Publications with LPKF Equipment, Part 2

Selection of internationally published scientific articles using LPKF equipment

May 2021

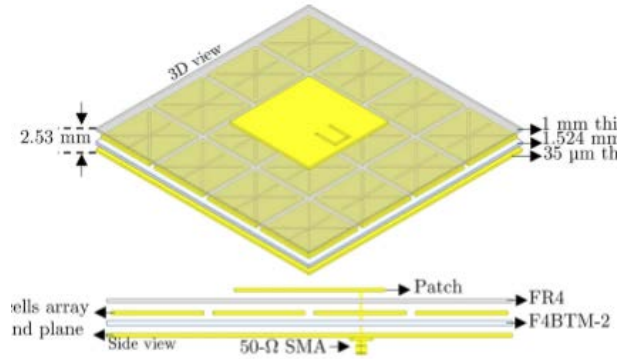
LPKF
Laser & Electronics

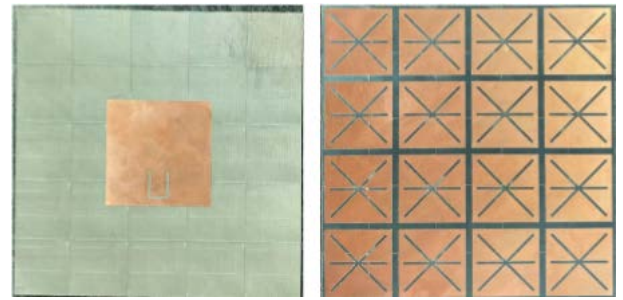
TOC: page, system, application

An ultra-thin double-functional metasurface patch antenna for UHF RFID applications

metasurface patch antenna (MPA)

UHF RFID





An ultra-thin double-functional metasurface patch antenna (MPA) was proposed, where it can operate not only in the antenna mode but also can simultaneously act as perfect absorber for normal incident waves, suitable for RFID applications in the 868 MHz band. The MPA structure consists of a typical coaxially-fed patch antenna merged, for the first time, with a metasurface absorber acting as artificial ground. A methodology for the unit-cell design of the metasurface is proposed followed by an equivalent circuit model analysis, which makes it possible to transform a low-loss (*tanδ* =0.0015) unit-cell with highly-reflective characteristics to a perfect absorber for …

The MPA structure proposed in the current study comprises a typical patch antenna (Fig. 1a–d) that its ground plane is substituted with a metasurface absorber structure (Fig. 1b–e). It can be a potential RFID reader as it can operate not only in a normal antenna mode with improved performance but also act as an absorber to suppress scattering, which can effectively reduce the incorrect reading of RFID systems in multipath environment. The patch is printed on a 1-mm-thick inexpensive FR4 epoxy substrate. The metasurface absorber structure composed of 4x4 unit-cell matrix. A laser etching machine (LPKF ProtoLaser S4) was used to realize both the patch and the absorber structures, shown in Fig. 1d,e, respectively. The overall MPA thickness is only 2.53 mm.

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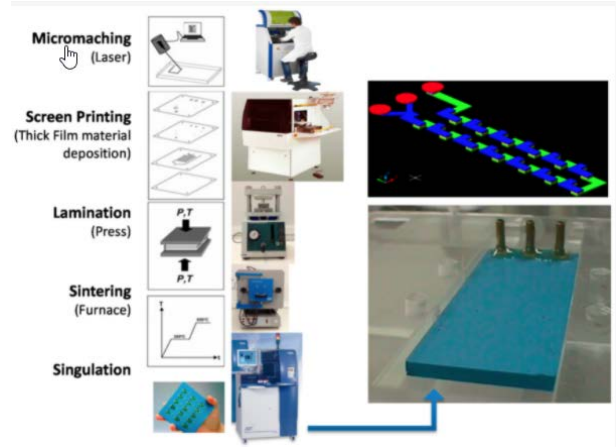
https://www.nature.com/articles/s41598-020-79506-5

Fab on a Package: LTCC Microfluidic Devices Applied to Chemical Process Miniaturization

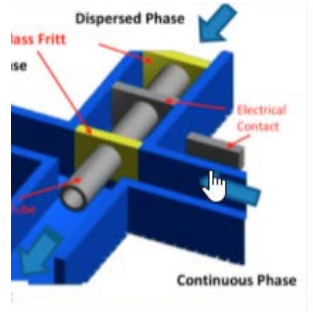
microfluidic devices; LTCC technology, chemical process intensification

