

les défis du cea

The magazine of research
and its applications

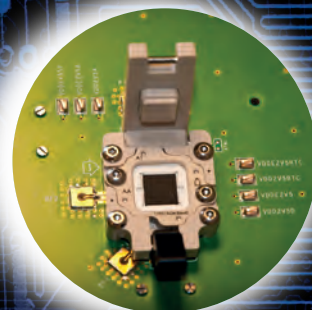
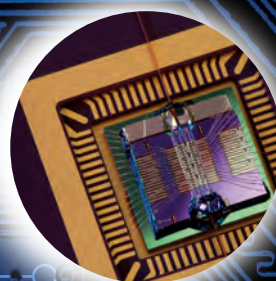
Extract from issue May 2017



50

years

of Leti Innovation



MARIE-NOELLE SEMERIA,

Director of Leti,
α CEA Tech institute



Jewels of innovation for multiple markets

How would you define Leti, the CEA Tech institute you direct since 2015?

"Initiatives are indisdisciplined actions that have succeeded!"
This statement of Michel Cordelle, Leti's first director in 1967, clearly illustrates our story. At the time, a handful of electronics specialists working for CEA researchers insisted that electronics be given its own laboratory. They had fully understood that innovation is synonymous with change in relation to industry and employment. The framework was established.
In 1972, Leti director Jacques Lacour identified MOS (*Metal Oxide Semiconductor*) technology in the USA. In 1977, he founded the EFCIS startup to produce this type of integrated circuit in France. This initiative, which later led to the founding of STMicroelectronics,

kick-started a real dynamic: skills in infrared detection prompting establishment of Sofradir, today's international leader; accelerometers equipping our cellphones; FDSOI technology (see following article) revolutionizing microelectronics; tomorrow, 3D Coolcube™ integration technology. Leti research teams know how to make small, intelligent, communicating, safe, low energy consuming objects.

What accounts for these successes?

In addition to this seminal pioneering spirit, our strength is that we concentrate and consolidate a wide range of technologies: CMOS, sensors, communication systems, packaging and 3D integration, power electronics, imagery, integrated circuits, specific architectures,

data fusion and many others. This melting pot that is Leti is unique in the world. In conjunction with our partners, it allows us to develop a project's entire value chain right up to pre-production stage. For example, in power electronics, our know-how extends from a single chip to the entire vehicle! Similarly, we do not satisfy ourselves with the status quo: we seek differentiating, industrializable solutions in conjunction with our partners. Each year, Leti launches between 5 and 6 start-up projects: the technologies industrialized by these companies are innovative gems for many markets. Aledia (LEDs), Wavelens (variable focus optical lenses on silicon) or Avalun (portable biological analyzer) are perhaps tomorrow's global benchmarks!
Today, we can say that there's a little bit of Leti in all our cellphones,

boxes, high-tech medical appliances and ever more in our day-to-day objects!

What markets are you currently targeting?

We target changing markets, in which technological innovation may make the difference at French companies. This is the case of the Internet of Things (IoT) and 5G communication technologies as well as the car with its intelligent sensors, data fusion algorithms, GaN power components and secure hardware solutions. Or again, the connected healthcare market, in which we can draw advantage from sensor and data processing technologies for personalizing care. Finally, data centers and high-performance computing with an approach combining photonics, 3D integration and new calculation and memorization architectures.

1967

Leti founded, previously CEA Grenoble's Electronics Department

1972

1000 transistor circuit produced (5 micron technology)

1979

X-ray scanner technology transferred to Thomson CGR

Moreover, just like CEA Tech institutes List and Liten with which we cooperate closely, we accompany both high-tech and conventional SMEs and companies in full mutation, thereby enabling them to differentiate and gain in competitiveness.

What will be Leti's new R&D areas?

I'll quote six that are vehicles of change and take advantage of a multidisciplinary approach: artificial intelligence with its new neuromorphic and quantum calculation technologies; augmented and virtual reality implementing new imagery and screen concepts; development of new medical protocols through Leti's medical system platform and Clinitech; complex, intelligent and safe cyber physical systems; cybersecurity from a physical attack standpoint; materials engineering, in which new functions originate.

