Publications with LPKF equipment

Selection of internationally published scientific articles using LPKF equipment

October 2023

LPKF
Laser & Electronics

TOC: page, system, application

Laser & Electronics

LPKF ProtoLaser R

LPKF Laser & Electronics

Implantable bioelectronic systems for early detection of kidney transplant rejection

Early-stage organ transplant rejection can be difficult to detect. Percutaneous biopsies occur infrequently and are risky, and measuring biomarker levels in blood can lead to false-negative and -positive outcomes. We developed an implantable bioelectronic system capable of continuous, real-time, long-term monitoring of the local temperature and thermal conductivity of a kidney for detecting inflammatory processes associated with graft rejection, as demonstrated in rat models. The system detects ultradian rhythms, disruption of the circadian cycle, and/or a rise in kidney temperature. These provide warning signs of acute kidney transplant rejection that precede …

The step-by-step fabrication procedure of the sensor appears in fig. S5. After release from the substrate, the sensor contact pads were soldered to a small flexible printed circuit board. This flex-PCB contained the renal capsule suture holes and served as an intermediate connection point between the wires and sensor. The wires were connected to the flex-PCB using through-hole solder joints. … A final step involved preparation of the abdominal wall suture tab by spin coating a ~600 µm thick poly(dimethyl)siloxane (PDMS) onto a surface-treated silicon wafer and cutting the pattern out with an infrared laser cutter (Protolaser R, LPKF Laser and Electronics SE).

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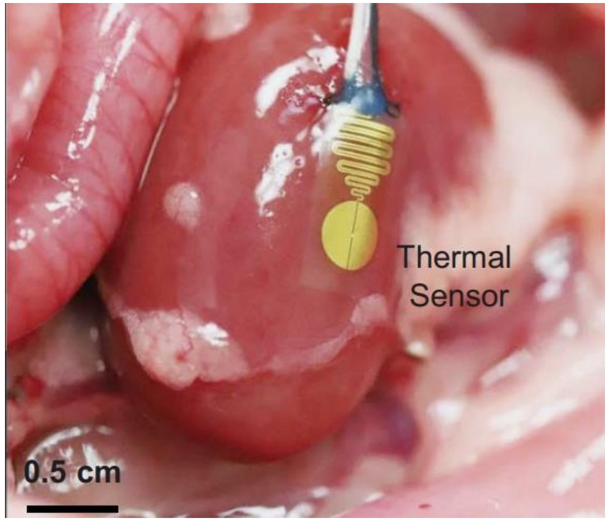
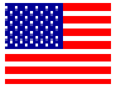
https://rogersgroup.northwestern.edu/files/2023/sciencekidney.pdf

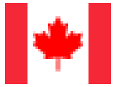
Epidermal electrophysiology, cut-and-paste transfer, large area multichannel wearable sensor



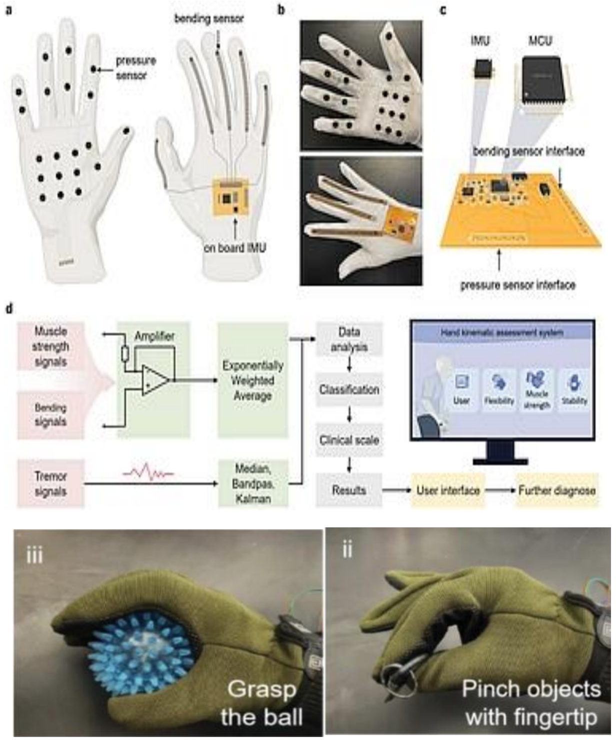
Learning Hand Kinematics for Parkinson's Disease Assessment Using a Multimodal Sensor Glove

