

materials with cross-link densities well above the gel point behaved like viscous liquids. That seemingly strange result occurs because the debonding behavior depends not only on the properties of the adhesive layer but also on how well the probe sticks to the adhesive. If the energy needed to deform the adhesive material is less than the energy needed to create a crack between the adhesive and the probe, then the debonding will follow the bulk-deformation mechanism of viscous liquids. Otherwise, it will follow the

interfacial mechanism of elastic solids.

To test that explanation, the researchers ran a new experiment on material with 2% curing agent. But instead of a steel probe, they used a glass probe that had been treated with plasma. The plasma opens up sites for chemical bonds that enhance the adhesion between the probe and the polymer material. Sure enough, the material that displayed the elastic mechanism when the steel probe was used followed the viscous mechanism in the new experiment with the treated glass probe.

There's a lot left to understand about pattern formation in the viscoelastic regime. In particular, the shapes of the fingers and their behavior in the later stages of debonding remain unexplained. Says Lindner, "We would be happy if our results stimulate theoretical investigations and help answer these questions."

Johanna Miller

Reference

1. J. Nase, A. Lindner, C. Creton, *Phys. Rev. Lett.* **101**, 074503 (2008).

physics update

These items, with supplementary material, first appeared at <http://www.physicstoday.org>

Frequency combs help untangle astrophysical spectra. By resolving light into its component frequencies, spectrographs can reveal, for example, the Doppler shift in light that travels to Earth from other solar systems with orbiting exoplanets or from the far reaches of the universe. But before it can be put to work, a spectrograph must be calibrated, and that process inevitably introduces measurement uncertainty. To reduce those uncertainties, Tilo Steinmetz and colleagues developed a calibration procedure that can dramatically improve spectroscopic precision, and they demonstrated their technique by obtaining the most accurate spectrum of the Sun's photosphere to date. The key ingredient is a laser frequency comb, a series of equally spaced, precisely known frequency spikes that, as the white stripes in the figure show, can serve as a template with which astrophysical spectra can be compared (see *PHYSICS TODAY*, June 2000, page 19, and December 2005, page 19). Because the comb is reproducible, the calibration can be replicated from run to run. Moreover, frequency combs may help isolate systematic spectrograph uncertainties that, one hopes, can be

understood and minimized. A plausible goal, according to Steinmetz and company, is to measure redshifts of objects whose speed along the line of sight is changing by 1 cm/s over a year's time. That would allow for a direct measurement of cosmic acceleration. Closer to home, higher-precision spectroscopy would enable astrophysicists to identify Earth-like exoplanets by measuring the characteristic Doppler shifts experienced by a star as it is gravitationally tugged by an orbiting planet. (T. Steinmetz et al., *Science* **321**, 1335, 2008.) —SKB

New limits on prehistoric oxygen levels. The evolution of life on Earth is closely intertwined with the evolution of Earth's physical environment, particularly the concentration of atmospheric O₂. The oxygen increase arising from the development of photosynthesis in the Precambrian is thought to have created an "oxygen catastrophe" that challenged the dominant anaerobic organisms but spawned increased biodiversity and set off the Cambrian explosion in the fossil record. And low oxygen availability has been associated with two large-scale extinctions in the past 550 million years. One record of atmospheric oxygen levels is evidence—such as charcoal or polycyclic aromatic hydrocarbons—for prehistoric wildfires in the geological record. Such wildfires would have required a minimum O₂ concentration for combustion, and new work by Claire Belcher and Jennifer McElwain at Ireland's University College Dublin has refined what that minimum concentration is. Unlike prior investigations of combustion limits, the researchers simulated realistic atmospheric conditions and used natural samples of pine and moss. The team found that the threshold O₂ concentration for combustion is 15%. Several models infer O₂ levels from paleogeochemical records for carbonates, sulfates, and other materials. But some of those models may now need to be reevaluated, since they predict prolonged periods with oxygen concentrations below the 15% threshold at times in the Mesozoic Era for which there is fossil evidence for wildfires. (C. M. Belcher, J. C. McElwain, *Science* **321**, 1197, 2008.) —RJF

Holography in quantitative biology. In recent years, scientists have learned to make light-sensitive molecular probes and incorporate them into biological tissue. When stimulated by the correct wavelength, the probes then make available for study targeted dynamic processes of living systems. In a typical experiment, static optical elements such as lenses are used to focus light on a region of tissue, where all photoactivity—wanted or unwanted—is then observed. A new, active element for optical imaging is the liquid-crystal spatial light modulator, used to tailor light's distribution in such applications as optical tweezers and adaptive optics. Valentina Emiliani of the University of Paris

