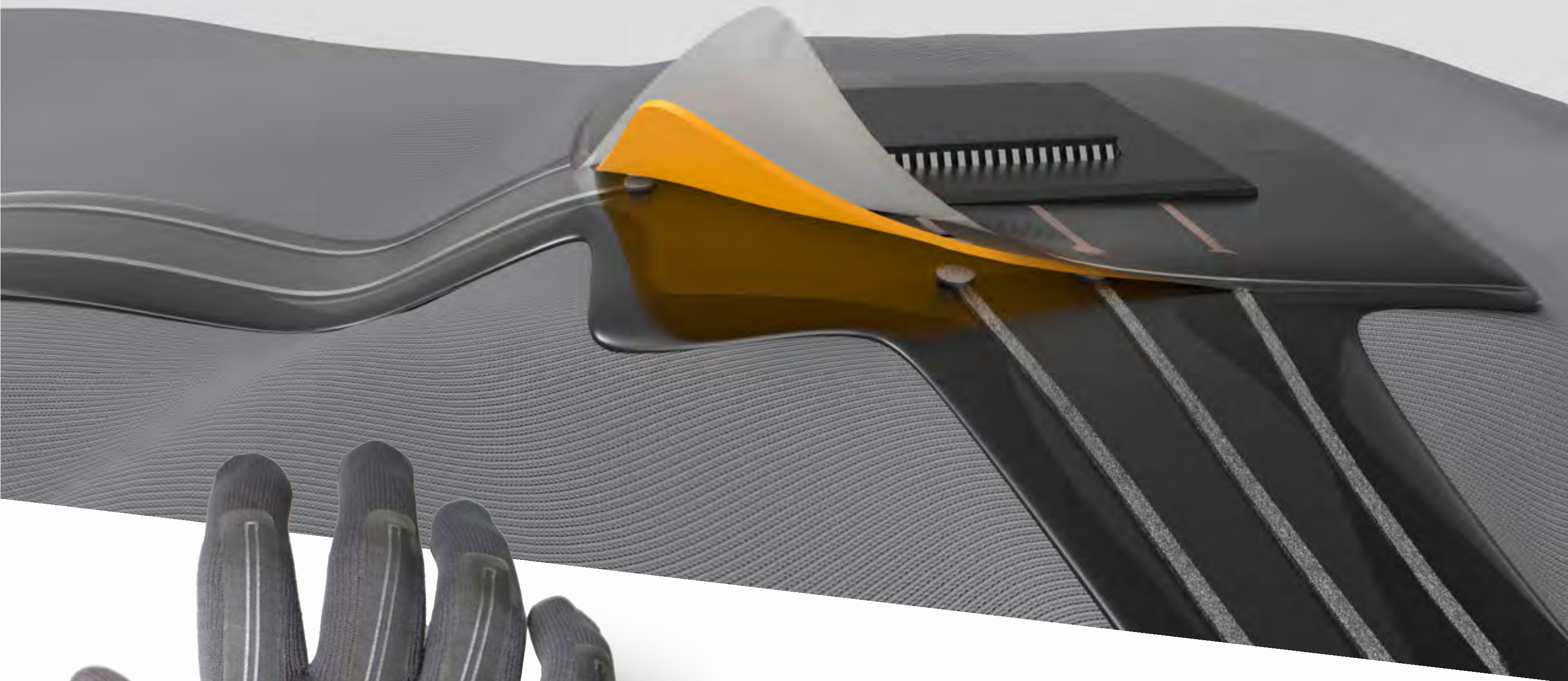
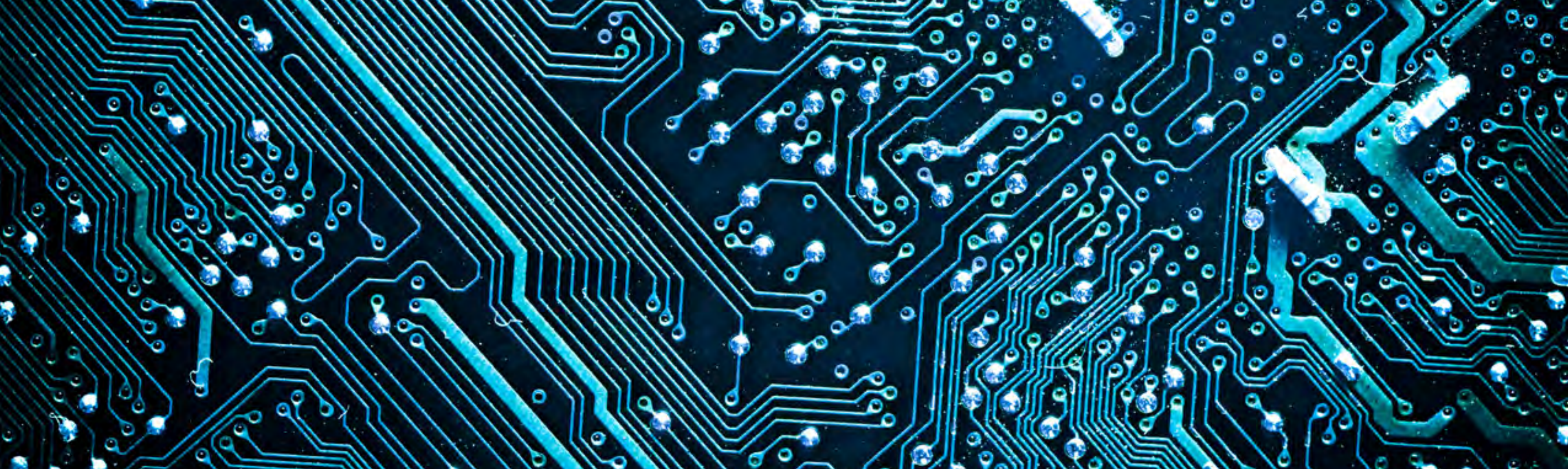
DEVICE-READY STRETCHABLE CIRCUITS UNLOCK EXCITING NEW DESIGN POSSIBILITIES FOR WEARABLE ELECTRONICS



