Publications with LPKF equipment

Selection of internationally published scientific articles using LPKF equipment

April 2023

TOC: page, system, application

LPKF ProtoLaser U4

Material used:

PET

Application area:

Wearable sensor

Published:

10/2020

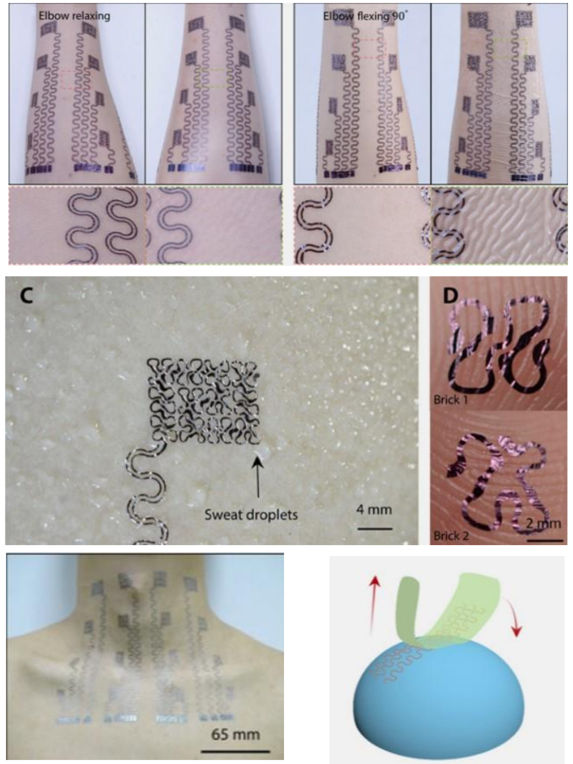
Laser & Electronics

Electrically compensated, tattoo-like electrodes for epidermal electrophysiology at scale

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

Epidermal electrophysiology is widely carried out for disease diagnosis, performance monitoring, human-machine interaction, etc. Compared with thick, stiff, and irritating gel electrodes, emerging tattoo-like epidermal electrodes offer much better wearability and versatility. However, state-of-the-art tattoo-like electrodes are limited in size (e.g., centimeters) to perform electrophysiology at scale due to challenges including large-area fabrication, skin lamination, and electrical interference from long interconnects. Therefore, we report large-area, soft, breathable, substrate- and encapsulation-free electrodes designed into transformable filamentary serpentines that can be rapidly fabricated…

Fabrication processes of the large-area tattoo-like electrodes: We developed a modified “cut-and-paste” process, as shown in fig. S14. It began with the lamination of a layer of commercial 1.1-µm-thick transparent PET (polyethylene terephthalate) film (Nanyang Technology, China) on a wetted commercial water-transfer paper (Shanghai Ziyue Digital Technology, China) (fig. S14A). The PET film was metallized by depositing 10-nm-thick chromium and 100-nm-thick gold in sequence after drying the wetted paper. Depending on the resolution requirement of pattern of wires, either the laser machine (LPKF ProtoLaser U4, Germany) or the mechanical cutter (CE6000-40, GRAPHTEC, Japan) was used to pattern the metallic PET film (fig. S14B).



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https://www.science.org/doi/10.1126/sciadv.abd0996

LPKF ProtoLaser U4

Material used:
Dupont Pyralux AP8535R

Application area:
Medical

Published:
12/2020

Reliable, low-cost, fully integrated hydration sensors for monitoring and diagnosis of inflammatory skin diseases in any environment

dermatological diagnostic, wearable sensor, hydration sensor

Present-day dermatological diagnostic tools are expensive, time-consuming, require substantial operational expertise, and typically probe only the superficial layers of skin (~15 µm). We introduce a soft, battery-free, noninvasive, reusable skin hydration sensor (SHS) adherable to most of the body surface. The platform measures volumetric water content (up to ~1 mm in depth) and wirelessly transmits data to any near-field communication–compatible smartphone. The SHS is readily manufacturable, comprises unique powering and encapsulation strategies, and achieves high measurement precision (±5% volumetric water content) and resolution (±0.015°C skin surface T)

Fabrication of SHSs: Initial prototypes and proof-of-concept devices involved use of a laser cutter (LPKF U4, LPKF Inc., DE) to pattern a double-sided copper-clad laminate (Pyralux AP8535R, DuPont Inc., USA) and standard microsoldering techniques. To avoid damage to the critical sensing components, soldering the thermistor (NTCG063JF103FT, TDK Corporation, Japan) and heater resistors (RR0306P-681-D, Susumu Co. Ltd., Japan) using a low-temperature solder paste (TS391AX10, Chip Quik Inc., USA) and heat gun temperature of 200°C for less than 5 s was the final step in component assembly. Initial devices were prototyped in a laboratory setting, and the final designs were then sent to an external ISO-9001-compliant vendor for full manufacturing and