Parkinson’s disease, smart glove, wearable bioelectronics





Hand dysfunctions in Parkinson's disease include rigidity, muscle weakness, and tremor, which can severely affect the patient's daily life. Herein, a multimodal sensor glove is developed for quantifying the severity of Parkinson's disease symptoms in patients’ hands while assessing the hands’ multifunctionality. Toward signal processing, various algorithms are used to quantify and analyze each signal: Exponentially Weighted Average algorithm and Kalman filter are used to filter out noise, normalization to process bending signals, K-Means Cluster Analysis to classify muscle strength grades, and Back Propagation Neural Network to identify and classify tremor signals with an …



Fabrication of Electronics: Flexible printed circuit (FPC) was patterned using a UV laser system (LPKF; Protolaser U4) for mechanical support and electrical interconnections of electronic components. The FPC has dimensions of 43 mm * 38 mm and contains passive components (resistors and capacitors), microcontroller (STM32F103C8T6), DC–DC converter (AMS1117-3.3 V), operational amplifier (LM358), and IMU (MPU-9250). The IMU is connected to the FPC through a low-temperature reflow process with a soldering paste and a heat gun. Flex 4.5” flexible bending sensors and ZNS-01 flexible thin-film pressure sensor are electrically connected by soldering thin copper wires with the FPC reserved interface, respectively.

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https://onlinelibrary.wiley.com/doi/full/10.1002/advs.202206982

LPKF ProtoLaser U4

Material used: **FR4, flex**

Application area: **Medical**

Published: **6/2023**

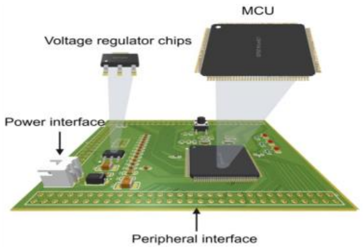
LPKF Laser & Electronics

Personalized and Safe Soft Glove for Rehabilitation Training

hand rehabilitation; flexible glove; motion threshold; pneumatic control

Traditional hand rehabilitation devices present a challenge in providing personalized training that can lead to finger movements exceeding the safe range, resulting in secondary injuries. To address this issue, we introduce a soft rehabilitation training glove with the function of safety and personalization, which can allow patients to select training modes based on rehabilitation and provide real-time monitoring, as well as feedback on finger movement data. The inner glove is equipped with bending sensors to access the maximum/minimum angle of finger movement and to provide data for the safety of rehabilitation training. The outer glove contains flexible drivers, …

We developed a battery-powered main control circuit board for data processing and control, as shown in Figure 5. The main control circuit board consists of MCU, power management module, bending-sensor conditioning circuit, and I/O interfaces (Figure S2), which are integrated on a fast-prototyping PCB board patterned using a UV laser system (LPKF; Protolaser U4). The power management module is composed of a 12 V lithium battery combined with a voltage regulator chip, which provides 12 V, 5 V, and 3.3 V power supply for different modules of the rehabilitation training system. The ingenious design of the voltage regulator circuit can prevent voltage inversion after power failure and suppress self-excited oscillation, ensuring the stability of the entire system.



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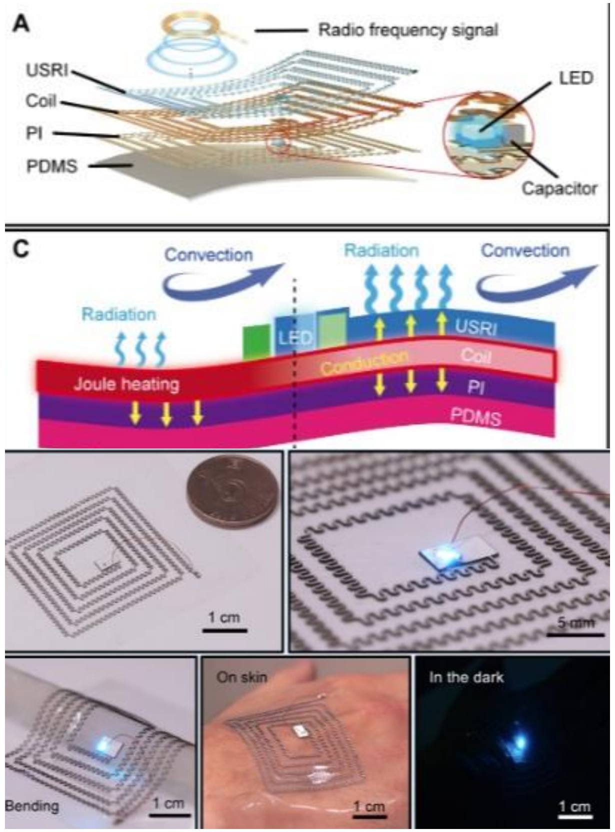
https://www.mdpi.com/2079-9292/12/11/2531