Liquid Wire's groundbreaking metal gel conductor and circuit architecture have led to the world's first washable, stretchable, fatigue-free circuit capable of hosting all the functionality of a traditional PCB, in a pliable membrane that can be bonded onto any textile substrate.

Liquid Wire™
MADE TO MOVE



Traditional electronics are rigid and brittle, with tremendously limited ability to move or mechanically deform. This is entirely due to limitations in hard conductors and solders. The electrons themselves, the fields, currents, impedances, data flow and logic operations are inherently mobile and dynamic. Liquid Wire is on a mission to free these electrical signals from the rigid constraints of traditional electronics manufacture and assembly.

The conductors used to bind together elements of a circuit today must be chemically etched or melted into place at high heat. Both processes require substrate materials to hold the metals together that are conditioned specifically to withstand these harsh processes. This has limited the industry to essentially two plastic elements: FR4, a glass fiber filled epoxy resin, and Polyimide, a semi-flexible film that cannot be creased or folded bidirectionally. Because of this, electronics need to be packaged in tightly assembled boxes with restrictive packing rules. Even when electronics are embedded in a device, they must reside separately from the function they control. Liquid Wire completely upends this paradigm.

Using advanced liquid metal alloys based on the non-toxic eutectic chemistry of gallium-indium conductors, Liquid Wire interconnects sensors, integrated circuits, and entire embedded systems in a completely new and unbounded way. We provide circuit architectures and functional circuit blocks which we call Core Component Blocks™ (CCBs) that are built using our breakthrough material advances in liquid metal processing.

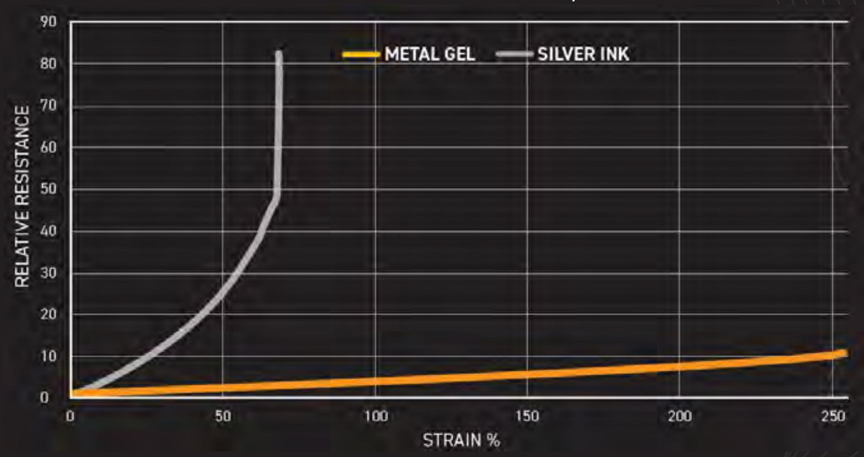
This white paper is an overview of the unique and advantageous characteristics of Liquid Wire's proprietary metal gel material and our ready to use solution for wearable tech and deformable structures, fully compatible with traditional elements of flexible hybrid electronics.