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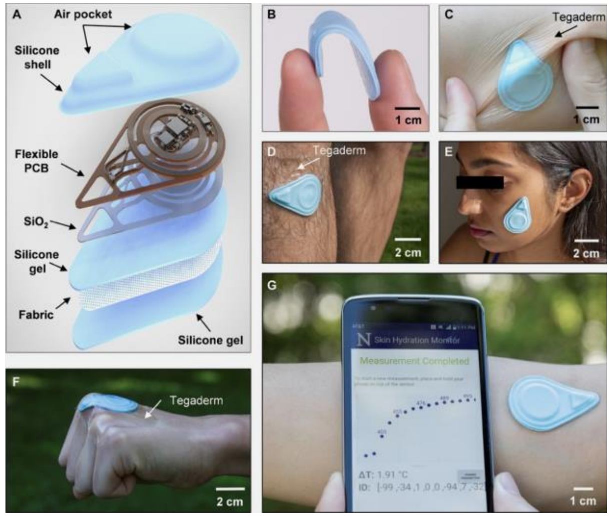
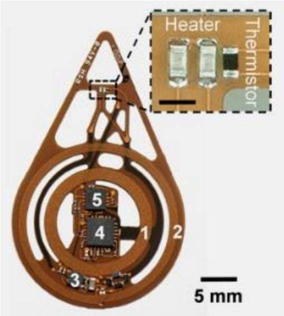
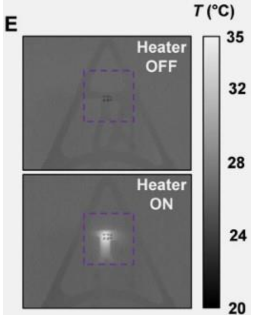
https://www.science.org/doi/10.1126/sciadv.abd7146







LPKF ProtoLaser U4

Material used:

DuPont Pyralux AP7164R, AP8535R

Application area:

Medicine

Published:

12/2020

LPKF Laser & Electronics

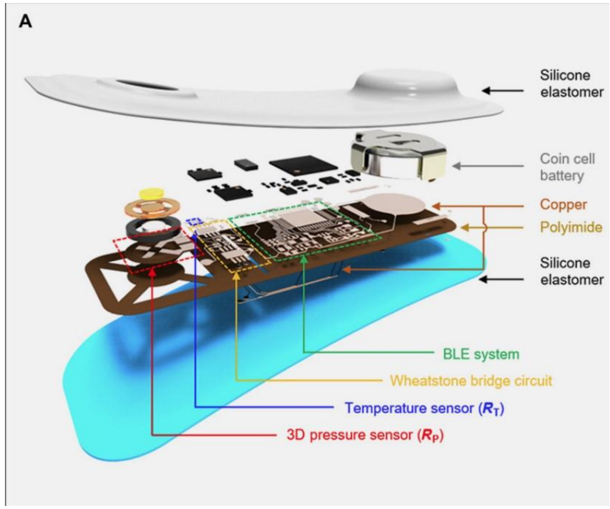
Wireless, skin-interfaced sensors for compression therapy

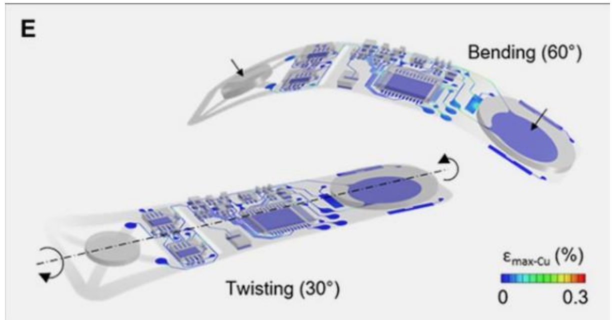
Therapeutic compression garments, wearable electronics, medical sensor

🇺🇸 🇰🇷

Therapeutic compression garments (TCGs) are key tools for the management of a wide range of vascular lower extremity conditions. Proper use of TCGs involves application of a minimum and consistent pressure across the lower extremities for extended periods of time. Slight changes in the characteristics of the fabric and the mechanical properties of the tissues lead to requirements for frequent measurements and corresponding adjustments of the applied pressure. Existing sensors are not sufficiently small, thin, or flexible for practical use in this context, and they also demand cumbersome, hard-wired interfaces for data acquisition. Here, we introduce a flexible, wireless monitoring system for tracking both temperature and pressure at the interface between the skin …

Fabrication of the electronics: FPCB design layouts used EAGLE CAD version 9 (Autodesk). Fabrication began with patterning a sheet of FPCB (12-µm-thick top and bottom Cu layer, 25-µm-thick middle PI layer; AP7164R, DuPont) into the necessary shapes using an ultraviolet laser cutter (LPKF U4). Solder paste (Chip Quik TS391LT) joined the 3D pressure sensor and the various surface-mount components including BLE SoC (nRF52832, Nordic Semiconductor), BLE antenna (2450AT18A100, Johanson Technology Inc.), AMP (INA333, Texas Instruments), reference resistors (RMCF0201FT, Stackpole Electronics Inc.), and temperature sensor components (NTC; NCP03XH, Murata) onto the FPCB by reflow using a heat gun (AOYUE Int866).