Ultrathin, soft, radiative cooling interfaces for advanced thermal management in skin electronics

wearable electronics, thermal management, wearable display

Thermal management plays a notable role in electronics, especially for the emerging wearable and skin electronics, as the level of integration, multifunction, and miniaturization of such electronics is determined by thermal management. Here, we report a generic thermal management strategy by using an ultrathin, soft, radiative-cooling interface (USRI), which allows cooling down the temperature in skin electronics through both radiative and nonradiative heat transfer, achieving temperature reduction greater than 56°C. The light and intrinsically flexible nature of the USRI enables its use as a conformable sealing layer and hence can be readily integrated with skin electronics. Demonstrations include passive cooling down of Joule heat for flexible circuits …

The schematic illustration of the fabrication process is shown in fig. S23. Fabrication began with spin coating (600 rpm, 30 s) a layer of PDMS (PDMS:curing agent, 15:1) on a quartz glass slide (75 × 75 mm) followed by baking at 70°C for 5 min. Afterward, a foil of Cu (18 µm)/PI (30 µm) was paved on the layer of PDMS and then patterned by laser cutting (ProtoLaser U4; LPKF Laser & Electronics) to form a copper serpentine coil (35 × 35 mm, coil width: 180 µm; see fig. S24). Afterward, the LED (emission wavelength: 488 nm, typical working current: 25 to 60 mA) (64) and capacitor (70 pf) were soldered at the soldered dot. The enameled wire is thermally bonded with soldering paste at the connection port. Next, the top surface of the LED was tightly attached with tape (magic tape, 3M) …



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https://www.science.org/doi/10.1126/sciadv.adg1837

LPKF ProtoLaser U4

Material used:

Flex, PDMS

Application area:

Wearables

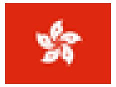
Published:

12/2022

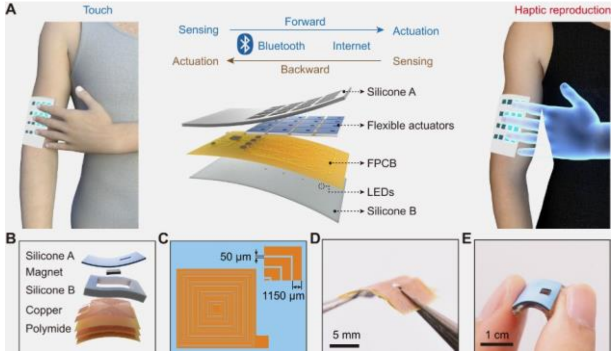
LPKF Laser & Electronics

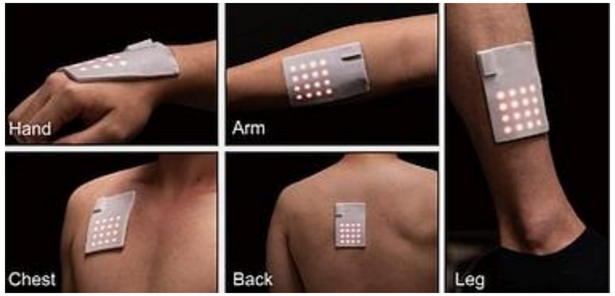
Touch IoT enabled by wireless self-sensing and haptic-reproducing electronic skin

e-skin, self-sensing, touch IoT, haptics



Tactile sensations are mainly transmitted to each other by physical touch. Wireless touch perception could be a revolution for us to interact with the world. Here, we report a wireless self-sensing and haptic-reproducing electronic skin (e-skin) to realize noncontact touch communications. A flexible self-sensing actuator was developed to provide an integrated function in both tactile sensing and haptic feedback. When this e-skin was dynamically pressed, the actuator generated an induced voltage as tactile information. Via wireless communication, another e-skin could receive this tactile data and run a synchronized haptic reproduction. Thus, touch could be wirelessly conveyed in …





Fabrication of the flexible coil: First, a thin copper-clad PI film (18-µm-thick Cu and 12.5-µm-thick PI) was flattened on a glass substrate with dimensions of 75 mm by 75 mm and cured at 75°C for 30 min. … After exposure under ultraviolet (wavelength of ~350 nm) with a designed mask and development in AZ300 MIF developer, the copper film was wet-etched into the desired pattern in a FeCl3 solution. Last, the patterned copper-clad PI film was cut into square single-layer sheets with a laser-cutting machine (ProtoLaser U4, LPKF Laser & Electronics). By connecting the electrodes of three sheets in a clockwise direction and bonding those using PDMS, a multilayer bendable flexible coil was prepared.