NOT AN **INK**

Metal gel differs entirely from traditional conductive inks. Silver inks, carbon inks and other printable conductors rely on conductive filler particles suspended in a volatile solution that must be cured into an elastic binding medium. However, high conductivity requires excessive loading of filler particles, which reduce the stretchability of the cured composite.

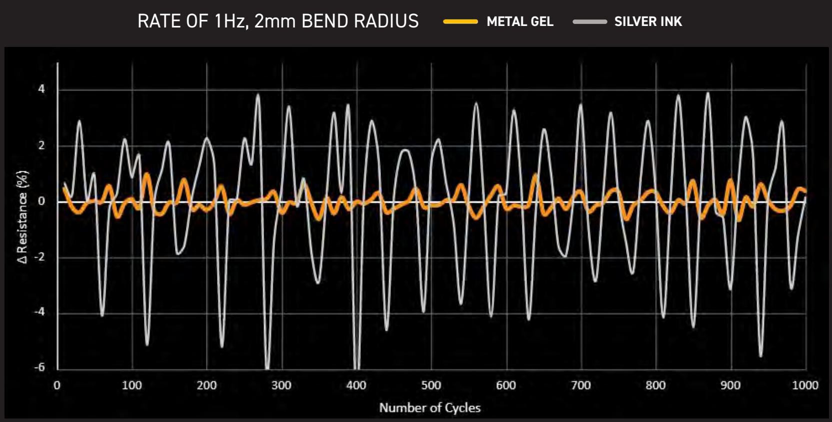
With inks, microtears inevitably form as conductive particles are pulled apart from each other and the binding medium fatigues. In addition, curing of the inks is typically a chemical process involving solvents, polymers and high temperatures. This process must be compatible with the hosting substrate and the resulting cured ink must also be mechanically matched to the substrate lest delamination occur on flexing and stretching.

METAL GEL VS. **SILVER INK: RESISTANCE/STRAIN**
Extension Rate 0.25 mm/s



On stretch, metal gel is far more conductive than silver ink. Its resistance changes linearly as strain is increased, then returns to the original resistance even after 30,000+ stretch cycles.

METAL GEL VS. SILVER INK: VIA IMPEDENCE DURING CYCLIC BEND TESTING
RATE OF 1Hz, 2mm BEND RADIUS



Liquid metals bypass these trade-offs. Alloys that are fully metallic and highly conductive, while remaining in a liquid state which enable extraordinary stretchability. They do not chemically bond to the substrates they are printed on, do not go through a cure stage, and can withstand arbitrarily high processing temperatures. They confer many other advantages as well.

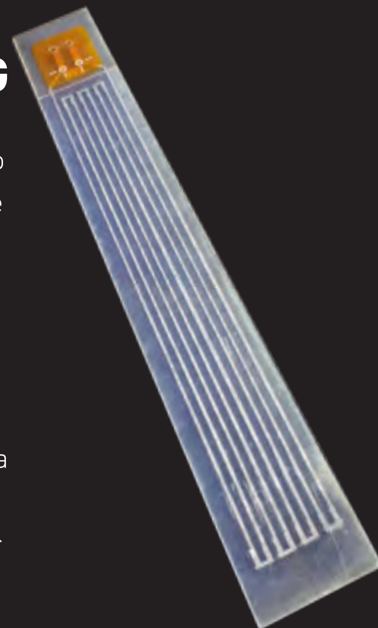
SELF-SOLDER™ & **DEFORMABLE VIAS**

Metal gel flows into itself and makes ohmic contact with metals it flows against. This feature of the material is called Self-solder™ and is a key behind circuit architectures built using liquid metals. The material behaves as both the solder and the conductive element of the circuit. The internal structure of metal gel provides sufficient stability so that components can be directly attached to a metal gel trace without concern for losing contact or short circuits.

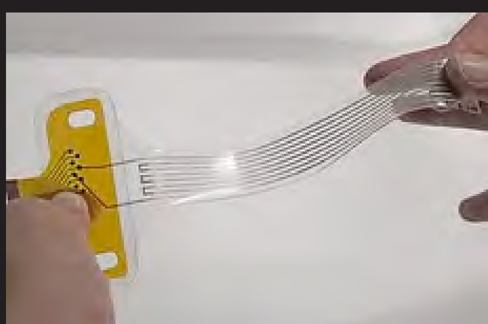
The increased mechanical strength of this metal gel also enables patterning of multi-layer circuitry, with deformable via structures directly connecting individual planar layers. A high resiliency elastic electrical connection is made between component and circuit. CTE mismatches, shock and vibration and multiaxial strains are all cushioned by the soft attachment of flex PCB or packaged components to an elastic substrate.