How is innovation nourished?

Innovation takes root in a cultural environment and its driving force is encountered in perpetual confrontation with the outside world because, to innovate, we must distinguish ourselves and understand what forms the value of this distinction: the 40% energy saving of FDSOI circuits and their compatibility with communication functions; the 10,000-fold gain in GaN screen brilliance; our capacity to control microelectronics techniques on 300 mm diameter wafers, etc. Grenoble's cultural environment is fertile with Minatec, Giant, French

Tech startups, the Minalogic hub, etc. We're also active in innovation ecosystems, such as the Consumer Electronics Show in Las Vegas, which allow us to compare our innovations with others across the world. For 50 years, Leti's research teams have known how to reinvent themselves by capitalizing on their knowledge and know-how and by recruiting new profiles to remain at the forefront. Cooperation with our academic partners is essential, as is the work of our thesis and post-doctoral students, who explore new avenues with us. This is vital, as are our equipment investment capacity forming the basis of our white room facilities. ♦

Interview by Aude Ganier

2760

PATENTS INCLUDING 310 LODGED IN 2016

1900

RESEARCHERS AND 250 THESIS AND POST-DOCTORAL STUDENTS

60

STARTUPS FORMED

330

INDUSTRIAL PARTNERS

1985

2000 m² of white rooms inaugurated by President of France

1991

SOI Smart Cut™ patent granted

Startups on Top!

Bag-Era



A software solution for ensuring consistency of systems comprising network-connected hardware, software and services.

2016 / Leti
IRT Nanoelec spin-off

elichens



Miniaturized, connected, non-dispersive infrared gas detectors for air quality-related services.

2014 / 20 Leti patents
+ a common laboratory

Exagan



Gallium nitride/Silicon power components for converters: 25% cheaper and 3x more compact than existing components.

2014 / Several dozen Leti
and Soitec patents.

Iconic FDSOI

FDSOI technology seemed to foretoken a major change in the chip industry almost 40 years ago at Leti. A few years later, this view was supplemented by the conviction of a handful of engineers. Then came the gamble taken by a few manufacturers... A revolutionary patent... Establishment of a full technological and industrial ecosystem... International partnerships... Today, FDSOI technology is integrated into millions of consoles and smartphones and it's now becoming a standard across the nomadic electronics, automotive engineering and the Internet of Things sectors.

by Mathieu Grousseau

In real terms, Fully Depleted Silicon on Insulator is a technology involving the smallest calculation unit in every processor: the transistor. The driving idea was to fashion transistors in an ultra-thin silicon film/wafer on an insulating silicon-oxide layer, rather than in a block of solid silicon. This presence of oxygen ions within the silicon strengthens the

performance characteristics: They are intrinsically immunized against current leakage when placed on an insulating layer. However, wafer quality was not up to this in the technology's early years and, more important, solid silicon was achieving wonders in the microelectronics industry. For example, according to Moore's Law, voiced by a co-founder Intel in 1965, transistor surface area was halving every two years!

This is the real starting point for thin-film electronics.

Olivier Faynot, Leti engineer



electronics' resistance to radiation; this is why Leti focused on implementing FDSOI for the CEA's military applications beginning in the 1980s. Moreover, thin-film-based components offer advantageous

Ultrathin silicon or solid silicon? Leti's SmartCut™ process

In 1991, this situation led to Leti's Michel Bruel proposing a revolutionary process for cutting out and bonding, at the atomic level, ultrathin silicon films oxidized on the surface: the SmartCut™ process. Implemented today by Soitec, which Leti launched in 1992, this process produces very high quality layers of silicon and silicon oxide at controlled thicknesses between a

few nanometers and a few microns, bonded to a silicon wafer.

"Furthermore, SmartCut™ is compatible with standard microelectronics standards, allowing rapid production of very high quality wafers," explains Leti engineer Olivier Faynot. "This is the real starting point for thin-film electronics."

