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Transparent Stretchable Liquid-Metal Circuits

Touchscreen technology has gained widespread popularity in recent decades and will only continue its growth in the future. Touchscreens rely on thin film materials that are electrically conductive and optically clear. Such materials are typically integrated into an LED or LCD display and function as touch-sensitive electrodes that convert finger contact into electrical signals.

Although touchscreens are pervasive in computing devices and consumer electronics, they are limited to surfaces that are rigid and are either flat or have moderate curvature. What is missing, is an optically clear material with the ability to conform to highly curved, foldable, soft, or stretchable surfaces. This lack of material architecture is what is required for wearable computing, augmented reality, and other applications that require close contact with the human body.

These next generation of touchscreens will depend on a new material: Arieca's Imperceptible Microfluid Liquid Metal Electronics. By combining new flexible electronic circuit boards with our new flexible transparent conductor technology, touchscreens can be created that are mechanically robust, flexible, and stretchable while being electrically conductive, soft as skin while still optically clear.

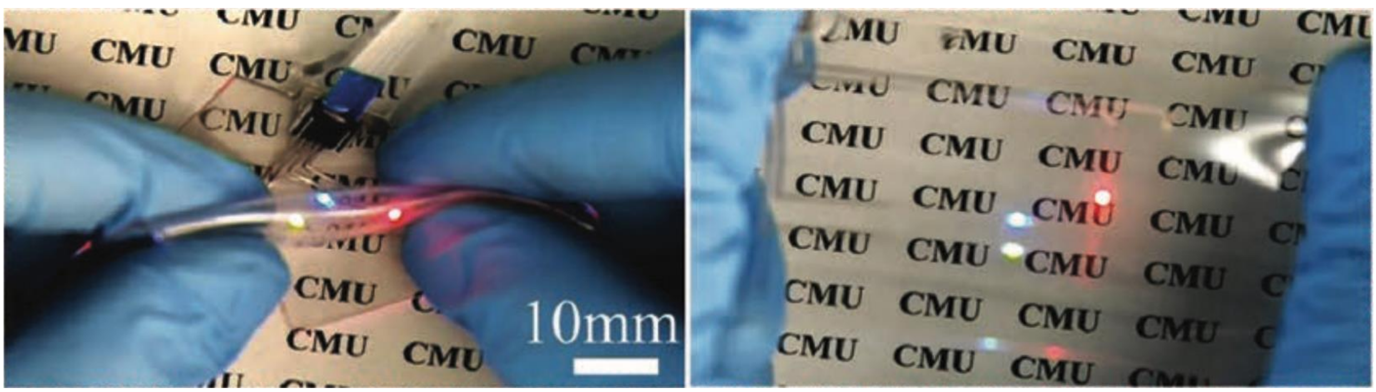

Figure 1. Circuit showing an exceptional combination of mechanical deformability, electrical functionality, & optical transparency

Current solutions

Transparent conductors like Indium Tin Oxide (ITO) have been central to the development of touch screen displays. The mechanical limitations of these conductor's brittle nature have impaired progress in the development of flexible touchscreens. Current efforts to address this issue are either conductive nanoparticle fillers blended with elastomers, or patterned metal grids deposited on an elastomer.

The market standard in transparent conductive displays is Indium Tin Oxide. These are rigid materials with a strain limit under 10%, making it unsuitable for bending and stretching applications. The modulus of elasticity for ITO is 116 GPa, making it extremely hard. This makes ITO impossible for applications where flexible and elasticity is essential. These approaches are inferior to our solution due to nanoparticle-accelerated degradation and embrittlement of the touch screen device and the inability of metal grids to be stretched without failure. In contrast, Arieca's new material uses the unique properties of gallium-based liquid-metals (LM) to create a more robust future for transparent elastic conductors.