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https://www.science.org/doi/10.1126/sciadv.abe1655

LPKF ProtoLaser U4

Material used:
Dupont Pyralux AP8535R

Application area:
Medical research

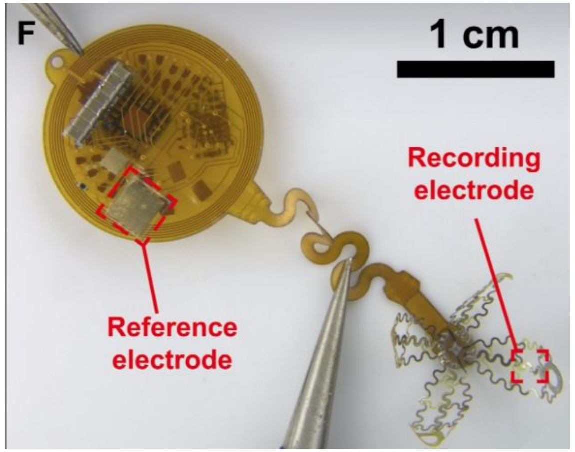
Published:
10/2022

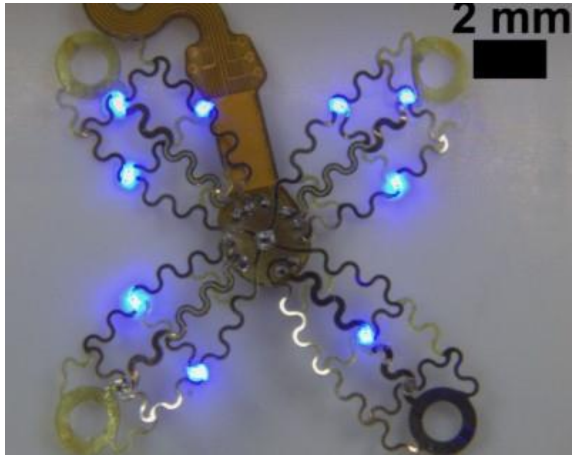
Wireless, fully implantable cardiac stimulation and recording with on-device computation for closed-loop pacing and defibrillation

Implantable electronics, wireless energy harvesting

Monitoring and control of cardiac function are critical for investigation of cardiovascular pathophysiology and developing life-saving therapies. However, chronic stimulation of the heart in freely moving small animal subjects, which offer a variety of genotypes and phenotypes, is currently difficult. Specifically, real-time control of cardiac function with high spatial and temporal resolution is currently not possible. Here, we introduce a wireless battery-free device with on-board computation for real-time cardiac control with multisite stimulation enabling optogenetic modulation of the entire rodent heart. Seamless integration of the biointerface with the heart is …

Device fabrication: Flexible circuits were constructed of Pyralux AP8535R, and thin films were constructed using physical vapor deposition. High-precision laser structuring (LPKF U4) was used to structure the top and bottom copper layers (17.5 µm) on the PI layer (75 µm) substrate for the main body. The interface layers were composed of titanium (50 nm), silver (250 nm), platinum (50 nm), and a substrate layer of PI (18.5 um). Flexible circuits were cleaned with flux (10 min; Superior Flux and Manufacturing Company, Superior no. 71) via ultrasonic cleaning (Vevor, Commercial Ultrasonic Cleaner), followed by isopropyl alcohol wash (2 min; MG Chemicals), and deionized (DI) water rinse.





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https://www.science.org/doi/10.1126/sciadv.abq7469

LPKF ProtoLaser R

Material used:

Si, SiO_2, Mg, Zn, Mo, PLA, CA, PLGA, BTP

Application area:

Bioresorbable sensors and electronics - REPORT

Published:

10/2022

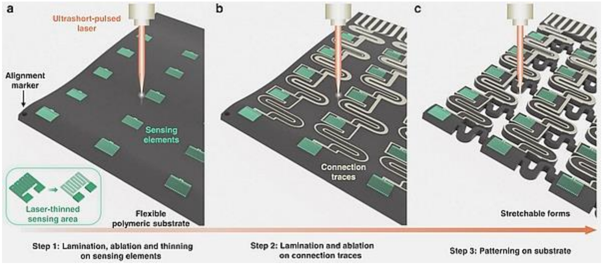
LPKF Laser & Electronics

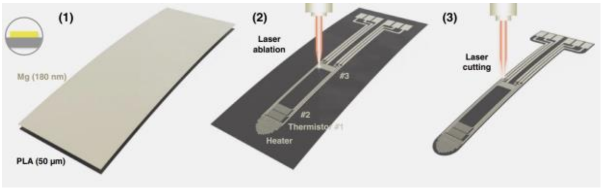
High-speed, scanned laser structuring of multi-layered eco/bioresorbable materials for advanced electronic systems