With room temperature processing, unlimited ability to withstand heat cycling, and ability to hold in place once printed, metal gel eliminates the need for chemical etching, chemically compatible cure steps or solder steps. This completely opens up the universe of substrate materials in addition to TPU that metal gel can be used with.

LINEARITY FOR STRAIN AND COMPRESSION SENSING



Beyond transmitting digital information, metal gel is also very effective for measuring strain and compression due to the material's remarkable linearity of electrical properties under deformation. Because metal gel has no internal structure to break down (as is the case with typical cured conductive inks) its resistance and impedance values stay constant and the only electrical change that occurs on stretch or compression is purely a function of length and cross-sectional change. This means on stretch, metal gel provides linear feedback for measurements of strain and compression.



PLIABLE SENSOR

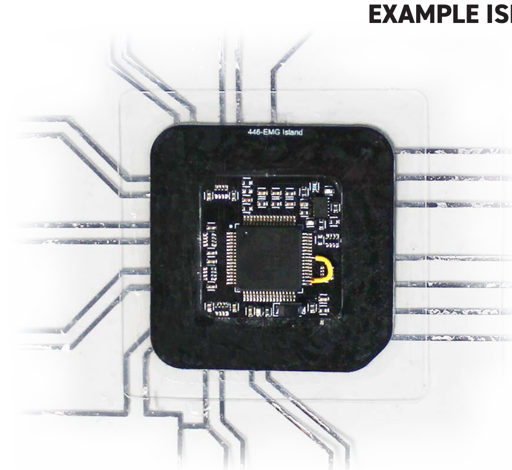
STRETCHED SENSOR

What's more, the same metal gel conductor giving a measurement of stretch acting on the circuit can simultaneously transmit digital data on established protocols like I2C, USB and SPI. The resistance and impedance changes are easily detectable but have negligible effect on digital signal transmission and no disruption to the underlying function of the electrical system. This allows circuit topologies supporting complex functionality which are highly conformable and enable very precise and accurate multi-axis measurements of movement.

WEARABLE TECHNOLOGY
LEVERAGING **TPU ISLAND ARCHITECTURE**

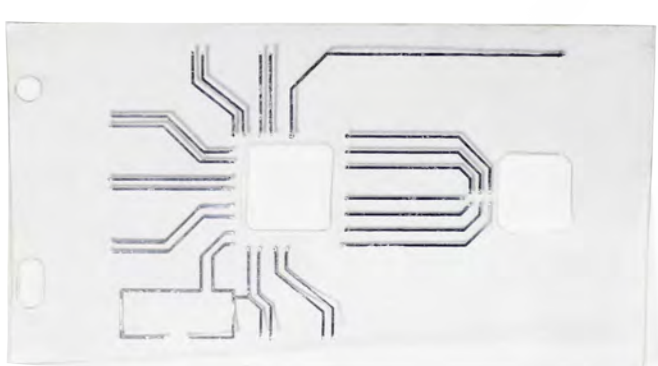
Wearables are humanity's oldest technology, with tens of thousands of years of development and refinement behind textiles and textile bonding. In the last half-century, the pace of innovation in this space has rapidly accelerated. The addition of synthetic fibers and seam tapes have allowed ultralightweight technical garments to be produced in a very cost-effective manner. TPU, in particular is a ubiquitous high performance elastic film used in the apparel industry and acts as the base for our multilayer "Island Architecture".

EXAMPLE ISLAND

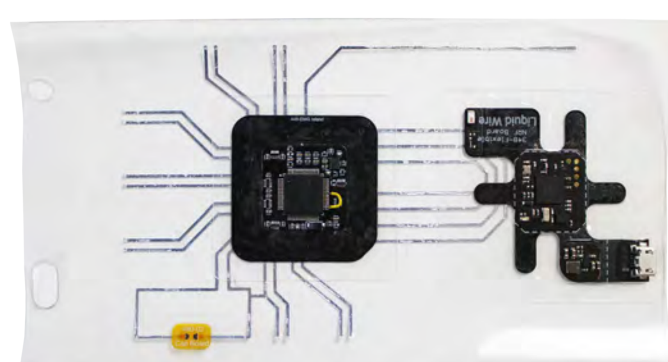


Liquid Wire solves this with a radical new approach to liquid metal processing. The resulting material is paste-like, flows only under shear, and holds shape to such a degree that interconnects can be printed and then laminated over.

