Harnessing the beautiful physics of the opal

Do you know what makes an amorphous blob of hydrated silicon dioxide—more commonly marketed as an opal gemstone—flash those pretty colors? It is made of glass beads spaced at about the wavelength of visible light, causing certain frequencies (colors) of light to diffract and reflect their flashing beauty back out at mesmerized jewelry shoppers. Well, the nano-science geniuses at my alma mater, the University of Illinois, are harnessing that same basic concept to more efficiently (if less attractively) generate electricity from light.

Currently, the most affordable way of doing this is to employ the photovoltaic silicon semiconductors you find in onboard solar suaroofs or EV-charging garage roofs. But these panels efficiently convert only the near-infrared light to electricity, wasting much of the rest. If an engineered super-opal could absorb full spectrum light energy and convert most of it into infrared, you could raise the theoretical photovoltaic energy conversion efficiency limit from silicon’s 29 percent to something more like 80 percent. Such a deal

Using techniques such as atomic layer deposition or chemical vapor deposition, materials such as tungsten or a hafnium-dioxide ceramic can be formed into a 3D structure in which less useful energy frequencies bounce around and remain trapped, while photons of a more useful energy frequency (here we are tuning for infrared) escape. In a solar application, it acts like a completely opaque “filter,” absorbing all energy on one side and emitting most of it on the other side as the infrared radiation our photovoltaic cells prefer. According to U of I materials science professor Paul Braun, “Looking at realistic losses, getting to the order of 50 percent efficiency seems plausible. That’s still about twice as efficient as we can get today with conventional flat-plate solar.”

But don’t cancel your solar carport order just yet—the operating temperature sweet spot for this tech is 1500-1800 degrees F, so we’re talking about loads of mirrors concentrating sunlight onto a single spot—rooftop solar mirror farms will never fly with your neighborhood association. But these opal-like crystals don’t particularly care where they get the heat energy from which they make photons. Your car’s catalytic converter quickly reaches usefully high temperatures. Coat it in this material, with a vacuum air gap of about an inch to an array of photovoltaic cells, and suddenly you’re making solar electricity in the dark. No automotive testing has been conducted, but Braun reckons the efficiency of such a system should surpass that of today’s thermoelectric solutions—especially if you swap the silicon for germanium, which is even better optimized for infrared conversion.

And there’s another potential automotive hook to this nanocrystal technology. Producing battery anodes and cathodes of crystalline nickel or copper metallic foams shows great promise at absorbing and releasing energy quickly enough to allow electrochemical batteries to behave like ultra-capacitors. We’ll keep an eye on University of Illinois technology spinoff company Xerion, because if this gem of an idea pans out to production, we might finally have electric cars that recharge in minutes and cell phones that recharge in seconds.