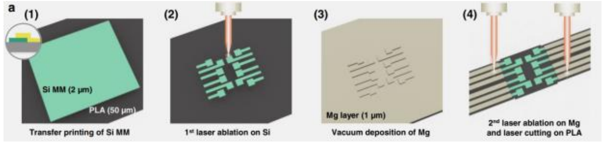
Biomedical engineering, sensors and biosensors, surface pattering

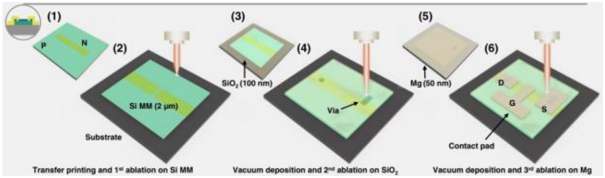
Physically transient forms of electronics enable unique classes of technologies, ranging from biomedical implants that disappear through processes of bioresorption after serving a clinical need to internet-of-things devices that harmlessly dissolve into the environment following a relevant period of use. Here, we develop a sustainable manufacturing pathway, based on ultrafast pulsed laser ablation, that can support high-volume, cost-effective manipulation of a diverse collection of organic and inorganic materials, each designed to degrade by hydrolysis or enzymatic activity, into patterned, multi-layered architectures with high resolution and accurate overlay registration.

Tool and processing modes for laser ablation: The ablation processes described here used a commercial picosecond-pulsed laser system (wavelength: 1030 nm; pulse duration: 1.0 ± 0.2 ps; beam diameter: 15 µm; maximum processing area: 30 cm × 23 cm; LPKF Laser & Electronics, OR, USA). The average power (80–200 mW), scanning speed (200–600 mm/s), frequency (40–200 kHz), and the number of repetitions were adjusted according to different application scenarios. Grid distance (2–7 µm) and grid mode (X-parallel, Y-parallel, and XY-parallel) were adjusted to meet patterning requirements. The ablation process enabled by this laser allowed material thinning, complete removal, and cutting by appropriate selection of these parameters.









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https://www.science.org/doi/10.1126/sciadv.abo6163

LPKF ProtoLaser U3

Material used:
double-sided adhesive film

Application area:
Drug delivery

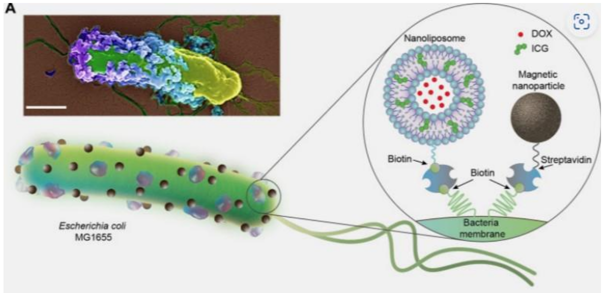
Published:
07/2022

LPKF Laser & Electronics

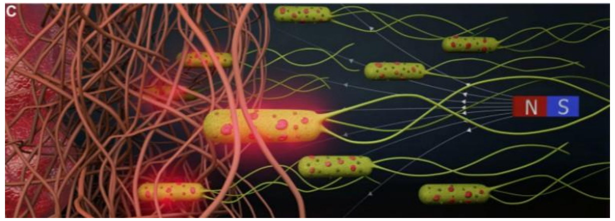
Magnetically steerable bacterial microrobots moving in 3D biological matrices for stimuli-responsive cargo delivery

Microrobots, drug delivery, drug liberation

Bacterial biohybrids, composed of self-propelling bacteria carrying micro/nanoscale materials, can deliver their payload to specific regions under magnetic control, enabling additional frontiers in minimally invasive medicine. However, current bacterial biohybrid designs lack high-throughput and facile construction with favorable cargoes, thus underperforming in terms of propulsion, payload efficiency, tissue penetration, and spatiotemporal operation. Here, we report magnetically controlled bacterial biohybrids for targeted localization and multistimuli-responsive drug release in three-dimensional (3D) biological matrices.