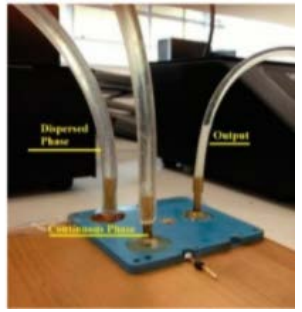
Microfluidics has brought diverse advantages to chemical processes, allowing higher control of reactions and economy of reagents and energy. Low temperature co-fired ceramics (LTCC) have additional advantages as material for fabrication of microfluidic devices, such as high compatibility with chemical reagents with typical average surface roughness of 0.3154 µm, easy scaling, and microfabrication. The conjugation of LTCC technology with microfluidics allows the development of micrometric-sized channels and reactors exploiting the advantages of fast and controlled mixing and heat transfer processes, essential for the synthesis and surface functionalization of nanoparticles.



LTCC Microfabrication

The microfluidic devices were fabricated employing the LTCC process as shown in Figure 1 (cutting layers, thick film deposition, lamination, sintering, and dicing) [16]. The layers with the microchannel geometries were fabricated using a diode pumped IR laser, model U-15 1064 nm Ultrafast Laser Maker (RMI Laser, LLC, Lafayette, Colo.) and a prototyping machine equipped with an ultraviolet laser (355 nm wavelength), model LPKF ProtoLaser® U3 (LPKF Laser & Electronics AG, Garbsen, Germany). Thermo-compression lamination process is done by means of a uniaxial laminator …





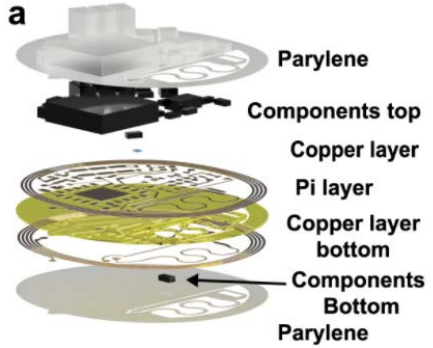
Micromanufacturing Laboratory, Center for Bionanomanufacturing, Institute for Technological Research, 05508-901 São Paulo, Brazil

https://www.mdpi.com/2072-666X/9/6/285/htm

Wireless battery free fully implantable multimodal recording and neuromodulation tools for songbirds

wireless, battery-free, fully implantable

Wireless battery free and fully implantable tools for the interrogation of the central and peripheral nervous system have quantitatively expanded the capabilities to study mechanistic and circuit level behavior in freely moving rodents. The light weight and small footprint of such devices enables full subdermal implantation that results in the capability to perform studies with minimal impact on subject behavior and yields broad application in a range of experimental paradigms. While these advantages have been successfully proven in rodents that move predominantly in 2D, the full potential of a wireless and battery free device can be harnessed with flying species, where …



Device fabrication. Flex circuits were composed of Pyralux AP8535R substrate. Top and bottom copper layers (17.5 µm) on a substrate polyimide layer (75 µm) were defined via direct laser ablation (LPKF U4). Ultrasonic cleaning (Vevor; Commercial Ultrasonic Cleaner 2L) was subsequently carried out for 10 min with flux (Superior Flux and Manufacturing Company; Superior #71) and 2 min with isopropyl alcohol (MG Chemicals) and rinsed in deionized water to remove excess particles. Via connections were manually established with copper wire (100 µm) and low temperature solder (Chip Quik; TS391LT). Device components were fixed in place with UV-curable glue (Damn Good 20910DGFL) and cured with a UV lamp (24 W) for 10 min. The devices were encapsulated with …

Departments of Biomedical Engineering, The University of Arizona, Tucson, AZ, USA.

