Superhydrophobic Nanocomposite Films Deposited on Various Surfaces and Outdoor Works of the Cultural Heritage

Ioannis Karapanagiotis

Many plant surfaces like, for instance, the leaves of *Nelumbo nucifera* Gaertn., exhibit enhanced water repellency (superhydrophobicity) which is attributed to their textured surfaces with hierarchical micrometer- and nanometer-sized structures. Interestingly, similar specially textured topographies have been observed in the wings of some insects. In the case of water repellent leaves, airborne, dust particles can be removed by water droplets that roll off the (self-cleaning) surfaces. The leaves of *N. nucifera* afford an impressive demonstration of this effect, which is, therefore, called the "Lotus-Effect". Superhydrophobic surfaces exhibit specific wetting characteristics which are evidenced by very high static contact angles (typically higher than 150^o) and very small values of contact angle hysteresis (typically smaller than 8^o).

The remarkable ability of nature has inspired several researchers to fabricate surfaces which imitate the surface structures of the superhydrophobic biosurfaces, by using numerous techniques and methods. Water repellent coatings can be important in many applications including for example the prevention of icing in cold weather and the promotion of self-cleaning processes induced by rainwater on outdoor surfaces (automobiles, buildings, antenas, traffic lights etc.), the prevention of clotting in artificial blood vessels, the decrease of corona activity developed in conductors of transmission lines under rainy conditions, the production of waterproof and stain resistant textiles and the reduction of friction in water (boat or swimsuit coatings). Another promising application of the superhydrophobic coatings is their use as surface protective barriers for the preservation and conservation of monuments, because the most important degradation factor of outdoor, immoveable cultural heritage is rainwater which can cause stone deterioration through cycles of freezing and thawing inside the pores of the stone or by intraporous crystallization of the salts transferred by water.

A very simple method that can be used to impart superhydrophobicity to a large variety of different surfaces including silicon, glass, silk, wood, concrete, sandstone and different types of marble, is presented. It is noteworthy that some of the aforementioned materials have been very often used in outdoor cultural heritage. The method is summarized as follows: nanoparticles are dispersed in a polymer solution. The mixture is then sprayed on the substrate and the resulting composite polymer-nanoparticle film exhibits superhydrophobic properties. Consequently, the suggested strategy appears to have the following important advantages: (i) it can be used to treat a large variety of different surfaces; (ii) it is a low-cost and very simple method because it is a one-step process and includes the use of some very common materials; and (iii) it can be used for the treatment of large surfaces (including buildings and monuments) because the deposition of the composite film is achieved by a simple, fast spraying technique. Interestingly, superhydrophobicity can be achieved using various hydrophilic nanoparticles (silica, alumina and tin oxide nanoparticles were successfully tested). Furthermore, the substrate has almost no effect on the hydrophobic character of the applied coatings. The use of nanoparticles can enhance the hydrophobic character of intrinsically hydrophilic (Young contact angle $\theta_Y <90°$) and hydrophobic ($\theta_Y>90°$) polymers such as poly(methyl methacrylate) (PMMA) and poly(alkyl siloxane) (Rhodorsil 224 or Porosil), respectively. Contact angle measurements are interpreted with respect to nano- and micro-features existing on the surface of the water repellent polymer-nanoparticle composite coatings and are discussed in light of Wenzel and Cassie-Baxter models. The predictions of the latter are in a good agreement with the experimental results.

Water repellency, evaluated by contact angle measurements, cannot be the only criterion for the selection of a product used for the protection of outdoor cultural heritage. A good protective material must not affect the aesthetic appearance of the stone substrate, should assure a good permeability for water vapour and must decrease the amount of water absorbed by capillarity. The effect of the nanoparticles in the properties of the protective organic coatings with respect to the aforementioned criteria is investigated.