For magnetic guidance experiments, microchannels with three reservoirs were prepared with PMMA pieces and double-sided adhesive films on a round cover glass. The reservoirs were filled with McCoy's 5A medium (Gibco), a single HT-29 tumor spheroid was placed in each of two reservoirs, and bacterial biohybrids were loaded in the third reservoir. The microchannel was placed on an inverted optical microscope equipped with a custom-made, 1D magnetic guidance setup with two circular permanent magnets separated by a distance of 100 mm, which generated a homogeneous magnetic field (26 mT) along one axis and directed bacterial biohybrids toward a spheroid (16). PMMA pieces were cut to shape with a CO2 laser cutter (Epilog Laser), whereas the double-sided adhesive films were prepared using a UV laser system (LPKF ProtoLaser U3).



Physical Intelligence Department, Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany.

https://www.science.org/doi/10.1126/sciadv.abo6163

LPKF ProtoLaser U3

Material used:
Ecoflex, NdFeB, PMMA

Application area:
Soft millirobots for drug delivery

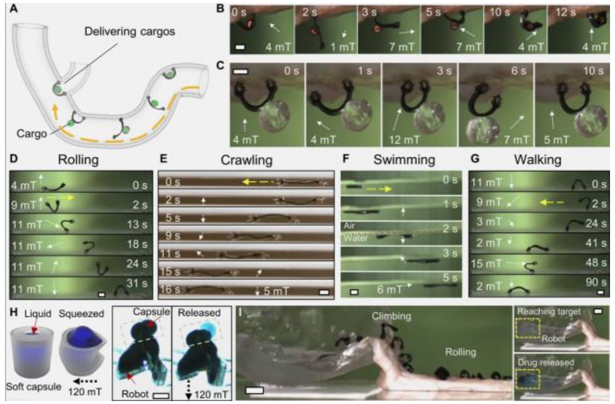
Published:
09/2022

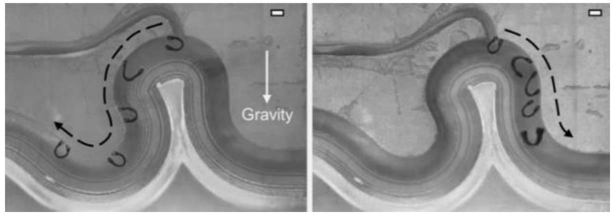
LPKF Laser & Electronics

Wireless soft millirobots for climbing three-dimensional surfaces in confined spaces

3D metadevices, programable kirigami

Kirigami-engineering has become an avenue for realizing multifunctional metamaterials that tap into the instability landscape of planar surfaces embedded with cuts. Recently, it has been shown that two-dimensional Kirigami motifs can unfurl a rich space of out-of-plane deformations, which are programmable and controllable across spatial scales. Notwithstanding Kirigami's versatility, arriving at a cut layout that yields the desired functionality remains a challenge. Here, we introduce a comprehensive machine learning framework to shed light on the Kirigami design space and to rationally guide the design and control of Kirigami-based materials from the meta-atom to the metamaterial level.





Fabrication of the ferromagnetic-elastic robot body: First, Ecoflex 00-30 silicone rubber (Smooth-On Inc.) and NdFeB microparticles (average diameter, 5 µm; MQFP-15-7, Neo Magnequench) were mixed at a 1:2 ratio by weight and then poured onto a poly(methyl methacrylate) substrate with 150-µm-thick spacers, against which a razor blade was scraped for the control of the sheet thickness (fig. S1A). The scraped mixture was cured at 90°C on a hot plate for 30 min. The cured sheet was then cut into a 4 mm–by–2 mm rectangular sheet using a laser machine (LPKF ProtoLaser U3, LPKF Laser & Electronics AG) as shown in fig. S1B. The material has a density of 2.5 g/cm3 and a Young's modulus of 163±5 kPa measured by a tensile testing machine (5940 series, Instron GmbH).

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https://www.science.org/doi/10.1126/sciadv.abn3431

LPKF ProtoLaser U3

Material used:

FR4

Application area:

Soft robotics

Published:

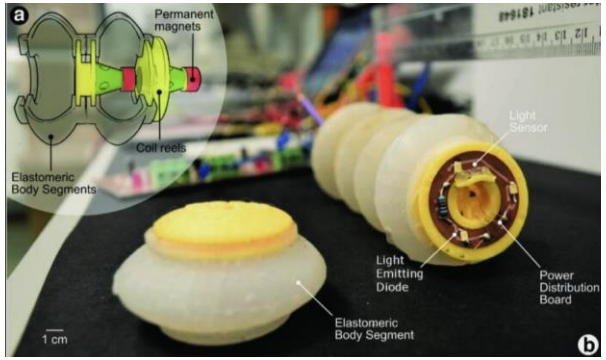
12/2016

Laser & Electronics

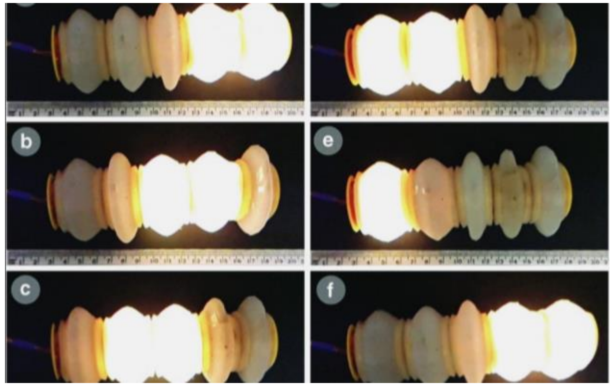
Using Voice Coils to Actuate Modular Soft Robots: Wormbot, an Example