https://www.nature.com/articles/s41467-021-22138-8

LPKF ProtoLaser U4

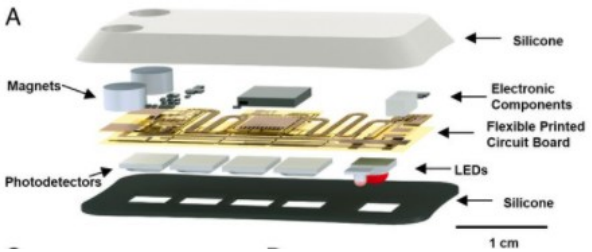
Material used:
DuPont Pyralux AP7164R

Application area:
Wearable bio-sensor

Published:
11/2020

A wireless, skin-interfaced biosensor for cerebral hemodynamic monitoring in pediatric care

Wearable electronics, near-infrared spectroscopy, bioelectronics, cerebral hemodynamis



The standard of clinical care in many pediatric and neonatal neurocritical care units involves continuous monitoring of cerebral hemodynamics using hard-wired devices that physically adhere to the skin and connect to base stations that commonly mount on an adjacent wall or stand. Risks of iatrogenic skin injuries associated with adhesives that bond such systems to the skin and entanglements of the patients and/or the healthcare professionals with the wires can impede clinical procedures and natural movements that are critical to the care, development, and recovery of pediatric patients. This paper presents a wireless, miniaturized, and mechanically soft, flexible …

Device Fabrication

Fabrication began with a 25-µm-thick polyimide sheet, with 12-µm-thick Cu on both sides (AP7164R; Dupont) and outlined using an ultraviolet laser cutter (ProtoLaser U4; LPKF). Electronic and sensor components, along with a pair of magnets (5862K13; McMaster Carr), were bonded to the circuit board by solder paste (TS391LT; Chip Quik). The board was folded and encapsulated within thin layers of medical-grade silicone (Silbione RTV 4420; Elkem) defined by an aluminum mold and subsequently filled with soft silicone (Ecoflex 00-10; Smooth-On). The final shape was outlined using a CO2 laser cutter (VLS3.5; Universal Laser).

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https://www.pnas.org/content/117/50/31674

LPKF ProtoLaser U4

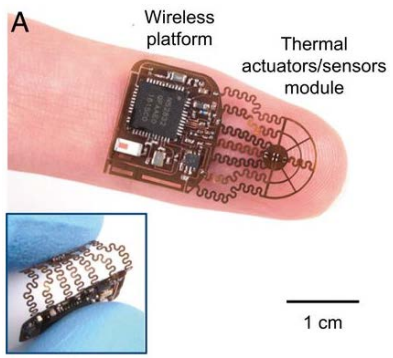
Material used: **Pyralux AP8535R**

Application area: **Wearable bio-sensor**

Published: **02/2021**

Wireless, soft electronics for rapid, multisensor measurements of hydration levels in healthy and diseased skin

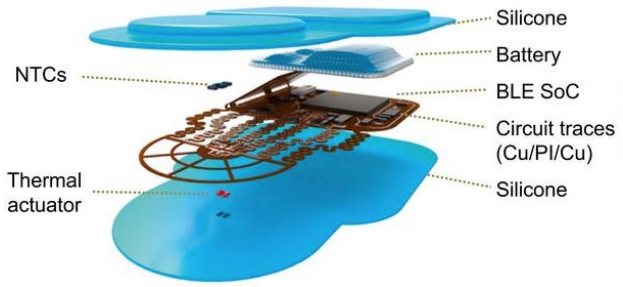
Wireless electronics, flexible electronics, bio-medical devices, health monitoring, diagnostics



Precise, quantitative measurements of the hydration status of skin can yield important insights into dermatological health and skin structure and function, with additional relevance to essential processes of thermoregulation and other features of basic physiology. Existing tools for determining skin water content exploit surrogate electrical assessments performed with bulky, rigid, and expensive instruments that are difficult to use in a repeatable manner. Recent alternatives exploit thermal measurements using soft wireless devices that adhere gently and noninvasively to the surface of the skin, but with limited operating range (~1 cm) and high sensitivity to subtle …

Fabrication of the Electronics.

