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NPG Asia Materials (2013) 5, e64; doi:10.1038/am.2013.46
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www.nature.com/am

RESEARCH HIGHLIGHT

A new trick to harness the sulfur surplus

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NPG Asia Materials (2013) **5,** e64; doi:10.1038/am.2013.46; published online 27 September 2013

In the early-to-mid 1800s, Charles Goodyear[1] discovered that natural rubbers became more robust when heated in the presence of a small amount of sulfur. We now know that this 'vulcanization' process stems from sulfur's ability to form chemical bridges that strengthen the polymer chains in the rubber and is routinely used to produce tires among other common goods. An international team from the University of Arizona, Seoul National University, the University of Hamburg, and the University of Delaware developed what they refer to as 'inverse vulcanization'.[2] In this process, sulfur is used as the primary ingredient and reinforced with a stryenic additive. The method involves adding 1,3-diisopropenylbenzene (DIB), which effectively intercepted radicals formed at elevated temperatures and afforded useful copolymeric materials enriched with sulfur. The real trick, however, was timing: adding the DIB after the sulfur was liquefied and in its reactive form appeared to be critical. The ratio of DIB-to-sulfur was also an important factor as the physical, electronic and optical properties displayed by the composites were dependent on their elemental compositions.

The realization of this process comes at a good time. According to the authors, more than 60 million tons of sulfur are produced annually as a result of petroleum refining processes. Although much of this is used to make other chemicals (for example, sulfuric acid), more than 7 million tons goes unused every year. Hence, elemental sulfur is inexpensive and abundant. It also has a high refractive index, high electrochemical capacity and other desirable properties useful for optical and energy storage applications.[3,4] A drawback with sulfur is that it has limited solubility, which makes processing the material difficult. With their clever solution, the team has overcome a long-standing problem and demonstrated how sulfur may be used as a feedstock to make high-performance plastics or lithium-sulfur batteries with high specific capacities. They even showed that sulfur may be amenable with methods used to create nanostructured films found in contemporary microelectronic devices.

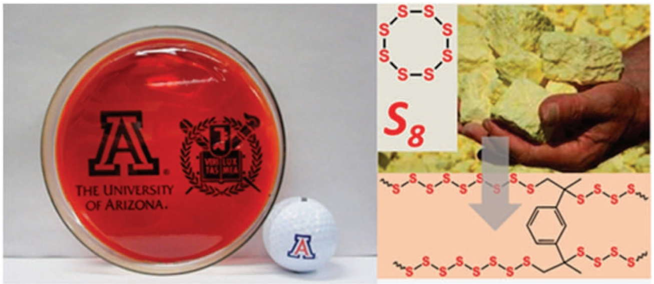

Figure 1 (left) A picture of a transparent composite enriched with sulfur. (right) Treating sulfur to 1,3-diisopropenylbenzene at elevated temperatures results in the formation of a crosslinked copolymer. The graphic was generously provided by the authors of the paper and used with permission from the *NPG*.

Despite the elegant and scalable chemistry, challenges remain. For example, considering the limited solubility and chemical compatibility of sulfur, it will be interesting to learn if other compounds are amenable to polymerization. Akin to what has been observed in other classes of polymers,[5] an ability to incorporate functional groups is certain to broaden the properties displayed by materials that contain high sulfur contents. In addition, details of the molecular structure of the copolymers are not yet refined, which raises questions about the sizes of the polymer chains formed and other property defining factors. Regardless, in a world motivated to explore new environmentally friendly chemistries, this work successfully forged an interface between polymer chemistry, sustainability and energy to utilize a rapidly growing resource (Figure 1).

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