PHYS.ORG

3-D printed egg whites outperform existing flexible electronics materials

May 26 2020, by Anna Demming

Qiang Chang, first author of the egg white liquid report holding sample of the egg white hydrogel and liquid in Malcolm Xing's lab at the University of Manitoba. Credit: Xing

Devices flexible enough to be worn in comfort, sensitive enough to measure a pulse and transparent and thus barely noticeable are an attractive prospect for a range of applications from monitoring biometrics to hands-free user interfaces. However, the material properties required remain a tall order. Much research has focused on the possibilities of synthetic conductive polymers or conducting nanomaterials combined with flexible or stretchy substrates, but none so far have been able to simultaneously meet the electronic, optical and mechanical demands of these applications. Now, reporting in *Advanced Functional Materials* researchers in Canada and China suggest that a substance derived from egg whites could outperform other more economically and environmentally costly alternatives.

Basic phase transitions

Malcolm Xing, a researcher at the University of Manitoba in Canada, first turned his attention to egg whites while pondering bioadhesives. "One day when I cracked an egg to prepare for egg-based food, I found the egg white, transparent and sticky, always remained on the inner shell," explains Xing. Further investigation revealed that a hydrogel binding material formed from the egg white could withstand the weight of 6-kg masses, even underwater. But further surprises arose when the egg white amino acid chains crosslinked in the hydrogel were not set. Xing and his collaborators found that the same alkaline solution used to form the hydrogel when added to egg white eventually went on to trigger a further phase transition back to a liquid that had just the high transparency, ionic conductivity and low viscosity that could benefit flexible electronics.

The proteins in egg whites are rich in carboxy groups, as Xing and his collaborators had observed in previous research. When an alkaline solution is added, these form carboxyl ions, changing the electrostatic interactions at play between the molecules so that they rearrange and crosslink, forming a gel that is stable in dilute alkaline solution. However, when this hydrogel remains steeped in a basic environment, it begins to hydrolyze, which changes the structures of the amino acid chains again, forming a liquid. "To our knowledge, we are the first to report this Janus role of alkaline solution, possessing construction and destruction faces, in the whole liquid-solid-liquid transition process of egg white," says Xing.

Beating the competition

Both nanomaterial composites and conductive polymers are limited to a transparency of around 90%. Stretch is also a problem. Nanomaterials can provide conducting pathways through a stretchy material that is not normally conducting, but they are prone to aggregation, and stretching the material can lead to breaks in these pathways. Combining something like a conductive polymer with a stretchy elastomer is problematic due to mismatches in material properties, which leads to hysteretic changes in behavior. Another solution the researchers investigated is metal liquids, where the low viscosity prevents problems with mechanical mismatches, but their transparency is limited further, to around 85%.

Xing, Feng Lu and their collaborators in the University of Manitoba in Canada and the Southern Medical University in China characterized the egg white liquid that formed from the hydrogel and measured an ultrahigh transparency of 99.8%. Xing attributes this to the high percentage (95%) of the substance that is water, which is itself transparent. The network that then contains this water in the hydrogel is partly reflective, but since this collapses during the gel-sol transition, the liquid is even more transparent than the hydrogel.

The transition to a liquid also increases the conductivity from 16.9 S m^{-1} to 20.4 S m^{-1}. The firmer hydrogel can be easily 3-D printed before it liquidizes, which is convenient when producing hybrid structures with elastomers for stretchy electronic devices. When the liquid is encapsulated in elastomer channels, the material produced has a resistivity that increases with strain as the cross-sectional area decreases, and the hysteresis of this hybrid material after repeated stretching and relaxing is an impressively low 0.77%. "The negligible hysteresis was the big surprise when we adopted the egg white liquid as a conductor in wearable electronics, because it's not easy to obtain this kind of performance with this plain material and design," says Xing.

The researchers exploited these strain-responsive electronic properties in a range of devices. They demonstrated a wrist pulse monitor that could determine finer details of vascular function such as the radial augmentation index and pulse transit time. They produced a user-interface consul that could read facial expressions and drive a radio-controlled toy car with a flick of the wrist. Finally, they incorporated the egg-white liquid and elastomer structures into triboelectric nanogenerator devices that turn on an LED in response to clapping. Future research will focus on developing the egg white liquid as a smart material for soft robotics and artificial muscles.

More information: Qiang Chang et al. Protein Gel's Phase Transition: Toward Superiorly Transparent and Hysteresis-Free Wearable Electronics, *Advanced Functional Materials* (2020). DOI: 10.1002/adfm.201910080

Citation: 3-D printed egg whites outperform existing flexible electronics materials (2020, May 26) retrieved 24 April 2024 from https://phys.org/news/2020-05-d-egg-whites-outperform-flexible.html