Leti and Thomson joined forces to establish an SOI subsidiary for military applications. Thereafter, from the early 2000s onward, AMD and IBM have produced SOI microprocessors especially for computer, smart phone, tablet and video-game manufacturers, for which the excellent current-leakage characteristics of thin-film transistors provide a favorable trade off between processing speed and energy consumption.

But in the early years of SOI technology, "All that remained highly confidential, most often at the R&D stage conducted at Leti," recalls Leti researcher François Andrieu. It's a fact that this technology was not especially popular in the small world of microelectronics. The specialist recalls that, "Technology bricks were clearly missing." How could one effectively challenge the conventional, solid silicon-based MOS technologies, for which the clean rooms of the founding manufacturers had been designed? "Up to a certain point, there was an insufficient gain in performance for even our traditional partners to take the leap into large-scale production of SOI devices," Faynot admits.

1992

Gamma camera technology transferred to Sopha Medical Vision

1994

Aeronautical pressure sensor technology transferred to Thales

1996

First uncooled infrared bolometer image

Intel's FinFET and Leti's FDSOI revolutions

A bridge was crossed in the mid-2000s, when transistor size decreased to a few tens of nanometers. The specialists started to observe significant current leakage at the transistor grid. The consequence was that the electrical characteristics of these components started to deviate dangerously, making their control increasingly difficult at the industrial level. In simple terms, if compliance with Moore's Law was to continue, the microelectronics universe would need to start a revolution by inventing new transistor architectures.

In 2011, Intel proposed FinFET technology, a true paradigm change in microelectronics. In a traditional transistor, the electrical charges circulate in a planar channel deposited on a wafer; conversely, in a FinFET transistor, this channel comprises a silicon fin a few nanometers thick, surrounded by the transistor grid, thereby immunizing it against leaks. Success was immediate since this type of transistor offered very high performance characteristics in terms of speed. Was there still room for an alternative?

Faynot explains: "With regard to thin-film-electronics performance, improved wafer quality and the ever-better reproducibility of our results, we replied: yes". Moreover, with its 3D architecture, the FinFET is difficult to build, while the "conventional" planar structure of FDSOI makes fabrication easier. Above all, the promoters of FDSOI knew they had a major advantage up their

sleeve, a property that only thin-film transistors have: the so-called "rear face" electrical polarization of the insulating layer beneath the silicon film makes it possible to modulate the processing speed/energy consumption tradeoff as required. This means the circuit's energy consumption can be most finely

**At conferences,
we were told that
we were on the
wrong track!
But we had an insight!**

Olivier Faynot, Leti engineer

adjusted for the operations to be performed.

"This flexibility is clearly the spearhead of FDSOI", notes Andrieu. Still, confronted by Intel's firepower, Leti's microelectronics experts and their partners appeared very much alone in believing in FDSOI's chances. "At conferences, we were told that we were on the wrong track! But we had an insight!" Faynot recalls.

Foundation stones of an industry: from the UTSOI model to the Xiaomi smart watch

It remained to materialize FDSOI physically! Where and how to produce thin films in industrial quantities? Would suitable production performance be achieved? What degree of reliability? In short, there was no other solution than ♦♦♦

1997

First biochip circuit in cooperation with CisBio

2000

Delivery of RMN magnetic resonance magnetometer flight models for CHAMP satellite

Startups on Top!

Fluoptics



Fluobeam® imaging system and fluorescent tracers for guiding surgery integrated into cheap, portable systems.

2009 / A dozen Leti patents and annual cooperation contracts

Illumina



100 cm², 50 gr chip laboratory for analyzing 300 nl and larger droplets and DNA preparation operations for external sequencing stages.

2014 / Common patent applications after acquiring Advanced Liquid Logic

Iprasense



Lensless imagery technology that enhances tenfold the visual field compared with a microscope and video capture solutions for monitoring growth of cell cultures without marking.