Prototype devices used flexible copper-clad polyimide substrates (AP8535R; Pyralux) processed by laser ablation (Protolaser U4; LPKF), resulting in flexible printed circuit boards (fPCBs) to interconnect surface-mount components, including a BLE SoC (nRF52832; Nordic Semiconductor), resistors (RMCF0201FT; Stackpole Electronics), and temperature sensors (NTC; NCP03XH; Murata). Outcomes of studies of prototype fPCBs served as the basis for designs provided to an ISO-9001 compliant vendor (PCBWay) for final designs. Soldering wire (MM01019; Multicore) and soldering paste (SMDLTLFP10T5; Chip Quik) bonded the BLE SoC to the fPCB by heating at 400 °C, and …



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https://www.pnas.org/content/118/5/e2020398118

LPKF ProtoLaser U3

Material used:
PMMA, glass, double-sided tape

Application area:
Medical research

Published:
03/2021

LPKF Laser & Electronics

Shape anisotropy-governed locomotion of surface microrollers on vessel-like microtopographies against physiological flows

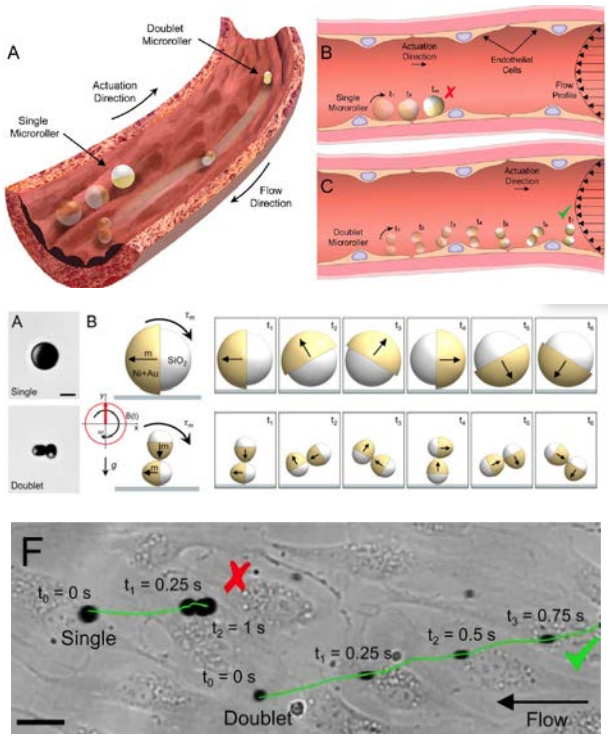
Surface microrollers are promising microrobotic systems for controlled navigation in the circulatory system thanks to their fast speeds and decreased flow velocities at the vessel walls. While surface propulsion on the vessel walls helps minimize the effect of strong fluidic forces, three-dimensional (3D) surface microtopography, comparable to the size scale of a microrobot, due to cellular morphology and organization emerges as a major challenge. Here, we show that microroller shape anisotropy determines the surface locomotion capability of microrollers on vessel-like 3D surface microtopographies against physiological flow conditions.

Cell Culture Experiments: For branched endothelialized microfluidic channels, double-sided adhesive tape was micromachined using an ultraviolet laser system (LPKF ProtoLaser U3) with a width of 300 µm for the smallest channel. Human umbilical vein endothelial (HUVEC) cells were grown in endothelial cell growth basal medium 2 (CC-3156, Lonza) supplemented with endothelial cell growth media 2 SingleQuots (CC-4176, Lonza) in a 5% CO2, 95% air humidified atmosphere. After reaching to confluence, HUVEC cells were trypsinized and then introduced into the microchannels coated with fibronectin (0.1 mg/mL for 1 h at room temperature) at a concentration of 107 cell/mL and cultured with media flow at 4 dyn/cm2 for 2 d.

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

https://www.pnas.org/content/118/13/e2022090118

Medical robots, surface rollers, circulatory system, microfluidics



LPKF ProtoLaser U4

Material used: **Pyralux AP8535R**

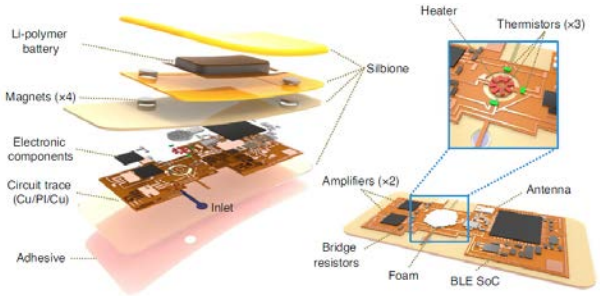
Application area: **Bio-medical research**