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https://www.science.org/doi/10.1126/sciadv.ade2450

LPKF ProtoLaser U4

Material used:

Foils of: Mg, Zn, Mo, W, Fe

Application area:

Implantable bioresorbable electronics

Published:

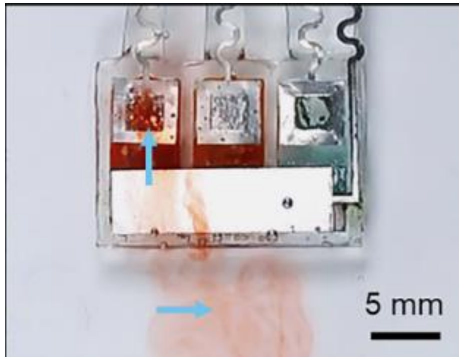
3/2023

LPKF Laser & Electronics

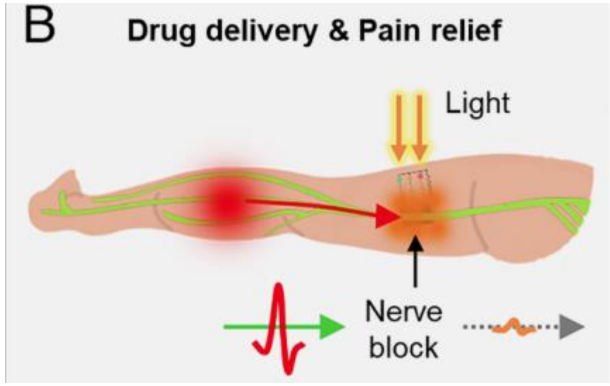
Self-powered, light-controlled, bioresorbable platforms for programmed drug delivery

Bioresorbable, self-powered, battery, drug delivery, light-controlled

Degradable polymer matrices and porous scaffolds provide powerful mechanisms for passive, sustained release of drugs relevant to the treatment of a broad range of diseases and conditions. Growing interest is in active control of pharmacokinetics tailored to the needs of the patient via programmable engineering platforms that include power sources, delivery mechanisms, communication hardware, and associated electronics, most typically in forms that require surgical extraction after a period of use. Here we report a light-controlled, self-powered technology that bypasses key disadvantages of these systems, in an overall design that is bioresorbable.



Fabrication of Transient Batteries: An ultraviolet laser prototyping system (LPKF U4) defined the shapes of the anodes and cathodes from foils of Mg (50 or 100 µm, Alibaba), Zn (10 or 20 µm, Alibaba), Mo (5 or 50 µm, Alibaba), and W (50 µm, Alibaba) and from foils of Fe (3 or 25 µm, Alfa Aesar). Mg-Fe, Mg-Mo, and Mg-W batteries incorporated anodes of Mg, cathodes of Fe, Mo, or W, and electrolytes of phosphate buffered solution (PBS, Sigma-Aldrich). Mg-MoO3 and Zn-MoO3 batteries combined anodes of Mg or Zn with MoO3 cathodes, respectively, in PBS electrolytes. Mixing 0.45 g MoO3 (Sigma Aldrich), 0.05 g carbon black, and 800 µL of 300 mg/mL poly (D,L-lactide-co-glycolide) (PLGA, lactide/glycolide 65:35, Mw 40 to 75k, Sigma-Aldrich) in ethyl acetate within a planetary mixer (Thinky ARE-30) …



Center for Bio-Integrated Electronics, Northwestern University, Evanston, IL 60208

https://doi.org/10.1073/pnas.2217734120

LPKF ProtoLaser U4

Material used: **Dupont Pyralux AP8535R**

Application area: **Wearables**

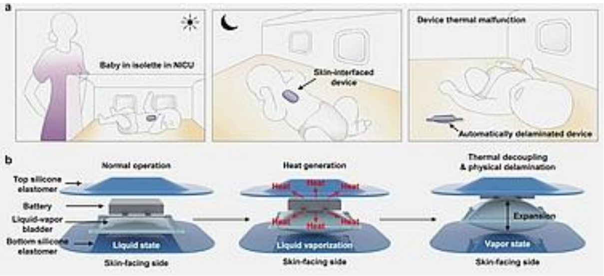
Published: **02/2023**

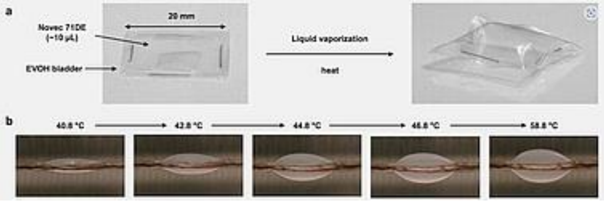
LPKF Laser & Electronics

Responsive materials and mechanisms as thermal safety systems for skin-interfaced electronic devices