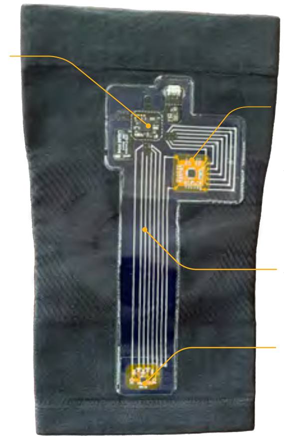
EXAMPLE METAL GEL CORE

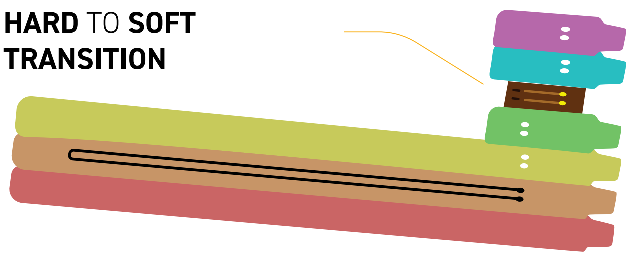


ISLANDS POPULATED



These Cores work as “transfer laminates” – the textile industry term for adhesive films that bond into textiles. Typically, transfer laminates are graphical or textured. In Liquid Wire’s case they are fully functional electronic components. This allows textile processing techniques to be used for electronics assemblies, enabling a base garment to be augmented with wearable technology in a single step process.





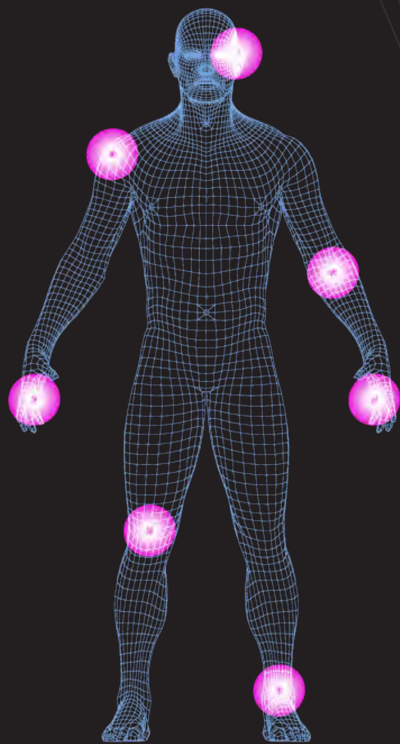
Liquid Wire's proprietary hard-to-soft transition techniques create a tremendously robust transition that is strong enough to withstand even the hostility of an environment like a washing machine and dryer. Similar to a tendon which firmly anchors a muscle to a semi-rigid bone, specialty adhesives and optional fiber fillers adhere and transition Islands to elastic interconnects.

MODULAR ARCHITECTURE READY FOR **APPLICATION**

Combining TPU Island Architecture Cores and Liquid Wire’s expertise in stretchable circuit design, we offer fully functional pre-engineered Core Component Blocks™. Each such block is a modular piece of complete functionality powered by a pre-designed Island. Linking blocks creates a system level solution. Each CCB is customizable, both through circuit topology of the elastic element and through modification of the associated Island. New blocks can be built around your application, hosting your technology. Any system that can currently be built on a flex PCB can be hosted as a CCB in the Liquid Wire TPU Island Architecture.

HOW WILL YOU **LEVERAGE LIQUID WIRE CIRCUITS?**

With the arrival of application-ready Liquid Wire stretchable circuits, electronic device manufacturers are rethinking what's possible with their technology. Circuits with self-healing fluid conductors that can be deformed and simply reflow back into place after virtually unlimited stretches represent an exciting new frontier in electronics design. Liquid Wire's advances in metal gel and hard-to-soft transitions have lifted constraints and given the electronics industry a new set of tools for developing devices with unprecedented pliability, durability, comfort, and consistently precise measurement. We can't wait to learn about the exciting ways you can think of leveraging Liquid Wire to enable your technology.



ABOUT **LIQUID WIRE**

Liquid Wire manufactures dynamically stretchable circuits and sensors that conform naturally to any flexible surface. Offering best-in-class pliability and durability, our proprietary metal gel soft circuits are washable, carrier substrate agnostic, and non-toxic. Our multi-disciplinary team of material scientists, embedded engineers, and manufacturing experts can guide you from idea generation through to mass production.

For a hands-on evaluation, request a demonstration kit including working examples of Liquid Wire circuits, pressure sensors, and strain sensors.

> Contact **Bill Hanrahan, EVP of Sales & Marketing** at **bill.hanrahan@liquidwire.com** to explore applying Liquid Wire circuits in your device.

Liquid Wire™
MADE TO MOVE

 | Learn more at: liquidwire.com
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