Published: **03/2021**

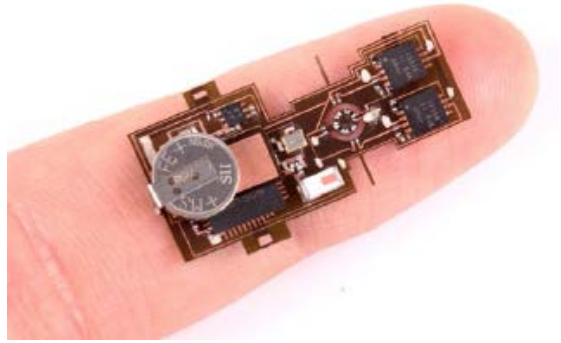
An on-skin platform for wireless monitoring of flow rate, cumulative loss and temperature of sweat in real time

Biomedical engineering, health care, microfluidics

Monitoring the flow rate, cumulative loss and temperature of sweat can provide valuable physiological insights for the diagnosis of thermoregulatory disorders and illnesses related to heat stress. However, obtaining accurate, continuous estimates of these parameters with high temporal resolution remains challenging. Here, we report a platform that can wirelessly measure sweat rate, sweat loss and skin temperature in real time. The approach combines a short, straight fluid passage to capture sweat as it emerges from the skin with a flow sensor that is based on a thermal actuator and precision thermistors, and that is physically isolated from, but thermally coupled to, the sweat.



Fabrication of the electronics. A thin, flexible film (AP8535R, Pyralux, DuPont) of copper/PI/copper (thicknesses of 18 µm, 75 µm and 18 µm) served as a substrate. An ultraviolet laser cutter (Protolaser U4, LPKF) ablated the copper to define conductive traces, bond pads and through-hole vias, resulting in a flexible printed circuit board (fPCB). A silver conductive paint (cat. no. Z05001, SPI Supplies) created conductive plugs between the top and bottom patterned copper layers through the vias when heated at 90 °C using a heat gun (AOYUE Int866). Soldering paste (TS391LT, Chip Quik) was used to join the various surface-mounted components, including the BLE SoC (nRF52832, Nordic Semiconductor), antenna (2450AT18A100, Johanson Technology), amplifier …



School of Electrical Engineering, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea

http://rogersgroup.northwestern.edu/files/2021/nelectflow.pdf

LPKF ProtoLaser U4

Material used: **Pyralux AP8535R**

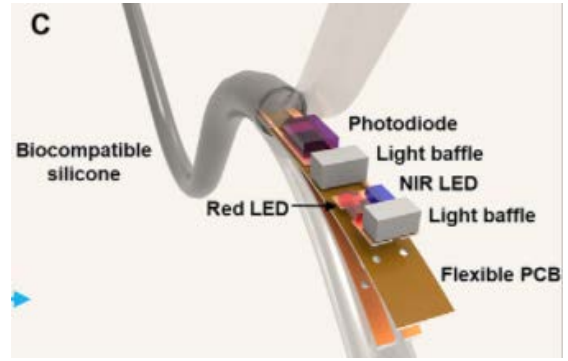
Application area: **Medical research**

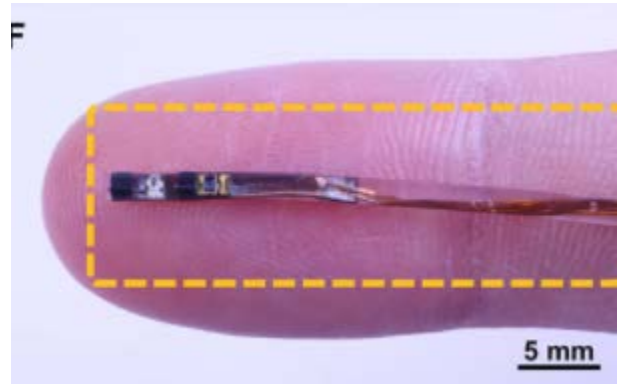
Published: **02/2021**

Wireless, implantable catheter-type oximeter designed for cardiac oxygen saturation