Thermal safety at wearable sensors, skin interfaced devices

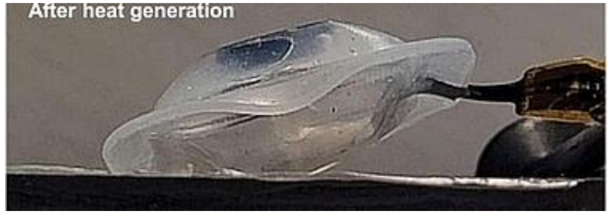
Soft, wireless physiological sensors that gently adhere to the skin are capable of continuous clinical-grade health monitoring in hospital and/or home settings, of particular value to critically ill infants and other vulnerable patients, but they present risks for injury upon thermal failure. This paper introduces an active materials approach that automatically minimizes such risks, to complement traditional schemes that rely on integrated sensors and electronic control circuits. The strategy exploits thin, flexible bladders that contain small volumes of liquid with boiling points a few degrees above body temperature. When the heat exceeds the safe range, vaporization rapidly forms highly effective, …





Fabrication of the battery with heater

An ultraviolet laser cutter (Protolaser U4, LPKF) ablated the copper coating on a thin, flexible film (AP8535R, Pyralux, DuPont) of copper/PI/copper (thickness: 18 µm/75 µm/18 µm), to pattern metal interconnect traces with widths of 60 µm. Cutting the seal of the pouch of a lithium polymer battery allowed removal of the active components (DNK201515, DNK power) and attachment of a copper resistive heating element. Reinsertion into the pouch and resealing completed the fabrication of the battery with heater (BwH) device.



Querrey Simpson Institute for Bioelectronics, Northwestern University, Evanston, IL, 60208, USA

https://www.nature.com/articles/s41467-023-36690-y

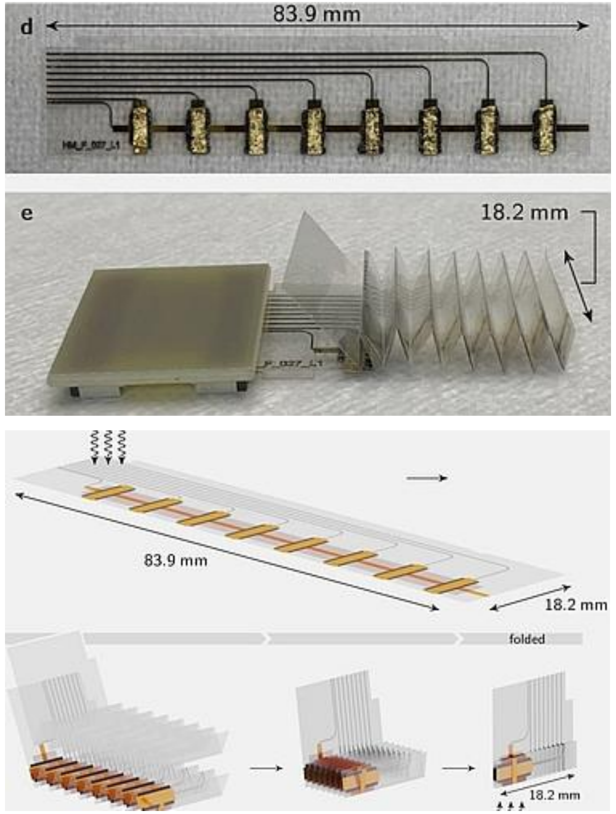
LPKF ProtoLaser R4

Origami-inspired perovskite X-ray detector by printing and folding

X-ray detectors, folded device, photoconductive gain

X-ray detectors are of pivotal importance for the scientific and technological progress in a wide range of medical, industrial, and scientific applications. Here, we take advantage of the printability of perovskite-based semiconductors and achieve a high X-ray sensitivity combined with the potential of an exceptional high spatial resolution by our origami-inspired folded perovskite X-ray detector. The high performance of our device is reached solely by the folded detector architecture and does not require any photolithography. The design and fabrication of a foldable perovskite sensor array is presented and the detector is characterized as a planar and as a folded device. Exposed to 50 kVp−150 kVp X-ray …

X-ray detector fabrication: The sensor array (see Fig. 1 for the sensor layout) was fabricated on top of a 25-μm-thick polyethylene naphthalate (PEN) substrate foil (Teonex Q51). Prior to the device fabrication, a LPKF ProtoLaser R4 lasercutter was used to engrave folding lines in the PEN substrate foil. Subsequently, the PEN substrate foil was rinsed with isopropanol and then ultrasonically cleaned with acetone (10min) and isopropanol (10min). For all subsequent fabrication steps the PEN substrate foil was connected with dicing tape to an additional 125-μm-thick PEN carrier substrate (Teonex). Initially, a ≈ 75 nm-thick gold bottom electrode was thermally evaporated. Afterwards, a 15 nm-thick NiO_x hole transport layer was sputtered using a Pro Line PVD75 …



