MODUL:

Chemistry and sport: Superhydrophobic coatings on aluminium for applications in sports

DESCRIPTION OF PRACTICAL:

The purpose of the exercise is to prepare the superhydrophobic surface of aluminium and its characterisation: contact angle, sliding angle, anti-icing properties.

Superhydrophobicity is a phenomenon most commonly associated with the lotus effect, since the leaves of the Holy Lotus (lat. Nelumbo nucifera) exhibit this kind of phenomenon. On the surface of the leaves, water forms into spheres that roll off the leaf. Surface reflects superhydrophobicity, if both conditions are fulfilled: the contact angle must be greater than 150° and sliding angle less than 10°. Superhydrophobicity also affects other surface properties, such as reduced time of icing (anti-icing), reduced ice adhesion to the surface, or the surface has the ability to self-clean. Such properties are an important advantage, e.g. for ski manufacturers.

Superhydrophobicity is a consequence of surface tension, due to the interaction between water (liquid), environment, and surface. The drop shape of the sphere has the smallest surface, therefore a drop of water forms. In the case of droplets, the forces between the liquid and the gas (atmosphere) FLV, the force between the surface and the fluid FSL, and the force between the surface and the gas FSV are in balance. Depending on the created balance, we conclude that the drop will take the shape of a sphere, a semicircle, or will form a film. The relation of all three forces is illustrated by the Young equation:

$$\cos\alpha = \frac{(Fsv - Fsl)}{Flv}$$

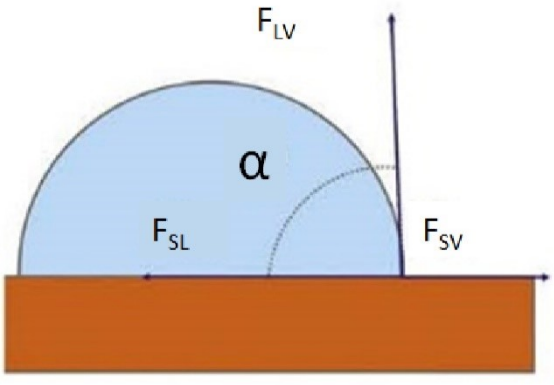

Figure 1: graphic representation of the Young equation.

The right angle (α=90°) of is the boundary between hydrophobicity (the formation of the sphere) and hydrophilicity (the formation of a film). Such a model is suitable for completely flat surfaces. But to achieve superhydrophobic surface a considerable rough surface is required.

In addition to the contact angle, it is also necessary to consider hydrophobicity as a sliding angle, which reflects the angle at which the droplet begins to move if the surface is leaned.

MATERIAL:

- Aluminium sheet, 2 mm thick, with size of 4 × 4 cm
- $FeCl_3 \times 6H_2O$
- $ZnCl_2$
- Emery paper
- 50 ml flask
- Weighing boat
- Spatula
- Distilled water
- Ethanol
- Perfluorodecyltriethoxysilane (FAS), $C_{16}H_{19}F_{17}O_3Si$

METHODS OF WORK:

SAFETY!

For safe working with chemicals in the laboratory, protective work equipment must be used and the instructions from the safety data sheets for individual chemicals must be followed. Waste chemicals are placed in packaging for waste chemicals.

Chemical	Hazard symbol	The significance of the sign
FAS		Corrosive Chemicals can cause burns or ulcers of the skin and eyes.

1. Surface preparation
   Ground the aluminium using emery paper until the surface is evenly smooth without visible scratch. Wash the samples with deionised water and ethanol and dried.

2. Etching and modification with FAS
   Etching perform on a sample of aluminium. There are two options to etch the surface:

   A) Etching with iron(III) chloride is carried out for 20 minutes at room conditions in a 1 M $FeCl_3$ solution.

   B) Etching with zinc(II) chloride is carried out for 30 minutes at room conditions in a 1 M $ZnCl_2$ solution.

3. After etching, the sample is washed thoroughly with deionised water to remove unreacted reagents from the surface. The surface modification is followed by immersion for one hour in 1% (m / m) alcoholic solution of FAS.

4. Assess the contact angle and sliding angle with a 5 µL drop of water which is placed on the surface of the sample. When measuring the sliding angle, the sample is slowly tilted until the drop moves.

5. Anti-icing properties are characterised by applying a 5 µL drop of water on a metal surface and placing the sample into a freezer. After 10 min, take the samples out and measure how long the ice takes to melt.

6. After the end of the exercise, collect the solution in a separate waste collection container. Flush the aluminium and return it to the assistant.

RESULTS:

Enter in the table the changes that you notice after dropping the water onto the surface. Mark the estimated value in the table with a cross.

	Hydrophilic	**Hydrophobic**	**Superhydrophobic**
Aluminium before grinding			
Ground aluminium			
Aluminium after etching with $FeCl_3$			
Aluminium after etching in and modification with FAS			
Aluminium after etching with $ZnCl_2$			
Aluminium after etching in and modification with FAS			

REPORT:

Observe the experiment and answer the questions.

QUESTIONS:

1. Describe the concept of hydrophilicity, hydrophobicity, oleophobia, and give an example in nature.
2. Calculate FAS molecular weight and calculate the mass fraction of silicon in the compound?
3. Calculate how many grams of FAS have to be weighed for the preparation of 20 ml of 1 wt.% of ethanol solution.
4. Describe the characteristics of the covalent bond?
5. Describe and draw a hydrogen bond between water molecules, H2SO4 and acetic acid?
6. The FAS molecule binds to the surface via a Si–O–Al bond. Is the process exo or endothermic?
7. Describe the term water allotropy?
8. How does superhydrophobicity effect on anti-icing properties? How the melting time of drop of water is correlated with surface hydrophobicity.
9. Explain for which applications in sport this coating can also be used?

EVALUATION OF THE PRACTICAL:

Knowledge for practical			
Experimental Exercise			
Results and answers			
Compliance with security rules:			
Review date:		Supervisor signature:	