Advanced Coating for Energy Applications

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ABSTRACT

Quest for oil and gas has increased in the past few decades and the industry is in a constant change of flux to identify new oil reserves and extraction methods to recover oil and natural gas from these reserves. One of the challenges in transportation and storage of extracted oil is the presence of multiphase flow causing increased drag, corrosion, abrasion and lowered operational life of the pipelines. Hence, a durable coating that can repel water and oil in the multiphase flow with high abrasion and corrosion resistance is highly desired for coating the inner wall of oil transporting pipelines. Most of the coatings are difficult to scale up due to the complex fabrication process employed and are most suitable for optical and electronic applications that have minimum wear and tear in their operation. Here, Oceanit will report some of the very exciting outcomes from our research in the area of novel functional coating materials with extreme wetting behavior. Oceanit's coatings are formulated to survive the extreme conditions faced in the oil and gas exploration and production.

Keywords: hydrophobic, hydrophillic, coating, wettability, flow assurance, corrosion

INTRODUCTION

Hydrophobicity refers to the physical property to repel a mass of water molecule. Ultrahydrophobic or superhydrophobic surfaces are commonly observed in nature, for example the leaves of lotus plant have surfaces that are extremely difficult to wet. The contact angle of a water droplet exceeds 150° and the roll-off angle is less than 10°, which is commonly referred to as the Lotus effect. The lotus effect is caused by a unique microstructure present on the leaf's surface that is causing the non-wettability and a roll-off effect (See Fig 1).

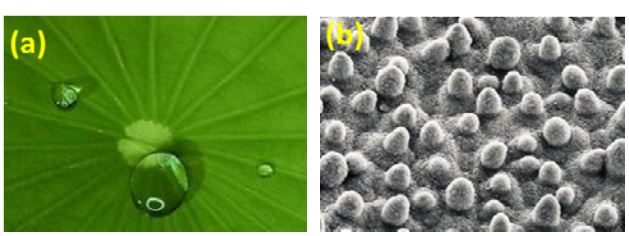

Figure 1: (a) Water droplet on lotus leaf and (b) microstructure on lotus leaf

A myriad of reports have been published in the recent years on ways to fabricate superhydrophobic non-wetting surfaces. But in all of these approaches, there is significant long term durability issues related to these approaches. In a practical working environment, damage and contamination of the microstructure will decrease the receding angle resulting in a large hysteresis, affecting the rolling behavior of water droplets (Fig 2). These scenarios could result in significant negative impacts where surface gloss stability, clean-ability and chances of running rust are key considerations. The use of low surface energy coatings such as Teflon™ or epoxy are highly scalable but is expensive and has poor mechanical strength and degrade from UV exposure and heat.

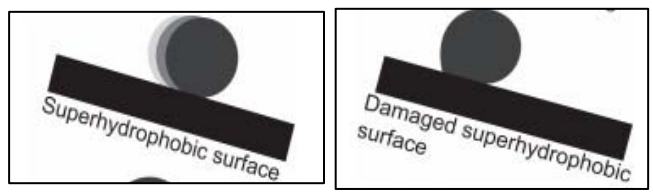

Figure 2: Due to the high contact angle and low hysteresis, water droplets easily roll off superhydrophobic surfaces. However, damage to the surface often leads to an increased contact angle hysteresis and, consequently, droplets stick to the surface (Image courtesy and reference Advanced Materials 23 (5), pages 673–678, 2011).

The market for anti-corrosion, anti-icing, and water repelling solutions are mature multi-billion dollar industries. The use of nanotechnology and advanced materials is beginning to impact these markets, and will do so for decades to come.

To overcome the drawbacks in current superhydrophobic coating technologies, Oceanit has developed a permanent coating that maintains its super water repelling and water attracting properties under harsh environmental conditions. Oceanit has also demonstrated a scalable process to permanently coat the surface of steel, aluminum, and polymer coated metallic surfaces. Oceanit's surface preparation process, called "Anhydra", is a bottom up approach to create nano-textured surfaces to either reduce or increase the surface energy resulting in a high water repellency or attraction.

Oceanit's superhydrophobic coating has extreme water repellant properties with a low roll off angle of less than 5° and a high water contact angle of 175°. Figure 3 is a

photograph of water accumulating on the superhydrophilic sample and water droplets that are almost round in shape like beads on the superhydrophobic sample.

Conversely, surfaces modified by Oceanit's superhydrophilic coating have a water contact angle of less than 5° (vs. 175°). Tilting the sample, the coating and surface tension of the water, holds the water in place, and keeps it from rolling off the sample. The extreme superhydrophobicity and superhydrophilicity behavior is the result of the surface texturing that was achieved through Oceanit's novel fabrication process.

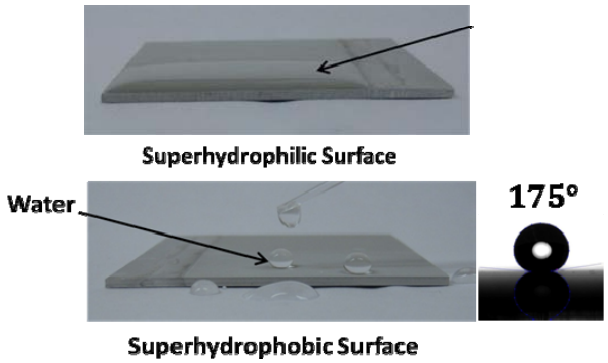

Figure 3: Photograph of water droplet on Superhydrophilic and Superhydrophobic Aluminum surface (Contact angle

Using a modified Anhydra treatment process, Oceanit has a also demonstrated extreme hydrophilicity and hydrophobicity on steel. A photograph of a hydrophilic and hydrophobic steel with inset containing the shape of water droplet is shown in Figure 4. As seen the picture, the hydrophilic steel show extreme hydrophilicity and its contact angle was estimated to be around 14° and hydrophobic steel clearly showed water beading on the surface of the steel.

