A breakthrough of monitoring energy storage in operation using optical fibers

The drive toward renewable-energy technologies, such as wind and solar, to help fight climate change puts a premium on ways to store and deliver power from these non-continuous energy sources. One intriguing piece in this power-management puzzle lies in supercapacitors—ultra-high-capacitance structures that can sop up, store and deliver significant amounts of charge, and that can withstand hundreds of thousands of charge-discharge cycles. But how can these closed devices be monitored in real time, to ensure that they are working at peak efficiency and to prevent potentially catastrophic failures in the renewable-power grid?

With the support of the National Natural Science Foundation of China, the research teams led by Prof. Guo Tuan (郭团) and Prof. Mai WenJie (麦文杰) at Jinan University, China, believe that they have come up with an answer (Light Sci Appl, doi: 10.1038/s41377-018-0040-y (https://doi.org/10.1038/s41377-018-0040-y)). To take advantage of electrochemical surface-plasmon-resonance (EC-SPR) for keeping tabs on supercapacitors, the Chinese-Canadian team devised a probe consisting of a commercial, telecom-grade single-mode optical fiber, with a tilted fiber Bragg grating imprinted in its core and with a nanometers thick coating of gold around the fiber's outer layer. They then embedded the sensor in one electrode of a two-plate capacitor, and pushed broadband polarized light through the fiber while the capacitor was running. When light strikes the interface between a metal and a dielectric, part of the light beam's energy is transferred into a subwavelength-scale electromagnetic surface wave in a phenomenon known as surface-plasmon-resonance (SPR). It turns out that the characteristics of the resonance are highly sensitive to chemical or physical changes at the metal-dielectric boundary. That's because the bonding of chemical substances on the metal surface changes the local refractive index and, thus, the phase velocity and attenuation distance of the SPR.

The team found that, as the charge density and ion distribution in the supercapacitor changed, those changes could be read directly in variations in the optical SPR spectrum—revealing "a stable and reproducible correlation between the real-time charge—discharge cycles of the supercapacitors and the optical transmission of the optical fiber." And that correlation remained solid over a number of charge-discharge cycles. This EC-SPR approach offers a unique, low-cost method for real-time monitoring of energy storage devices in operation and to fill an important gap in the renewable-energy picture.

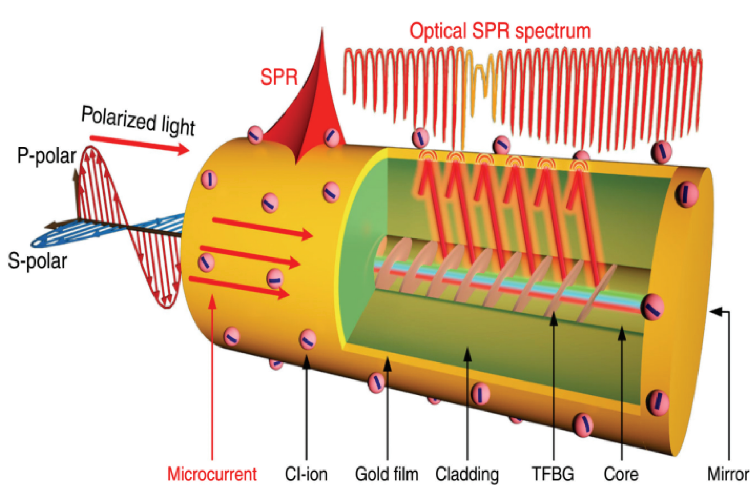

Figure Electrochemical surface-plasmon-resonance sensing principle and experimental demonstration with a gold coated tilted fiber Bragg grating sensor.