Wrinkling, folding, and beyond

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Some of nature's simplest light-harvesting systems rely on the presence of surface structures to increase internal light scattering. We have extended this concept to increase the efficiencies of man-made solar energy harvesting system. Specifically, we exploit the elastic instabilities of polymer surfaces under compressive mechanical stress to generate wrinkles and deep folds with prescribed dimensions and at pre-specified coverage over large areas. Because of curvature localization, finite deformations can cause wrinkles to evolve into folds. These wrinkles and deep folds act as photonic structures; they increase light coupling into and trapping within polymer photovoltaics. Devices on these surfaces show a 79 % increase in the external quantum efficiency (EQE) in the visible compared to analogous devices on flat surfaces. More significantly, we observe an exponential increase in near-infrared light absorption in these devices. In both experiments and numerical simulations, we find that these structures extend the useful range of energy conversion by > 200 nm, corresponding to a 600 % increase in the EQE in the near-infrared where light is otherwise minimally absorbed. While we demonstrate this concept with polymer photovoltaics, the controlled introduction of compressive stress provides a straightforward and economical route to large-scale patterning of photonic structures for flexible opto-electronics.

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Pilnam Kim earned her Ph.D. degree in 2009 from Seoul National University. Before joining the KAIST faculty (July 2012), she worked as a Senior Research Scientist at Korea Institute of Science and Technology (KIST) after spending two years as a post-doctoral fellow in the Department of Mechanical and Aerospace Engineering at Princeton University (2009-2011). Her research interests lie in the broad space of the dynamics of self-forming process and their applications.