Health care, implantable sensor, wireless sensor, oximeter

Accurate, real-time monitoring of intravascular oxygen levels is important in tracking the cardiopulmonary health of patients after cardiothoracic surgery. Existing technologies use intravascular placement of glass fiber-optic catheters that pose risks of blood vessel damage, thrombosis, and infection. In addition, physical tethers to power supply systems and data acquisition hardware limit freedom of movement and add clutter to the intensive care unit. This report introduces a wireless, miniaturized, implantable optoelectronic catheter system incorporating optical components on the probe, encapsulated by soft biocompatible materials, as alternative …





Fabrication of catheter-type oximeter probe

A flexible sheet of copper-clad polyimide (PI) (Cu/PI/Cu, 18/75/18 µm, AP8535R, Dupont, Pyralux) served as the substrate for the fPCB, with conductive traces, pads, and outline defined by patterned ablation of the copper using an ultraviolet (UV) laser system (ProtoLaser U4, LPKF Co.). The surface mount (SMT) electronic components, red, NIR LEDs, and PD were placed and attached using reflow soldering with low-temperature solder paste (Indalloy 290, Indium Corporation). This electronics module was connected to a detachable connector through four Teflon-coated copper wires (40 AWG enameled copper, Remington Industries) with a length between a few centimeters to 30 cm, …

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

https://advances.sciencemag.org/content/7/7/eabe0579

LPKF ProtoLaser U4

Material used: **Brass**

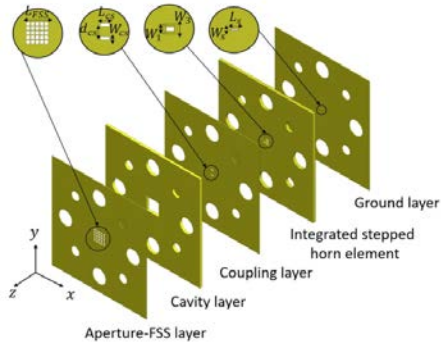
Application area: **RF -mm wave**

Published: **04/2021**

A 300-GHz low-cost high-gain fully metallic Fabry–Perot cavity antenna for 6G terahertz wireless communications

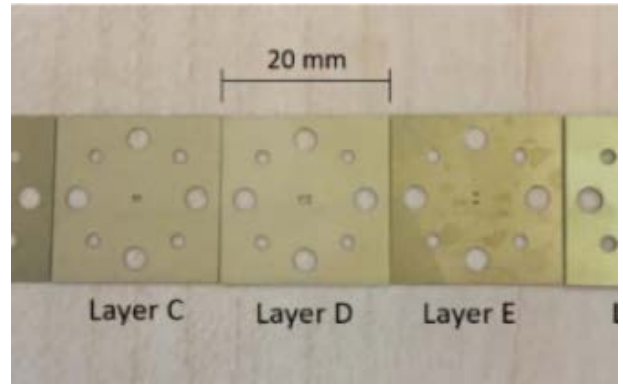
Sub-terahertz , MMW, 6G,

A low-cost, compact, and high gain Fabry–Perot cavity (FPC) antenna which operates at 300 GHz is presented. The antenna is fabricated using laser-cutting brass technology. The proposed antenna consists of seven metallic layers; a ground layer, an integrated stepped horn element (three-layers), a coupling layer, a cavity layer, and an aperture-frequency selective surface (FSS) layer. The proposed aperture-FSS function acts as a partially reflective surface, contributing to a directive beam radiation. For verification, the proposed sub-terahertz (THz) FPC antenna prototype was developed, fabricated, and measured.



Fabrication technology

A laser cutting brass technology has been used for each metal layer in the proposed antenna using LPKF ProtoLaser U4 laser machine with technical support from M2ARS (Ch. Guitton and F. Boutet). The seven brass metal layers needed for one antenna assembly, having different thicknesses as shown in Table 1, have been used to manufacture the proposed 300 GHz FPC antenna are shown in Fig. 6a. This brass is often used as a laser-cut metal, which is a highly reflective material. All brass metal layers are fixed by using four plastic screws as shown in Fig. 6. The ultraviolet (UV) laser beam wavelength (λ = 355 nm in the UV spectrum), is focused on each brass metal layer individually …



