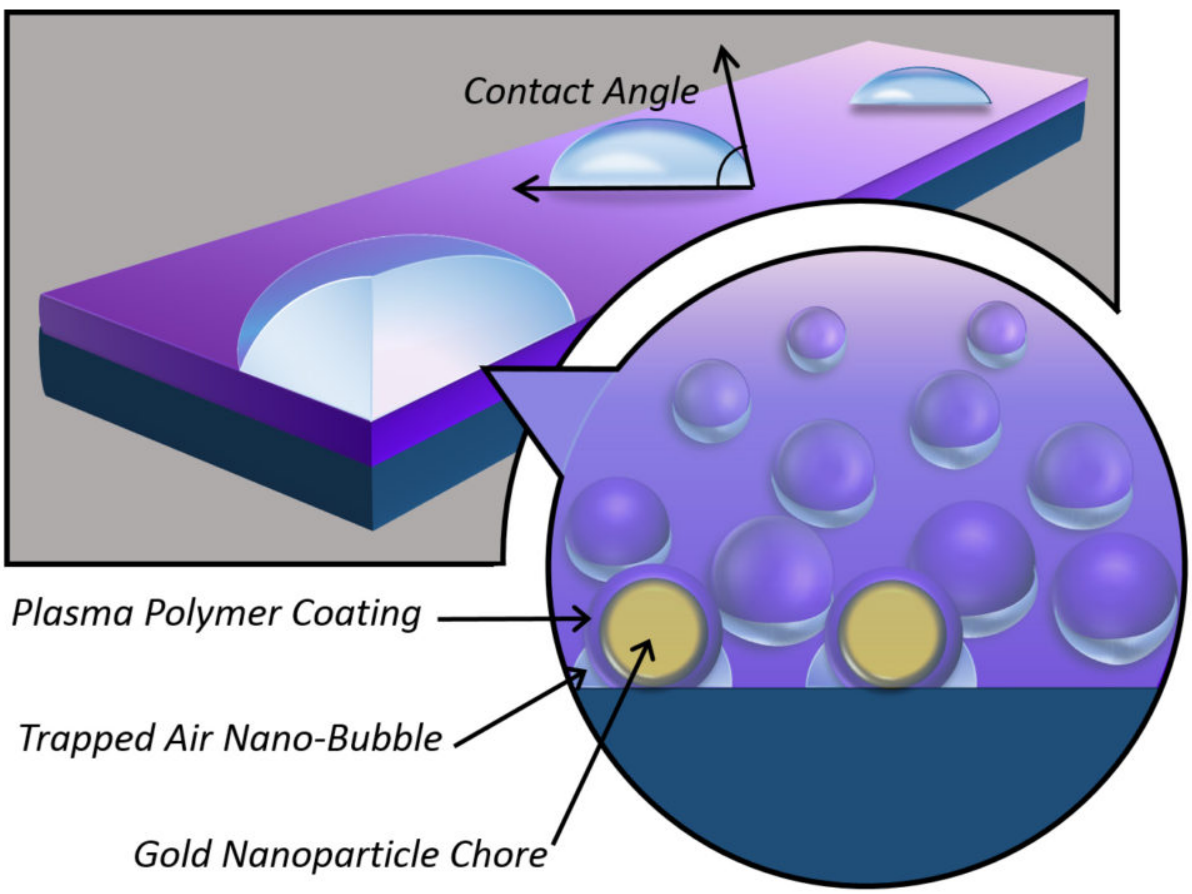

Fig. 1. Wetting of nanorough substrate schematic.

This is called nanotechnology. It is now possible, using a range of advanced techniques, to tailor the arrangement and shape of very small features purposely created on a solid surface. This has important everyday practical life applications because it allows engineers and scientists to control how water (and other fluids) will spread, advance and eventually wet the solid substrate. However, up to now, the theories used to predict wetting processes on rough substrates only apply to the case where the features are sizable, typically more the 0.1mm. When the size of the features decrease down to the nanoscale, the relative importance of physical forces on which these model theories are built changes and the models fail to describe what is actually happening in the real world.

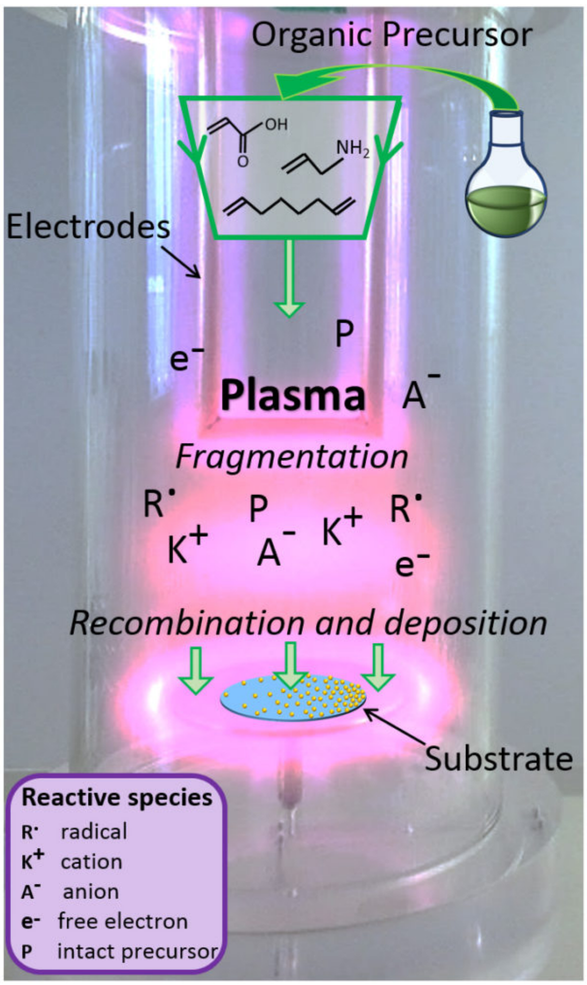

Fig. 2. Principle of plasma assisted thin film deposition.

Our research provided a new model capable to describe and predict how water will behave on substrates with nanotopographic landscape. We produce molecularly smooth coatings and decorated these films with gold nanoparticles of 3 different but known sizes. We further controlled the chemistry of the outer layer by depositing a final, only few nanometers thin overcoating on top of the nanoparticles (Fig. 1). The technique we used to do this is called plasma deposition. It works by using a powerful energy source to excite the vapour of a chemical precursor (an acid, an oil etc) to a stage beyond that of gases: the plasma state. In that state the molecules constituting the original chemical are fragmented, and turned into a mixture of charged and unstable particles which rearrange randomly on the surface of any solid they come in contact with (Fig. 2). We measured how water spread on our set of well define nanorough samples by measuring the angle a droplet surface make with the substrate. We confirmed that traditional theories fail to predict the experimental water contact angle (Fig. 1). We then demonstrated that our new model could predict the water contact angle on the nanorough surfaces, using as only known parameter the number density and size of the nanoparticles and the contact angle on the smooth substrate itself. These finding will help the field of nanotechnology by providing a simple tool capable of predicting the wetting behaviour of nanoengineered substrate and therefore guide the design of new advanced materials. Whether the final material need to repel or adsorb fluids, the engineers will be able to use our new equation which we call “the Ramiasa-Vasilev equation” to decide how many and which size of nanofeature to use to achieve their goals.

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