Modular robotics, voice coil actuator, multidimensional actuator

In this study, we present a modular worm-like robot, which utilizes voice coils as a new paradigm in soft robot actuation. Drive electronics are incorporated into the actuators, providing a significant improvement in self-sufficiency when compared with existing soft robot actuation modes such as pneumatics or hydraulics. The body plan of this robot is inspired by the phylum Annelida and consists of three-dimensional printed voice coil actuators, which are connected by flexible silicone membranes. Each electromagnetic actuator engages with its neighbor to compress or extend the membrane of each segment, and the sequence in which they are actuated results in an earthworm…



We fabricated acrylonitrile–butadiene–styrene plastic molds (for the elastomeric body segments) and coil reels using a 3D printer. We designed the coil reel to provide space for the PCB and with a cone for mounting the permanent magnet, as shown in Figure 1a. We glued the permanent magnet onto the cone using hot glue. We provide details of the coil-winding process in the Experimental section. We used CadSoft Eagle for designing the power distribution boards and we fabricated them on double-sided Cu-FR4-Cu 0.1-mm boards using with an LPKF Protolaser U3 laser micromachining system. We used 3D soft lithography to fabricate the elastomeric body segments using Ecoflex-50 (Smooth-On, Inc.). Figure 1 shows a modular soft robot consisting of five segments.



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https://www.liebertpub.com/doi/10.1089/soro.2016.0009

LPKF ProtoLaser U3

Material used:

Vinyl film, ecoflex

Application area:

Soft sensors - RFID

Published:

02/2019

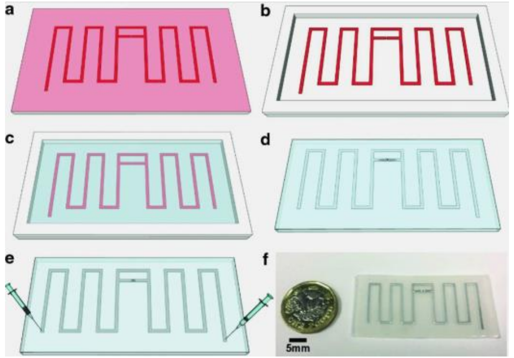
Laser & Electronics

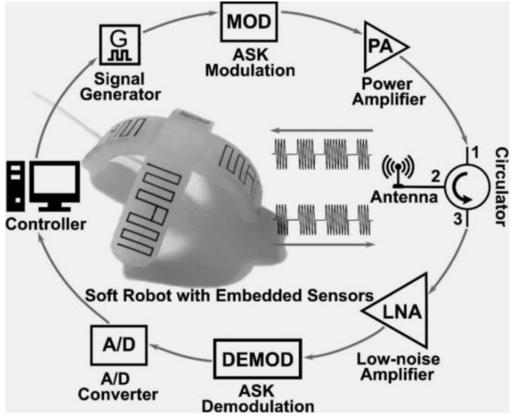
Soft Radio-Frequency Identification Sensors: Wireless Long-Range Strain Sensors Using Radio-Frequency Identification

soft sensing, RFID, antenna, wireless, passive

Increasing amounts of attention are being paid to the study of Soft Sensors and Soft Systems. Soft Robotic Systems require input from advances in the field of Soft Sensors. Soft sensors can help a soft robot to perceive and to act upon its immediate environment. The concept of integrating sensing capabilities into soft robotic systems is becoming increasingly important. One challenge is that most of the existing soft sensors have a requirement to be hardwired to power supplies or external data processing equipment. This requirement hinders the ability of a system designer to integrate soft sensors into soft robotic systems. In this article, we design, fabricate, and characterize a new soft …

Materials and Fabrication Methods: Figure 4 shows the soft-lithography fabrication process of our stretchable antenna (photographs of the fabrication process are shown in Supplementary Figure S2). We designed and fabricated an antenna mould with a laser micromachining system (Protolaser U3; LPKF) and a self-adhesive vinyl film (CRAFTRKZO; d-c-fix®), as shown in Figure 4a. A piece of vinyl film was attached to an acrylic substrate (2 mm Acrylic Cast; AMARI). The channel profiles were cut with the LPKF laser system. We peeled the vinyl residuals (negative) from the substrate and laid a 2 mm-thick acrylic frame along the mould edges as indicated in Figure 4b.





