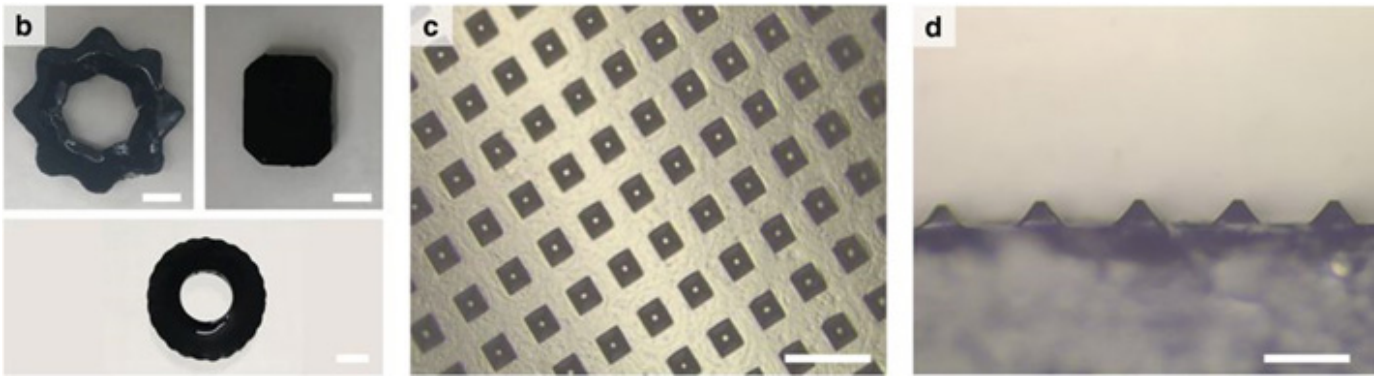
Docket #: S18-129

Stretchable, tunable conducting polymer hydrogels for implantable devices and tissue engineering

Engineers in Prof. Zhenan Bao's lab have developed highly conductive, stretchable composite hydrogel materials that can be used as soft electrodes that match the mechanical properties of a range of biological tissues. This technology combines a biocompatible, conductive PEDOT:PSS-based hydrogel network with a secondary network of material to achieve stretchability or other desirable properties (e.g., adhesiveness, cell binding or self-healing). A prototype of this composite produced a conductive interpenetrating network (C-IPN) with an elastic modulus that could be tuned between 8kPA – 374 kPa without compromising stretchability (>100% strain) or conductivity (>10 S/m). In addition, the material could be easily molded into different shapes to accommodate desired device architectures or experimental setups.

C-IPN's are designed to resolve the mismatch between the elastic modulus of standard conductive electrodes and soft biological tissues. In wearable or implantable devices, this could prevent scarring and enhance stability of bioelectronics interfaces. In tissue culture applications, this could provide appropriate mechanical properties and 3D architecture for cell viability along with the ability to electronically stimulate cells.



Stretchable PEDOT:PSS/polyacrylic acid hydrogels can be tuned to enhance a variety of features and molded into a variety of shapes, depending on the target application. Sample geometries made by casting into silicon molds: b various large shapes (1?cm scale bars); c, d micropatterns of pyramidal structures with features as small as 10??m (scale bar is 200??m c and 100??m d).

Stage of Research
The inventors fabricated prototype C-IPN (conductive interpenetrating networks) materials using a low concentration PEDOT:PSS hydrogel combined with a second polyacrylic acid network. This composite enabled control over the bulk mechanical properties:
-up to 23 S/m conductivity (a record for stretchable PEDOT:PSS-based hydrogels)
-ultra-soft elastic modulus that could be tuned between 8kPA – 374 kPa without compromising stretchability (>100% strain) or conductivity (>10 S/m)

Applications

- **Wearable/implantable devices** - stretchable conducting hydrogel could be employed in bioelectrode devices that interface with soft biological tissues such as brain or skin
- **Cell culture and tissue engineering** - conducting hydrogels provide a novel platform to enable electrical stimulation and measurement while preserving the appropriate 3D architecture and mechanical environment needed to mimic human tissue in vitro and to support viability of cells such as neurons or cardiomyocytes

Advantages

- **High performance:**
  - macroscopically connected conductive network results in record high conductivity for stretchable PEDOT:PSS-based hydrogels (23 S/m)
  - reproducible and stable conductivity not compromised over elastic modulus that spans three orders of magnitude
- **Highly stretchable:**
  - mechanical properties enhanced by creating composite with secondary material network
  - can be reversibly stretched to >100% strain
  - prevents stiffness mismatch at interface with biological tissue, reducing scarring and loss of signal
- **Versatile, tunable properties:**
  - fabrication method enables control over elastic modulus without compromising conductivity
  - elastic modulus spans 3 orders of magnitude (1-1000 kPa)
  - tissue-like low stiffness compatible with a wide range of biological tissues, from ultra-soft tissues like the brain (05.-1 kPA) to stiffer tissues like the skin and certain regions of the heart (100-500 kPA)
  - variety of potential materials for secondary network to produce desired properties such as stiffness, elasticity, adhesiveness, cell binding, sensing, injectability or self-healing
- **Precisely molded geometries** - composite hydrogel:
  - stays in a flowable, liquid state for solution-based fabrication
  - can be cast into arbitrary shapes with feature sizes as small as 10 microns
  - adjusts for different target applications
- **Biocompatible material** - PEDOT:PSS is biocompatible and non-cytotoxic that produces hydrogels with high water content

Publications

- Feig, V. R., Tran, H., Lee, M., & Bao, Z. (2018). Mechanically tunable conductive interpenetrating network hydrogels that mimic the elastic moduli of biological tissue. *Nature communications*, 9(1), 2740.

Patents

- Published Application: 20190390068

Innovators

- Helen Tran
- Zhenan Bao
- Vivian Feig

Licensing Contact

Evan Elder

Senior Licensing Associate

Email