Light Technology Institute (LTI), Karlsruhe Institute of Technology (KIT), Karlsruhe 76131, Germany

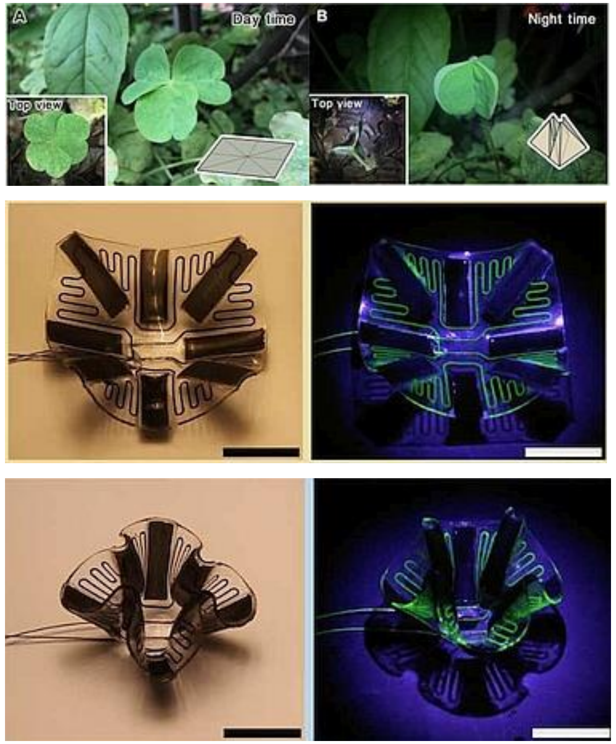
https://www.nature.com/articles/s41528-023-00240-9

LPKF ProtoMat S100

Plant-inspired TransfOrigami microfluidics

shape-adaptive flexible electronics, photomicroreactor,

The healthy functioning of the plants' vasculature depends on their ability to respond to environmental changes. In contrast, synthetic microfluidic systems have rarely demonstrated this environmental responsiveness. Plants respond to environmental stimuli through nastic movement, which inspires us to introduce transformable microfluidics: By embedding stimuli-responsive materials, the microfluidic device can respond to temperature, humidity, and light irradiance. Furthermore, by designing a foldable geometry, these responsive movements can follow the preset origami transformation. We term this device TransfOrigami microfluidics (TOM) to highlight the …



Design and working method of an optical flow cell: The optical flow cell was designed using AutoCAD (Autodesk) and fabricated via precision micromilling (LPKF ProtoMat S100) of black PMMA as described previously (67). Briefly, the flow cell is composed of two interlocking micromilled PMMA pieces with a channel cut into both pieces such that the 0.7-mm OD tubing (polytetrafluoroethylene, thin wall tubing, UT5, Adtech Polymer Engineering Ltd., UK) can fit into it. The light-to-voltage converter (photodiode, TSL257, ams AG, Austria) and light-emitting diode (LED; 370 nm; SST-10-UV-B130-E365-00, Luminus Devices, UK) are placed in the micromilled parts in a way that light emitted from an LED travels to an opposing photodiode via tubing (path length of 0.5 mm).

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https://www.science.org/doi/10.1126/sciadv.abo1719

LPKF ProtoLaser U4

Material used:

Cu foil, PI, PDMS

Application area:

Wearable sensors

Published:

03/2021

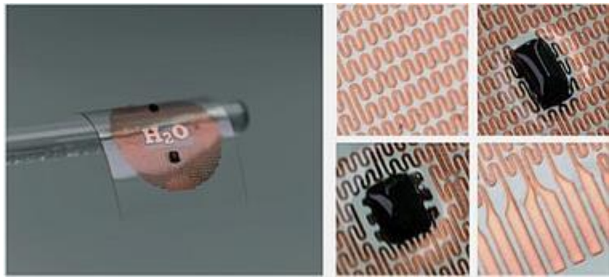
LPKF Laser & Electronics

Cohabiting Plant-Wearable Sensor In Situ Monitors Water Transport in Plant

electronic tattoos, flexible electronics, sap flow, water allocation

The boom of plant phenotype highlights the need to measure the physiological characteristics of an individual plant. However, continuous real-time monitoring of a plant's internal physiological status remains challenging using traditional silicon-based sensor technology, due to the fundamental mismatch between rigid sensors and soft and curved plant surfaces. Here, the first flexible electronic sensing device is reported that can harmlessly cohabitate with the plant and continuously monitor its stem sap flow, a critical plant physiological characteristic for analyzing plant health, water consumption, and nutrient distribution. Due to a special design and the materials chosen, the …