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https://www.liebertpub.com/doi/pdf/10.1089/soro.2018.0026

LPKF ProtoLaser U4

Material used:

Rogers RO 4350B

Application area:

RF

Published:

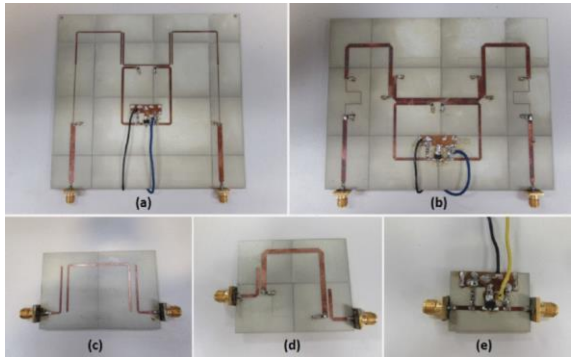
02/2021

Laser & Electronics

Lossy Microwave Filters With Active Shape Correction

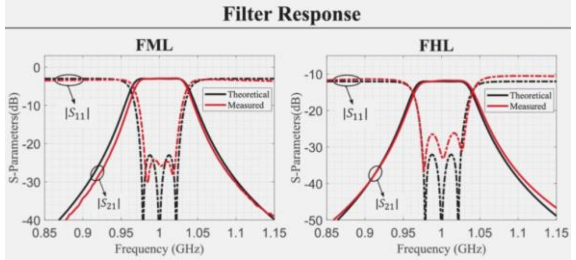
Lossy microwave filters, active filters, coupling matrix, lossy coupling matrix

Obtaining the prescribed microwave filter response is highly desirable for proper frequency selectivity in RF transceivers. As the traditional microwave filter design methods do not take into account finite unloaded quality factors, lossy resonators cause significant deviations from the prescribed filter response, especially in filters with narrow bandwidths or of high orders. This deviation gets more severe as the resonator losses increase. Building on the lossy filter design techniques by using an active shape correction mechanism, this paper proposes a new approach to recover the filter response when the filter has moderately-to-highly lossy resonators.



Fabrication and Measurements

To validate the proposed method, both prototypes were fabricated on a RO 4350B LoPro (Rogers Corp., Chandler, AZ) 30-mil-thick substrate with a copper thickness of 17.5 µm . For precise board patterning, an LPKF ProtoLaser U4 (LPKF, Garbsen, Germany) was used. For the lumped capacitors at the amplifier network, multilayer ceramic capacitors from Murata Electronics (Kyoto, Japan) and for the RF-choke inductors, Murata spiral inductors were used. For the amplifiers of the loss compensation networks, PGA-103 low noise amplifier from Mini-Circuits (Brooklyn, NY) was used with its prescribed stabilization network.



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https://ieeexplore.ieee.org/document/9363120

LPKF ProtoLaser S4

Material used:
FR4

Application area:
MW glucose sensor

Published:
12/2022

LPKF Laser & Electronics

Assessment of Finger Fat Pad Effect on CSRR-Based Sensor Scattering Parameters for Non-Invasive Blood Glucose Level Detection

CSRR, microwave sensor, glucose, Cole-Cole, finger fat-pad

This paper presents a very low profile and simple antenna design for dual beam and dual-band operation to be employed in future 5G mobile phones operating in the millimeter-wave bands of 26.75–30.31 and 35.83–41.22 GHz. The two distinct resonances at 28 and 38 GHz are achieved using a meta-material-based structure consisting of a closed-ring resonator (CRR) and a split-ring resonator (SRR) by co-centrically combining two planar hexagonal rings; i.e., an inner split-ring resonator (SRR) and an outer closed-ring resonator (CRR). The antenna has a high gain of 4.5 dBi. The antenna also exhibits a dual-beam radiation pattern in one of its planes. The overall antenna…

The proposed CSRR circuit design is shown in Figure 2a. It was designed to operate at 2.4 GHz on a low-cost FR-4 substrate (εr = 4.4, tanδ = 0.025) [35]. The operating frequency of 2.4 GHz was chosen to match the Industrial, Scientific, and Medical (ISM) band 2.4–2.5 GHz for ISM-band biomedical applications. The circuit prototype was fabricated using a Laser-based PCB Prototyping machine (LPKF ProtoLaser S4), as shown in Figure 2b. The overall size of the CSRR circuit is compatible with the fingertip dimension; its geometrical parameters are as follows: L = 60, LR = WR = 9.079, W = 15, W0 = 1.349, g = e = 0.500, h = 0.730, all units being millimeters. A fixture structure suitable for finger placement was also manufactured to ensure repeatable measurement to incorporate the fabricated

Figure 1. Anatomy of a human fingertip in (**a**) and the adopted Cole–Cole-based four-layers fingertip model in (**b**).