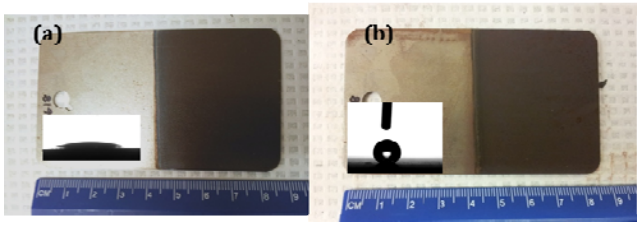

Figure 4: Photographs of (a) Hydrophilic steel and (b) Hydrophobic steel. (Inset showing shape of water droplet)

Figure 5 shows a more clear picture of water droplet sitting on the surface of the hydrophobic steel. The hydrophobic steel had a contact angle of 154° and shows very low roll off angle. The hydrophobic coating process can be applied for different kinds of steel surface with excellent water repellency.

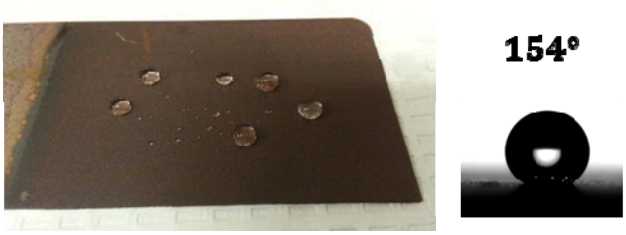

Figure 5: Photograph of hydrophobic steel surface

The hydrophilic property of the steel surface was also verified using the water retention rate through thermal imaging. Hydrophilic steel due its capability to hold more water, showed a increased heat retention rate compared to bare steel surface. Figure 6 shows the thermal images of steel and hydrophilic steel after removing from a hot water and two minutes after removing from the hot water. From the figure we can clearly see that the hydrophilic retains more water as it remains relatively hotter compared to the bare steel.

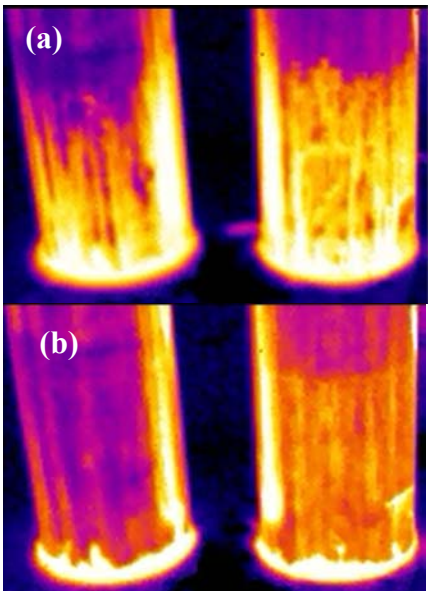

Figure 6: Thermal image of Steel (left) and superhydrophilic steel (right) (a) after removing from hot water bath (~50°C) and (b) after 2 mintues after removing

In addtion, Oceanit also conducted electrochemical corrosion tests on hydrophilic steel and compared it to uncoated steel. Linear polarization measurement conducted on steel and hydrophilic steel, showed that the hydrophilic coating doesn't show any degradation on the corrosion resistance of the steel surface. Due to the fact that the hydrophilic coating does not degrade the corrosion resistance of the steel, these types of coating can used in application were a hydrophilic surface is needed under wet conditions.

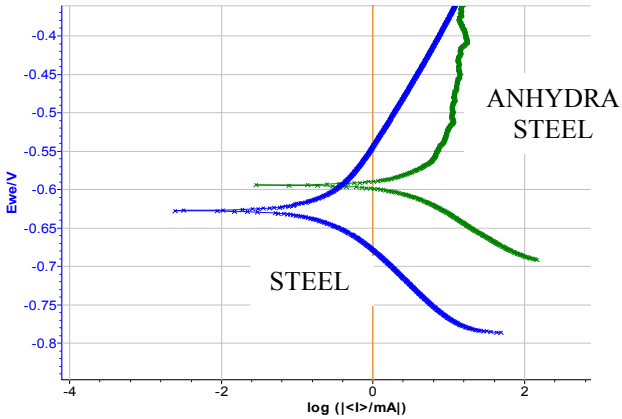

Figure 7: Tafel polarization plot of bare steel surface and anhydra steel surface

The use of superhydrophobic coating has been shown to reduce drag coefficient. Oceanit conducted drag measurements to study the effect of superhydrophobic coating on the inside of the pipe and determined that the superhydrophobic coated metal pipes can reduce the drag coefficient up to 35%. Drag reduction in fluid flow has potential impacts on reducing the cost of fluid pumping, improve the pumping efficiency and maintaining uninteruptted flow multiphase flow.

Oceanit's Anhydra coating is permanent and more durable than a spray on coating because the surface of the host material is modified and Anhydra is embedded into the host surface versus a spray coating which will eventually breakdown due to the weakness or defect in the interface between the host surface and spray on coating.

In addition, the inorganic nature of Anhydra modified surfaces offer excellent durability against abrasion and erosion which ultimately impacts the performance and lifespan of any equipment.

Oceanit's Anhydra process creates superhydrophobic/philic surfaces on metallic substrates in a scalable and controllable process to achieve low-friction surfaces, and corrosion, erosion and abrasion resistant surfaces. To recap, Oceanit's Anhydra coating process is:

- A permanent surface treatment
- A scalable process that transforms most metallic substrates of any size and shape.
- Stable over a wide temperature and extreme pressure range.
- Resistant to abrasion, corrosion and erosion.