201 N Braddock Ave. • Suite 334
Pittsburgh, PA 15206
(919)741-7549 • partner@arieca.com

From Imagination to Reality: A Self-Healing Liquid Metal-Elastomer Composite

Self-healing has mainly been seen in science fiction movies with techniques like self-healing body suits for superheroes who can regenerate their extremities when fighting. What has not been seen however is the ability for electronic components to be able to regenerate their intricate connections if damaged or torn. In general, most electrical connections are inherently rigid and brittle, which means they are limited in deformation, stretching, and impact loading. To address this issue, Arieca Inc. has developed a revolutionary composite structure by embedding liquid metal droplets into a soft elastomer resin to create soft and highly deformable circuit interconnections that can not only withstand typical loading conditions but also achieve unwavering resilience to mechanical damage.

Figure 1 illustrates the concept of this stretchable material architecture. The composite is made using droplets of gallium-based Liquid Metal (LM) alloy. These droplets are embedded into a soft, silicone elastomer. The LM alloys can then be formed into an intricate design that is electrically conductive. The exciting part of this advancement is that the material does not lose its electrical conductivity when stretched and these traces are able to reform when damaged. It is also important to note the circuit interconnects pictured in the figure have a much smaller footprint than most other stretchable circuits, which usually contain extra-wide traces of meandering wire. This reduced footprint means that the circuit interconnections are less likely to be damaged and less likely to exhibit a significant drop in electrical conductivity when damage.

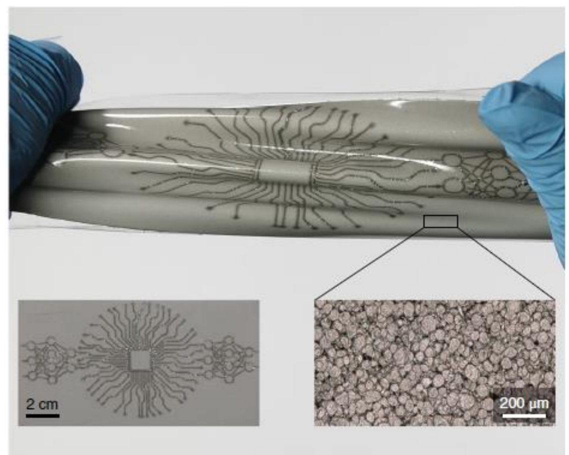

Figure 1: LMEE Composite with conductive traces

Electrical conductivity is the degree to which a specified material conducts electricity. Resistance is defined as the degree to which a substance or device opposes the passage of an electric current. This means that a material with a low resistance value has a high electrical conductivity. **Figure 2** illustrates how the material can maintain this electrical conductivity regardless of damage or deformation. The LM microdroplets begin by resting on the bed of the elastomer. As the material is compressed or stretched in the second part of the figure, the LM microdroplets connect to form conductive pathways. The smaller schematic in the upper right corner illustrates how these two droplets now have formed a singular circuit connection. The third part of Figure 2 illustrates how this composite can reconfigure itself to create new connections between the liquid metal microdroplets. The smaller schematic now illustrates how the two droplets have reconnected to form a parallel circuit that still provides the same conductivity as before the damage occurred.

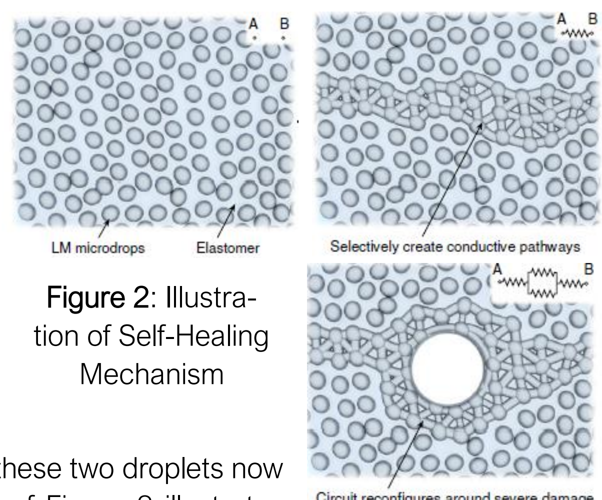

Figure 2: Illustration of Self-Healing Mechanism

Figure 3 displays a graph of the relationship of the normalized resistance and the percentage of strain applied to the material. The different colors represent various cycles of strain applied to each material and the varying levels of volume loading in each material's composition. This figure illustrates that regardless of the strain, volume loading, and number of cycles; the normalized resistance does not change by a large degree. Therefore, this material architecture can maintain a high electrical conductivity under a variety of adverse loading conditions.