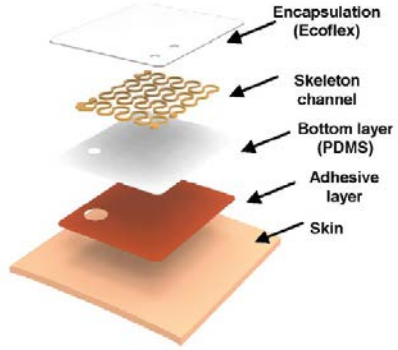
Institut d'Electronique et des Technologies du numéRique (IETR), UMR CNRS 6164, Université de Rennes 1, Campus de Beaulieu, 35042, Rennes Cedex, France

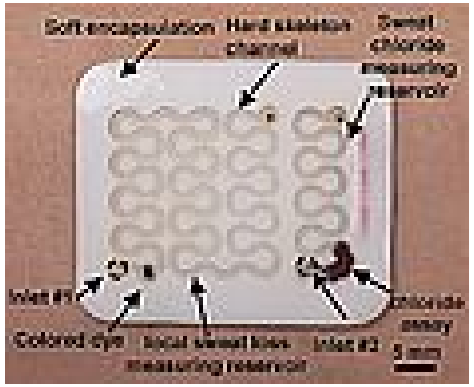
https://www.nature.com/articles/s41598-021-87076-3

Skin-Interfaced Microfluidic Systems that Combine Hard and Soft Materials for Demanding Applications in Sweat Capture and Analysis

microfludic devices, sweat analysis, wearable devices

Eccrine sweat contains a rich blend of electrolytes, metabolites, proteins, metal ions, and other biomarkers. Changes in the concentrations of these chemical species can indicate alterations in hydration status and they can also reflect health conditions such as cystic fibrosis, schizophrenia, and depression. Recent advances in soft, skin-interfaced microfluidic systems enable real-time measurement of local sweat loss and sweat biomarker concentrations, with a wide range of applications in healthcare. Uses in certain contexts involve, however, physical impacts on the body that can dynamically deform these platforms, with adverse effects on measurement reliability.





Fabrication:

… An automated cutting system based on a pulsed laser (LPKF ProtoLaser R, Germany) defined the outline of the serpentine skeletal geometry from the NOA microchannel system. Pouring PDMS(Sylgard 184; Dow corning, MI, USA; mixing ratio of base to curing agent: 10:1) mixed with white silicone dye (Reynolds Advanced Materials) at 10% wt on the PMMA-coated silicon wafer and spin-casting at 300 rpm generated a bottom substrate layer with thickness of 250 µm. Corona treating the NOA skeletal and the white PDMS layer enabled strong bonding between them. Pouring a low modulus silicone precursor (Ecoflex 35) on top after corona treatment, spinning at 150 rpm …

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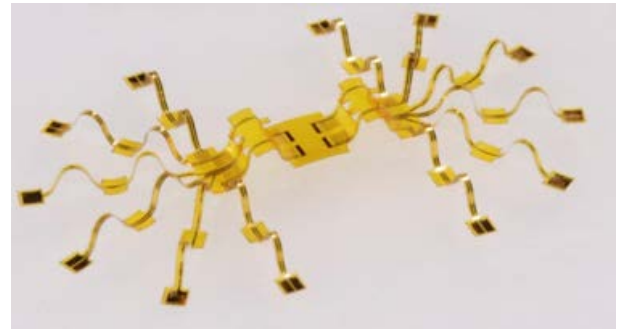
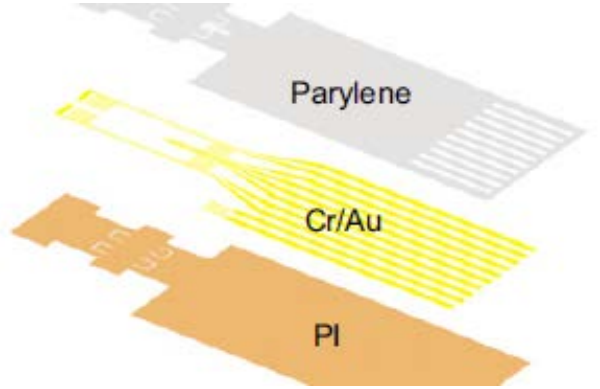
http://rogersgroup.northwestern.edu/files/2021/adhmskeleton.pdf

Compliant 3D frameworks instrumented with strain sensors for characterization of millimeter-scale engineered muscle tissues

three-dimensional electronics, electronic tissue scaffolds, bioelectronics, tissue engineering

