crystal–based solar cells with increased performance on a range of substrates.

As reported in the August issue of *Nano Letters* (DOI: 10.1021/nl801817d; p. 2551), the research team developed a method of synthesizing Cu_2S nanocrystals and assembled solar cells with the material. To prepare the nanocrystals, a suspension of copper (II) acetylacetone and oleic acid is injected into a solvent containing ammonium diethyldithiocarbamate, dodecanethiol, and oleic acid in an Argon atmosphere, while being heated to 180°C. After cooling and cleaning, the crystal structure is confirmed by x-ray diffraction to be of hexagonal chalcocite. Transmission electron microscopy (TEM) shows the crystals to be single-crystal structures, and having a diameter of 5.4 nm ± 0.4 nm. Additionally, two-dimensional Fourier transform (2DFT) of the lattice-resolved image of a single crystal shows the zone axes along the $[1\bar{2}1\bar{3}]$ direction. Additional analysis shows absorption in the UV–visible-near infrared across a range of ~1000 nm, and a bandgap of 1.32 eV.

After synthesis and analysis of the Cu_2S nanocrystals, solar cells were fabricated from the Cu_2S nanocrystals and CdS nanorods. Solutions of poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate), the Cu_2S nanocrystals and the CdS nanorods were spun, in sequence, onto an indium-tin-oxide (ITO) glass substrate, followed by the evaporation of aluminum onto the film. This fabrication process also had the distinct advantage of being processed at temperatures no greater than 150°C, a parameter that will allow for the use of plastic substrates, which was also demonstrated in this work. The newly formed nanocrystal-based solar cell also showed several significant improvements over the thin-film cells. Upon comparing the open circuit voltage (V_{oc}), it was determined that the V_{oc} for the Cu_2S/CdS nanocrystal cell was 0.6 V, which is better than the 0.54 V for the Cu_2S/CdS thin film cells, and that power conversion efficiency can exceed 1.6%. Additionally, after four months, the performance of the solar cell did not degrade like that of thin films. Re-examining the use of Cu_2S as a nanocrystal shows that there is great potential for this low-cost, environmentally safe material to be used in the next generation of photovoltaics.

TARA WASHINGTON

Toughness of Human Cortical Bone Measured with Realistically Short Cracks

Bone is harder to break than to split. However, the importance of short-crack (less than 500 μm) toughness cannot be overstated. K.J. Koester, J.W. Ager III, and R.O. Ritchie from Lawrence Berkeley National Laboratory have found that the true transverse toughness of human cortical bone is far higher than found in previous studies. Few fracture mechanics measurements have been made in the transverse (breaking) orientation in bone because the cortical shell in human bone is fairly thin, <5 mm. Here, the researchers measured the toughness *in situ* in a scanning electron microscope (SEM) using small samples containing short cracks, and reported that the driving force for crack propagation in the transverse direction was more than five times larger than that for the longitudinal (splitting) direction.

As described in the August issue of *Nature Materials* (DOI: 10.1038/nmat2221; p. 672), the researchers prepared samples from the midsection of frozen cadaveric humeral cortical bone oriented either longitudinal or transverse to the bone long axis. They notched each sample about half way through to form an initial crack. The crack-initiation toughness and the crack-growth resistance (*R*-curve) behavior of cortical bone were assessed *in situ* in an environmental SEM and *ex situ* using both nonlinear-elastic fracture mechanics and crack-deflection/twist mechanics complemented with *ex situ* fractographic analysis and synchrotron x-ray computed tomography (CXRT).

Bone has the desirable characteristic of increasing toughness with crack extension. As shown in supplemental movies, the mechanisms responsible for this effect develop differently in each orientation. Propagation across the Haversian (osteon) structures, which are the basic structural elements of compact bone, causes the crack to deflect and twist, while parallel propagation results in crack bridging. While all of these mechanisms toughen bone, the mechanisms operating for cracks propagating in the transverse orientation are more potent. That is, the stress intensity required to initiate a crack is similar in the two orientations; however, the deflection and twisting of the crack in the transverse orientation very rapidly increase the toughness of bone to higher levels than have been yet reported.

Using two-dimensional ESEM and three-dimensional CXRT imaging techniques, the mechanistic interactions between the internal weak interfaces in bone and the crack path were visualized. Crack growth parallel to the weak interfaces, that is, in the longitudinal direction, resulted in microcrack initiation ahead of the crack tip and toughening primarily by crack bridging. In the transverse direction the crack encountered perpendicular refractile boundaries, that is, cement sheaths, such that toughening could be associated with crack trajectories that undergo multiple in-plane deflections of ~90 degrees and simultaneous through-thickness twists of 0–90 degrees. This is the reason why transverse fractures in bone have extremely rough fracture surfaces; indeed, the toughness of bone develops much quicker and higher during crack growth in this orientation and is the reason why bone is more difficult to break than to split.

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