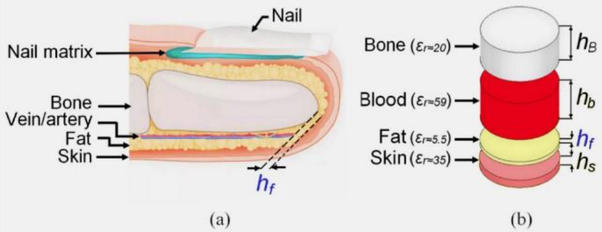
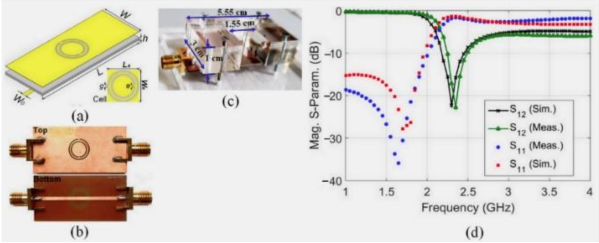


Figure 2. The designed CSRR circuit: (**a**) the geometrical parameters, (**b**) the photograph of the fabricated circuit prototype, (**c**) the geometrical dimensions of the fixture, and (**d**) the measured and simulated S-parameters of the CSRR sensor circuit prior to loading.



Institut Matériaux Microélectronique Nanosciences de Provence (IM2NP), UMR CNRS 7334, Aix-Marseille Université, 5 Rue Enrico Fermi, 13453 Marseille, France

https://www.mdpi.com/1424-8220/23/1/473

LPKF ProtoLaser U4

Material used:

LCO, PI, flex

Application area:

Batteries

Published:

01/2023

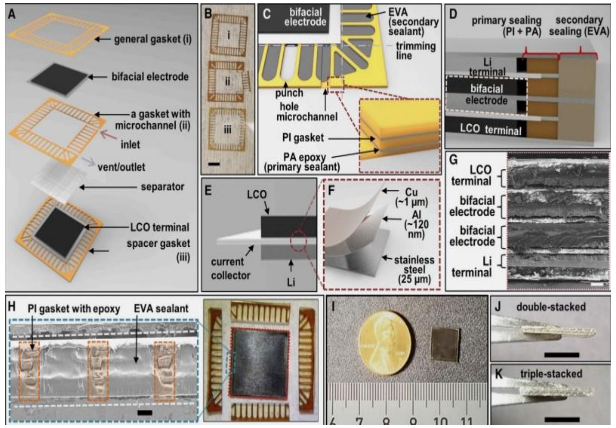
LPKF
Laser & Electronics

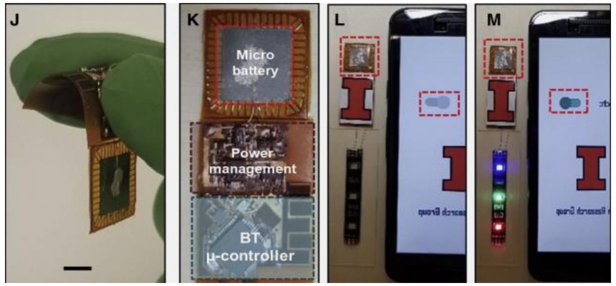
Serially integrated high-voltage and high power miniature batteries

Microbatteries, electrodeposition, hermetic packaging

Accessing high voltages (>9 V) and high power density in microbatteries with volumes below ∼0.25 cm3 is challenging. At such scales, energy density and voltage are highly constrained by packaging and serial integration of cells. Here, we demonstrate hermetically sealed, durable, compact (volume ≤ 0.165 cm3) batteries with low package mass fraction (10.2%) in single- (∼4 V), double- (∼8 V), and triple-stacked (∼12 V) configurations with energy densities reaching 990 Wh Kg−1 and 1,929 Wh L−1 (triple-stacked battery discharged at C/10) and high power density for continuous and pulsed discharge (∼124 mW cm−2 for triple-stacked battery at C/2 continuous discharge, ∼75 mW cm−2

Laser sanding, cleaning, and cutting of an electrodeposited LCO sheet yielded a precisely defined geometric surface area of LCO (0.85 × 0.85 cm2) on a current collector area of 1.0 × 1.0 cm2 (2 W for laser sanding, 6 W for laser cutting, ProtoLaser U4; LPKF, Garbsen, Germany).
Precision gasket cutting of the 25-, 50-, 75,- and 150-µm-thick PI (DuPont, Wilmington, DE, USA) films was performed using a laser cutter (ProtoLaser U4; LPKF).
A patterned multilayer foil of Cu-PI-Cu (18 µm/75 µm/18 µm thick, respectively; PI is polyimide) serves as a printed circuit board (PCB) that is processed by a professional-grade laser cutter (U4; LPKF Laser, Germany).





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