Fabrication of the Plant-Wearable Sap Flow Sensor A Cu film (6 µm thickness) was first laminated by a PI layer (1 µm) by spin coating. The Cu film was then fixed onto a glass slide coated with a cured PDMS layer (10 µm) as a temporary adhesive layer, followed by defining a Cu serpentine mesh by laser cutting (LPKF U4 laser system, LPKF Laser & Electronics AG, Germany). Then, a 1 µm PI layer was spin-coated on the sensor. A second laser cutting was applied to remove the PI for exposing the connection pads for the chip components, and the PTC thermistor and temperature sensors were welded on the pads with the solder pasting. At last, to make the sensor waterproof, the whole sensor was packaged using a additional thin layer of PDMS (≈10 µm). A wireless electronic …



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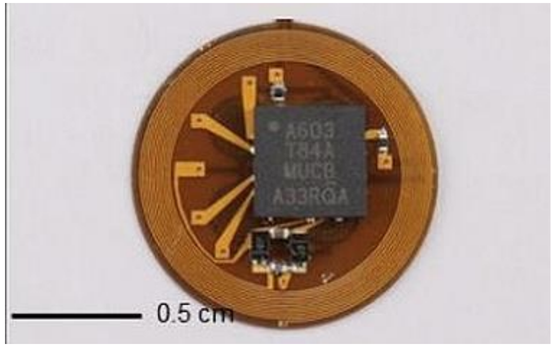
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8132156/

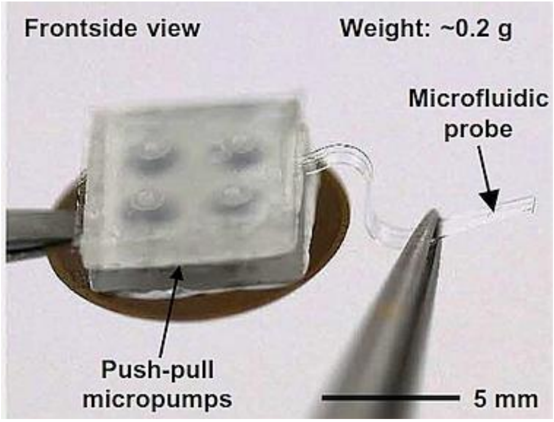
Wireless, battery-free push-pull microsystem for membrane-free neurochemical sampling in freely moving animals

Implantable electronic, neurochemical sampling

Extensive studies in both animals and humans have demonstrated that high molecular weight neurochemicals, such as neuropeptides and other polypeptide neurochemicals, play critical roles in various neurological disorders. Despite many attempts, existing methods are constrained by detecting neuropeptide release in small animal models during behavior tasks, which leaves the molecular mechanisms underlying many neurological and psychological disorders unresolved. Here, we report a wireless, programmable push-pull microsystem for membrane-free neurochemical sampling with cellular spatial resolution in freely moving animals. In vitro studies demonstrate …

The fabrication of wireless power harvesting and control electronics is based on our previously reported method (28). Briefly, a flexible sheet of copper clad polyimide film (Cu/polyimide/Cu, 18/75/18 µm) was used as the substrate. An ultraviolet laser cutting machine (ProtoLaser U4, LPKF, Germany) was used to fabricate the RF coil antenna, the leads and contact pads for electronic components, holes (diameter, 50 µm), and interdigitated electrodes for push-pull micropump. The interdigitated electrodes were then coated with gold via electroplating (thickness, 200 nm), and the holes were electroplated with copper to connect the top and bottom layers. Subsequently, electronic components, including capacitors (GRM0335C1H750GA01D, Murata Electronics …





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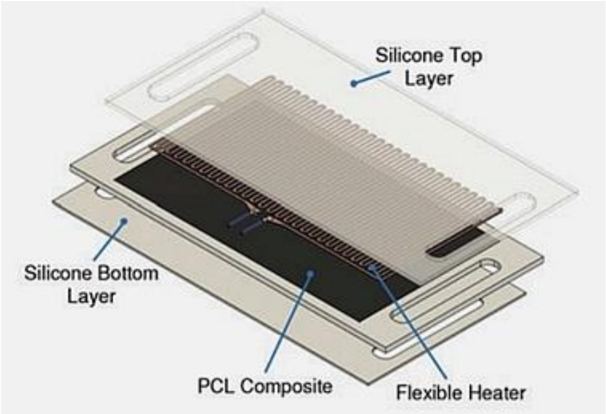
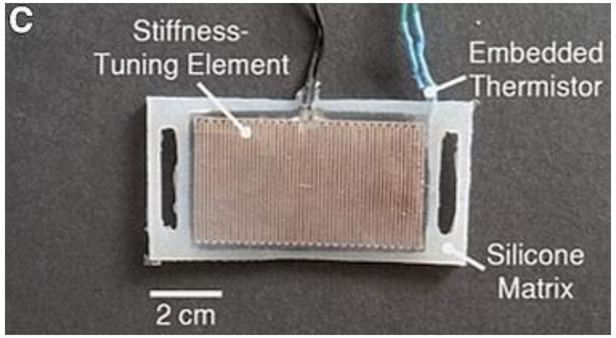
https://www.science.org/doi/10.1126/sciadv.abn2277

