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Smart surfaces offer green options for demulsifying produced waters

BY GARY BEERS • FOR ENERGY PIPELINE

OIL EMULSIONS

At a typical tank battery, the liquids pumped up from the formation are processed through a heater-treater to separate most of the oil from the water. The resultant produced water contains some residual oil, including dispersed oil droplets (oil emulsions). These tiny droplets pose a challenge when steps are taken to remove the remaining oil from the produced water, which usually is high in salts (a brine).

Current treatment technologies utilize polymer/ceramic membranes or electrostatic devices to separate the droplets from the water. These approaches have drawbacks such as plugging by oil droplets, low flux, fouling, and decline in efficiency due to surfactant adsorption. Also, the high salt content of the produced water causes issues. In short, these technologies are less than successful and have high energy demands (Photoinduced Superwetting Single-walled Carbon Nanotube/TiO₂ Ultrathin Network Films for Ultrafast Separation of Oil-in-Water Emulsions. ACS Nano, Volume 8, No.6: 6344-6352. 2014)

Emerging technologies, employing smart surfaces, offer more effective, economical, and green options for separating oil emulsions from salty produced waters. While these options are not yet commercialized, they offer an attractive foundation for building state-of-the-art approaches in the coming decade.

SMART SURFACES

Smart surfaces be can switched from hydrophobic (water repelling) to hydrophilic (water attracting)

by an external input and, as a result, can separate oil droplets from water. This property of surfaces is called switchable wettability. These surfaces may be flat or three-dimensional, such as membranes. Two examples of surfaces exhibiting switchable wettability are highlighted below.

PH-INDUCED OIL/WATER SEPARATION

In 2015, chemical engineers at Shanghai Jiao Tong University reported on the fabrication of a stainless steel mesh, when coated with a pH-responsive polymer, retained or released oil when wetted with acidic or neutral water containing an oil emulsion (Smart Fiber Membrane for pH-Induced Oil/Water Separation. ACS Applied Materials & Interfaces.

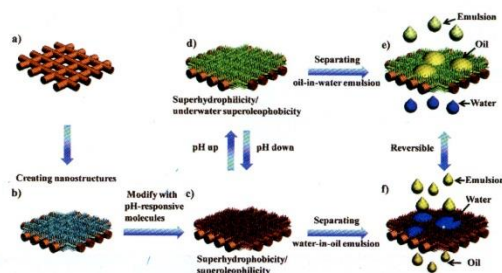


Figure 1. This is the process when a stainless steel mesh is coated with a pH-responsive polymer, retained or released oil when wetted with acidic or neutral water containing an oil emulsion.

Volume 7, Issue 35: 19643-19650. 2015). The smart fiber membrane is cost-effective and can easily be mass-produced. The following actions are shown on Figure 1:

- Action (a) The steel mesh is coated with the polymer to serve as the prepared membrane.



For over 50 years, GARY BEERS, has worked in numerous fields of environmental science as a consultant, regulator and educator. This career included senior management position with major consulting, nonprofit and public organizations. He has founded several successful firms to capture emerging resource management markets. One of his latest ventures, EnviroScienceINFO, provides content for public media.

- Action (b) Oil/water mixture is poured on membrane and water selectively passes through and oil is retained by the membrane.

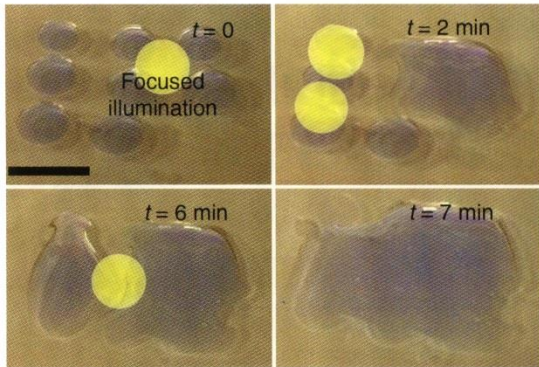


Figure 2. The yellow dots represent oil droplets and the clear dots represent water droplets. The “t” values indicate lapsed time, in minutes, after surface exposed to visible light.

- Action (c) After membrane is wetted with acidic water, oil/water mixture is poured on the membrane and the reverse separation occurs – that is, only oil passes through the membrane.

LIGHT-INDUCED OIL/WATER SEPARATION

In 2017, material science engineers at MIT reported using visible light to switch the wettability of a coated surface to separate oil and water (Visible Light Guided Manipulation of liquid Wettability on Photoresponsive Surfaces. Nature Communications Volume 8. Article 14968, 2017; Engineers Manipulate Water Using Only Light. Science Daily. April 2017).

The back story of this development reveals scientific ingenuity and helps explain the process.

Titanium oxide, an active ingredient in sunscreen, exhibits photoresponsiveness – that is, in the dark or when exposed to visible light it repels water, but when exposed to ultraviolet light it attracts water and becomes wettable. The engineers decided if they could get the compound to respond to visible light then they could switch on and off the compound’s ability to repel or attract water. Consequently, they could take the next step and separate oil from water. They decided to bind titanium oxide to polymer film on a layer of glass and then dip the coated glass into an organic dye. The successful result was a coated surface that would attract or repel water in response to exposure to visible light.

The engineers tested the smart surface in the sunlight by applying salty water containing emulsified oil. The concept worked as the water spread out and separated from the oil droplets.

A more rigorous test was completed. Under dark conditions, light beam was aimed at the edge of the oil/water mixture. The underlying change in the surface attracted water and the water droplets were driven together until they formed a single film and split off from the oil. This behavior is captured in Figure 2. The yellow dots represent oil droplets and the clear dots represent water droplets. The “t” values indicate lapsed time, in minutes, after surface exposed to visible light. Clearly, the water droplets merged and moved away from the oil droplets. The appearance, after seven minutes, shows the newly formed water mass has moved away from the oil droplets.

GREEN OPTIONS

Both options for separating oil from water have a low operating costs and energy demands, while requiring minimal additions of chemicals. Further, both can operate in a self-cleaning mode with the resultant waters containing any contaminants. Patents are obtained or in process and research on larger scale operations are underway. ♣

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