Editorial: Overlooking Glass?

On November 4th of last year, S. Donald Stookey, a leading glass scientist at Corning, died at the age of 99. His experiments in 1952 led to the serendipitous discovery of opaque, lightweight, and thermal-shock-resistant cookware, known to us as "Corningware." His later work on photosensitive glass led to color-TV picture tubes, and subsequently to applications as diverse as military encryption, holography, and laser machining. For his many groundbreaking discoveries he received the National Medal of Technology in 1987 and was elected to the National Inventors Hall of Fame in 2010.

Research on glasses occurs at the interface of basic materials physics, engineering, and industrial manufacturing and has given us a series of technological innovations, yet it does not have the cachet of other areas in the physical sciences. This is surprising since glass is our oldest engineering material. Throughout its over 5000-year history it has been used as a cutting tool, a currency and luxury good, window glass and art medium—and more recently an enabler of progress in science.

In this "International Year of Light" we will do well to remind ourselves that we control how light propagates by tailoring the refractive index of glass. Three major scientific advances are based on this technology. First, the optical microscope triggered a revolution in microbiology and physiology, and became an essential research instrument for the likes of Louis Pasteur and Santiago Ramón y Cajal, without whose accomplishments we would have neither vaccines nor an understanding of how neurons transmit information. Ramón y Cajal shared the 1906 Nobel Prize for Physiology for this latter achievement.

Second, the optical telescope triggered an equally profound revolution at very large scales, allowing Galileo to correctly identify the heliocentric nature of the solar system, and Lemaître to propose the big bang itself. Hand in hand with the discovery and fabrication of new tempered glasses came advances in the engineering of glass cutting and polishing that were essential to building the best optical microscopes and telescopes. Spectacularly, through a combination of clever engineering and insightful physics, optical microscopes can now image at the nanoscale—more than an order of magnitude better than the Nyquist limit. The 2014 Nobel Prize for Chemistry was awarded to Stefan Hell for these advances.

Third, Charles K. Kao revolutionized the way we communicate using optical fibers based on his work at Standard Communications Laboratories in the U.K.—an accomplishment again recognized through a Nobel Prize, this time in 2009 for Physics. Kao and colleagues discovered that minute impurities rather than fundamental physics limit light transmission through optical fibers: 90% of transmission can be blocked by a metal ion impurity of just 0.01 ppm. The fact that we can now communicate across continents using fiber-optic cables is a direct result of this finding, and of the subsequent development of ultraclean manufacturing techniques. The semiconductor industry now depends on many of these same techniques for reliable manufacture of devices ranging from home computers to communication satellites.

Notwithstanding these extraordinary applications, we spend our days surrounded by glass in buildings and cars, little noticing its presence. We constantly touch glass—for example, Gorilla Glass® is now in its 4th generation and has been implemented in 3 billion handheld devices. As many of us have discovered, Gorilla Glass tolerates enormous abuse: although only 400 μm thick, tests show that this glass survives 80% of drops from 1 m height. This material was developed at Corning through the centuries-old process of ion exchange: partially substituting potassium for sodium. Through an elegant processing procedure, this technology has since been extended to produce flexible glass, which has been further embellished into flexible, electroluminescent glass displays.

These applications use traditional oxide glasses; beyond these, bulk metallic glasses have been developed, leading to an expanding array of applications. Metallic glasses are injection moldable, yet have no grain boundaries and therefore are stronger than titanium and can be formed into features 100 times smaller than conventional metals. Their toughness has led to their incorporation into golf drivers; their low-magnetic-core losses have led to their use in high-efficiency electrical transformers, and their precise moldability has led to their development into

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microfluidic lab-on-a-chip devices. Precise, durable, inexpensive, and conductive, metallic glasses promise to be ideal for future applications such as biosensors and microactuators.

Although underrecognized, the progress in glass research over the last 50 years has been nothing short of phenomenal. Most of this research has been carried out in industrial laboratories, and to date very few studies have employed advanced scattering tools available through synchrotron and neutron sources. Modern computational and experimental capabilities are tailored to analyze critical structural and isotopic characteristics of amorphous materials, so there is considerable potential for physicists to contribute to this fast-moving and high-impact field.

Moreover, from a theoretical perspective, there are numerous fundamental issues underlying glass behaviors that call for definitive treatment. The glass transition itself is regularly debated at APS meetings, and the dynamics of strong and fragile liquids and melts are being probed using ever-larger molecular-dynamics simulations. Likewise, although low-temperature dynamics of glasses are generally attributed to two-level tunneling states, we still do not know which structural entities are actually responsible for this universal behavior. And despite the fact that the Anderson localization has taught us that there is a tight connection between disorder and electronic structure, fundamental questions persist regarding the role of topology and networks in crystalline versus amorphous solids.

From any standpoint—historical, practical, or theoretical—glass physics is a field crying out for better appreciation, new applications, and stronger treatment. Only time will tell whether the tide will turn and physics will begin to lead engineering in the future, but better ties between the two can only advance the field.

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