Source: *C.Pan, K. Kumar, J. Li, E. Markvicka, P., C. Majidi,* **2018** *Adv. Mater.*

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Imperceptible Microfluid Liquid Metal Electronics Advantage

Arieca's patent-pending transparent flexible conducting substrates uses grids of ultra-thin traces of liquid metal on a clear elastomer base that are invisible to the naked eye. These sheets have a revolutionary combination of elasticity and electrical conductivity:

a. Sheet resistance = 2.95 Ω m^{-2}
b. high strain limit (ε_{max} > 100%)
c. Resistivity = 1.77 × 10^{-6} Ω m
d. Mechanical stiffness = 250 kPa (ε_{max} > 100%)

This combination of properties has never been observed before in other material systems. These films are highly electrically conductive and transparent even at 100% tensile strain. Unlike previous efforts in transparent LM circuitry, the current approach enables fully imperceptible electronics that have not only high optical transmittance (>85% at 550 nm) but are also invisible under typical lighting conditions and reading distances because the lines trace width is ≥ 4.5 µm. Finally, the circuitry is completely compliant with the change in shape of its container, preventing delamination that occurs with stretching in other soft materials, opening the frontier to augmented reality and directly to bendable phones.

As seen in the image on the right, this new technology is stretched over the display of a web camera while also being visually imperceptible on the images taken from the same camera. The imperceptible electronic wiring successfully connects the air quality sensor and processor to the LEDS circled in the lower images. When combined with the flexible electronic circuit boards, this can lead touchscreens which can be rolled up, dropped, and stretched over new surfaces without external damage or loss of functionality.

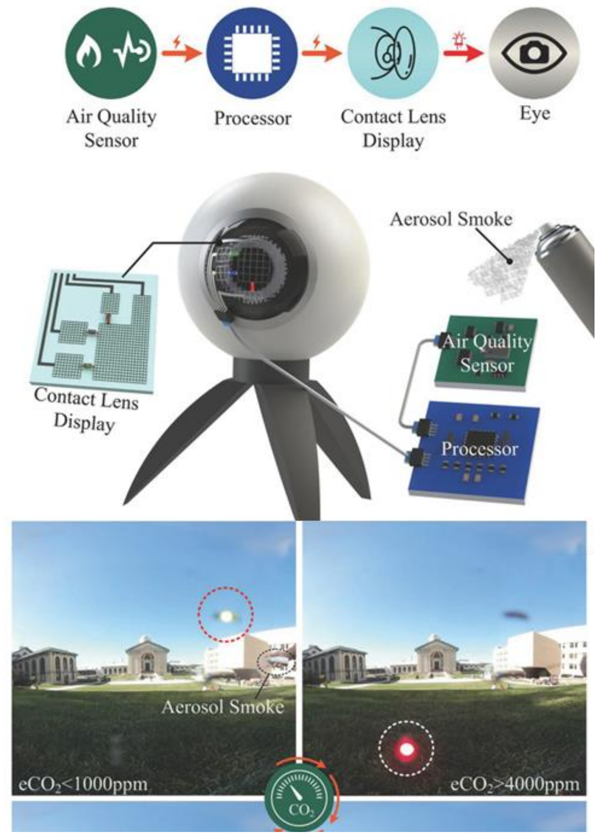

Figure 2. Block diagram and schematic of air quality monitoring system composed of a contact lens display based on an LM circuit, an eyeball camera, an air quality sensor, and a microprocessor.

Future Possibilities

We will use our imperceptible flexible electrodes towards the development of soft & stretchable touchscreens, displays, and electronics that have wide ranging applications. For example, rugged, shatter-resistant touch screens on phones and tablets that can be rolled up and tucked into a pocket present an alluring edge over current fragile, rigid technologies. Nobody likes shattering their phone display and having to operate the device by running fingers over shards of jagged glass – a new, malleable touch sensor could enable a lot more than just unbreakable screens.

When added to clothing designs our technology could allow for comfortable, compliant electronics integrated with clothing while minimizing limitations on the aesthetics. Applications include wearable adaptive health sensors that conform to our bodies without occluding large portions of the skin. The technology additionally allows for integrated electronic components in heads up displays without occlusion caused by wiring when developing novel devices for augmented reality or augmented recording as shown in the figures on the first page. **By eliminating the rigidity constraint created by current transparent conductors, we unfold the next generation of wearable computing.**

Source: *C.Pan, K. Kumar, J. Li, E. Markvicka, P., C. Majidi,* **2018** *Adv. Mater.*