Versatile Soft Robot Gripper Enabled by Stiffness and Adhesion Tuning via Thermoplastic Composite

Soft gripper, stiffness modulation, adhesion-based grasping, thermoplastic composite, tunable adhesion

Within the field of robotics, stiffness tuning technologies have potential for a variety of applications—perhaps most notably for robotic grasping. Many stiffness tuning grippers have been developed that can grasp fragile or irregularly shaped objects without causing damage and while still accommodating large loads. In addition to limiting gripper deformation when lifting an object, increasing gripper stiffness after contact formation improves load sharing at the interface and enhances adhesion. In this study, we present a novel stiffness and adhesion tuning gripper, enabled by the thermally induced phase change of a thermoplastic composite material embedded within a …





To apply uniform heat to the composite, we developed flexible resistance heaters by cutting serpentine copper traces, following the process established by Bartlett et al.42 and Markvicka et al.43 This process is depicted in Figure 3A. First, a 70 µm thick layer of flexible copper-clad polyimide (Pyralux FR8510R; DuPont) was laminated onto a polydimethylsiloxane (PDMS) bed (10:1 Sylgard 184; Dow Corning) with a rigid aluminum backing and cut using an ultraviolet laser (ProtoLaser U3; LPKF), as described in the study of Markvicka et al.43 The width of the resulting traces was 0.6 mm. Then, a 51 µm thick layer of adhesive transfer tape (VHB F9460PC; 3M) was laminated to the traces, and the traces and tape were pulled away from the PDMS bed as a single unit, which we refer to …

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https://www.liebertpub.com/doi/10.1089/soro.2020.0088

LPKF ProtoLaser U3

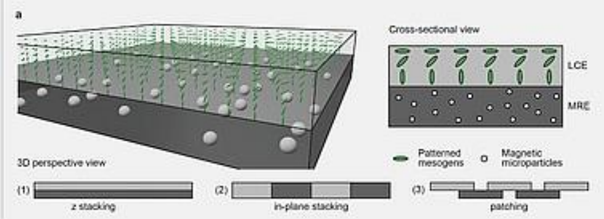
Wirelessly Actuated Thermo- and Magneto-Responsive Soft Bimorph Materials with Programmable Shape-Morphing

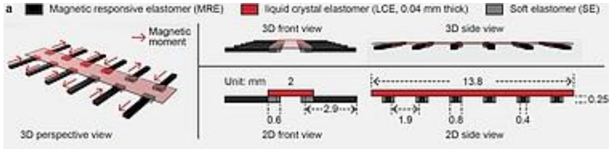
Soft materials that respond to wireless external stimuli are referred to as “smart” materials due to their promising potential in real-world actuation and sensing applications in robotics, microfluidics, and bioengineering. Recent years have witnessed a burst of these stimuli-responsive materials and their preliminary applications. However, their further advancement demands more versatility, configurability, and adaptability to deliver their promised benefits. Here, a dual-stimuli-responsive soft bimorph material with three configurations that enable complex programmable 3D shape-morphing is presented. The material consists of liquid crystal elastomers (LCEs) and …

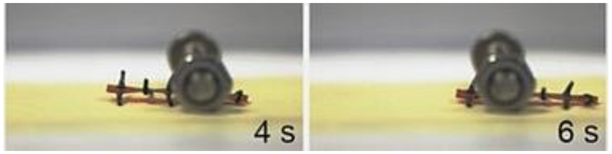
Bimorph Materials

The reported bimorph material with various integration configurations was prepared by placing LCEs in the modes prior to the casting of MREs or on top of the casted MREs. The curing of MREs formed a bond between LCEs and MREs. Devices were made of the material via laser cutting (ProtoLaser, LPKF Laser & Electronics AG) according to designs made in a software (AutoCAD, Autodesk Inc.). A magnetization profile was then programmed into the device by deforming it and magnetizing it in a strong magnetic field (1.8 T) generated by a VSM (EZ7, Microsense).

Soft materials, smart materials, shape-morphing, miniature robot







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