Tissue-on-chip systems represent promising platforms for monitoring and controlling tissue functions in vitro for various purposes in biomedical research. The two-dimensional (2D) layouts of these constructs constrain the types of interactions that can be studied and limit their relevance to three-dimensional (3D) tissues. The development of 3D electronic scaffolds and microphysiological devices with geometries and functions tailored to realistic 3D tissues has the potential to create important possibilities in advanced sensing and control. This study presents classes of compliant 3D frameworks that incorporate microscale strain sensors for high-sensitivity measurements of …





Fabrication of the instrumented 3Dframeworks began with spin coating (3,000 rpmfor 50 s) a layer of PDMS (10:1 mixing ratio) on a glass slide. Partial curing (90 °C for 60 s) of the PDMS, followed by lamination of a film of PI (12.5 µm in thickness) on top and complete curing (110 °C for 3 min) allowed further processing. A lift-off process defined a patterned metal layer (Cr/Au, 10 nm/100 nm in thickness) on the surface of the PI. Deposition of a layer of parylene C (5 µm) and subsequent patterning using oxygen plasma etching (March RIE) formed a top encapsulation layer. Laser ablation (LPKF ProtoLaser R) defined the outline of the 2D precursor, followed by transfer of the 2D precursor from the PDMScoated glass to a water-soluble tape (polyvinyl alcohol [PVA]).

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

http://rogersgroup.northwestern.edu/files/2021/pnasmuscle.pdf

LPKF ProtoLaser R

Material used: **PI**

Application area: **Medical research**

Published: **10/2020**

Soft, skin-interfaced microfluidic systems with integrated immunoassays, fluorometric sensors, and impedance measurement capabilities

Soft microfluidic systems that capture, store, and perform biomarker analysis of microliter volumes of sweat, in situ, as it emerges from the surface of the skin, represent an emerging class of wearable technology with powerful capabilities that complement those of traditional biophysical sensing devices. Recent work establishes applications in the real-time characterization of sweat dynamics and sweat chemistry in the context of sports performance and healthcare diagnostics. This paper presents a collection of advances in biochemical sensors and microfluidic designs that support multimodal operation in the monitoring of physiological signatures directly correlated to physical …

Electronics Design and Assembly: Fabrication began with patterning of a two-layer printed circuit board by processing of multilayer foils of Cu–PI–Cu (18 µm/75 µm/18 µm) with a UV laser cutter (ProtoLaser U4; LPKF). The main processor, RF430FRL152HCRGER (RF430, ISO/IEC 15693, ISO/IEC 18000-3; Texas Instruments), served as the NFC platform, with the ability to rectify incident power from a smartphone device at up to 720 µW at 2.0 V, depending on coupling efficiency, and relaying data over the 13.56-MHz communications link. The RF430 supports 14-bit Sigma-Delta ADC with triple analog inputs at an input range up to 900 mV and maximum sampling frequency of 2 kHz, down-sampled to 1-Hz resolution. Signal amplification and measurement of the main and …

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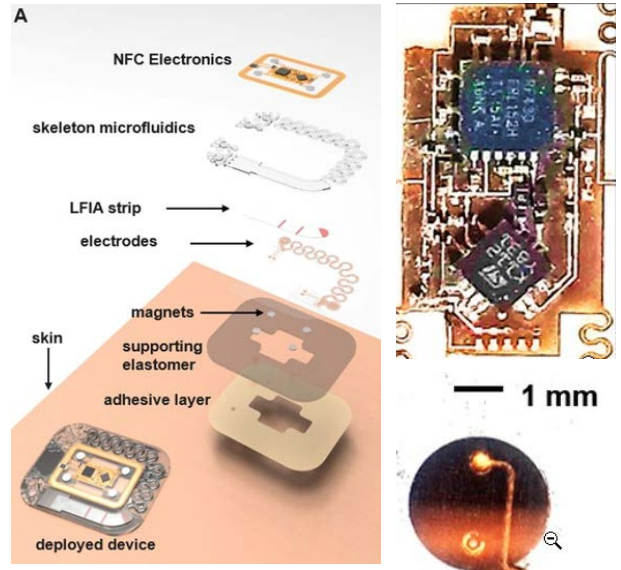
https://www.pnas.org/content/117/45/27906

Healthcare, soft materials, epidermal devices, sweat cortisol



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