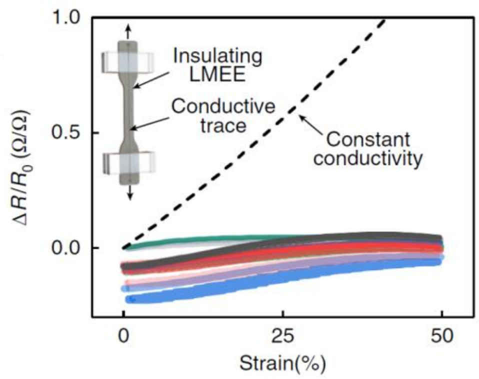

Figure 3: Normalized resistance as a function of strain

LM-embedded elastomer (LMEE) composites are greatly suited for the field of flexible electronics. **Figure 4** shows a composite with closely neighboring traces that are electrically stable under folding conditions of up to 180 degrees and has a bend radius of 1 millimeter. In innovative designs such as the Samsung Galaxy Fold or the Samsung Galaxy Z Flip, which utilize foldable displays, LMEE composites could increase the lifecycle of these devices by allowing for narrow liquid metal traces that are foldable and can regenerate if damaged by the user.

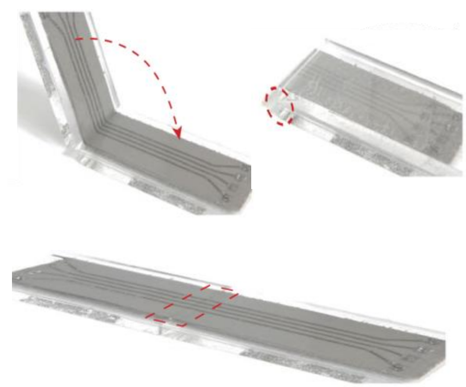

Figure 4: LMEE connections in a hinge application

Another promising application comes in the field of virtual reality (VR). VR devices currently utilize rigid electronics. With the application of LMEE composites, the circuits and displays can become more flexible and able to conform more naturally to the contours of the human body. Lastly, an important application of this technology is in soft matter robotics. Like in the highly acclaimed Terminator movies, LMEE composite can be used for electronics that exhibit the extraordinary resilience of soft biological tissue and organisms. **Figure 5** depicts the results of an experiment with a reconfigurable material that is transmitting DC power and digital communication signals to operate a counter display. Over time, the material is intentionally damaged through tearing and puncture. However, even with this randomized damage, the material retains its ability to remain electrically conductive and perform the counting function. Materials like this can be useful for applications where repairing the device may be impossible, such as on a NASA rover. This material allows repairs to be made autonomously without the need for manual repair.

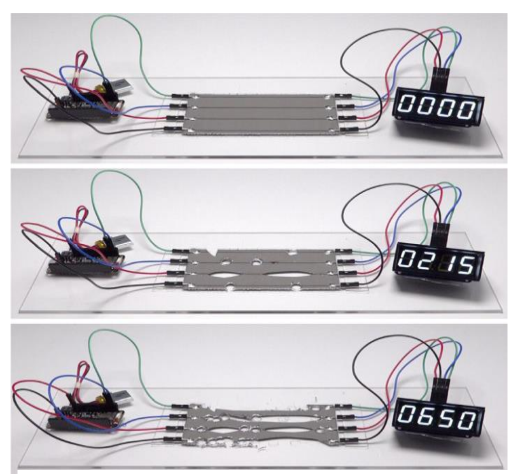

Figure 5: Recreation of electrical circuits around severe damage

The capabilities of Liquid Metal Embedded Elastomer composites are almost limitless and as technology continues to evolve so will the need for composites such as these. Arieca Inc. is continuing to push the envelopes of science and technology to meet the everchanging needs of our customers and provide innovate solutions to technological problems.

Markvicka, Eric J, et al. "An Autonomously Electrically Self-Healing Liquid Metal-Elastomer Composite for Robust Soft-Matter Robotics and Electronics." Nature Materials, 2018, www.nature.com/naturematerials.