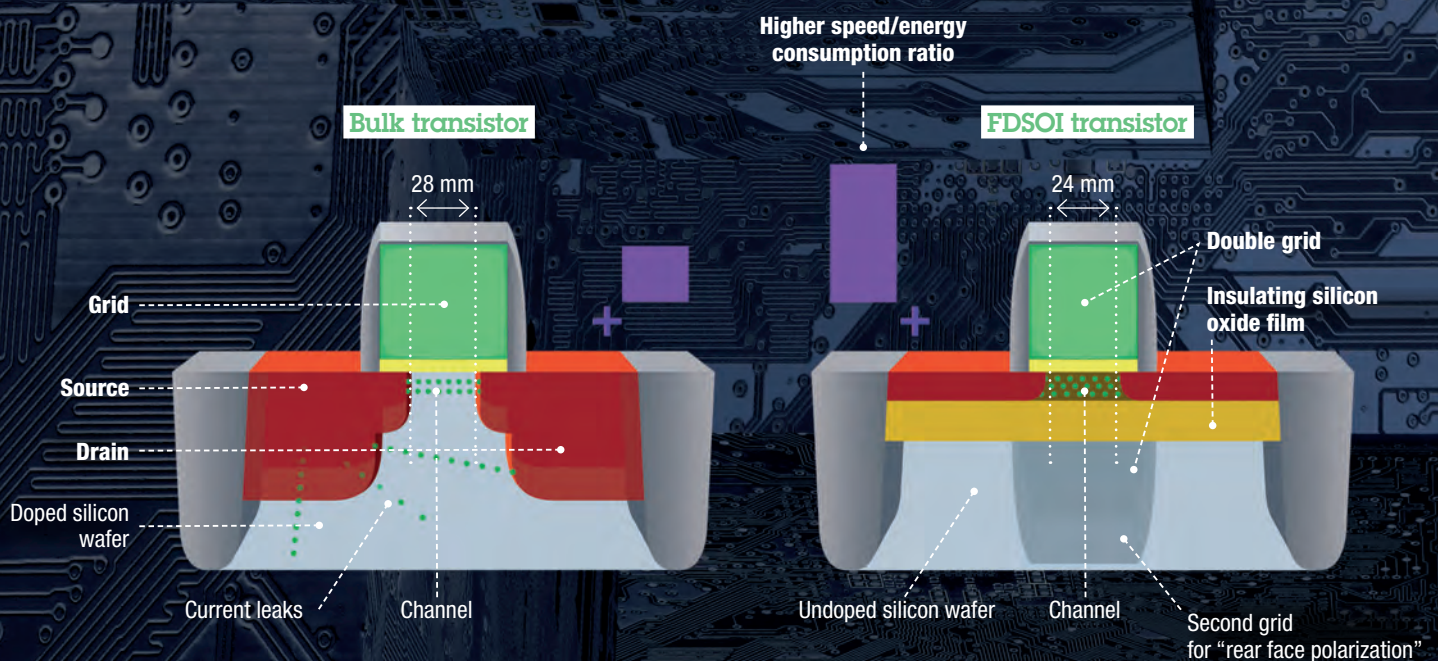
2013 / 10 Leti patents + a common laboratory.

The FDSOI transistor

PRINCIPLE



Leti-designed FDSOI technology is based around adding a film of insulating silicon oxide to conventional transistor architecture. This innovation ensures efficient, energy saving transistor operation, while responding to the challenge of miniaturization.



The quest for the infinitely small

There's a transistor at the heart of every micro-processor. It is composed of three elements supported by a doped, generally solid silicon wafer: the grid (or gate), the source and the sink.

When an electrical voltage is applied to the grid, an electron current flows between the source and the sink via the silicon. Thus, by applying or not applying a voltage, a transistor works like

a switch in an open or closed position, thereby producing the 0 and 1 composing binary data. To increase speed and lower energy consumption of transistors, the microelectronics industry has continually reduced their size down to around 20 nanometers, at which current leaks appear, causing a deterioration in transistor performance.

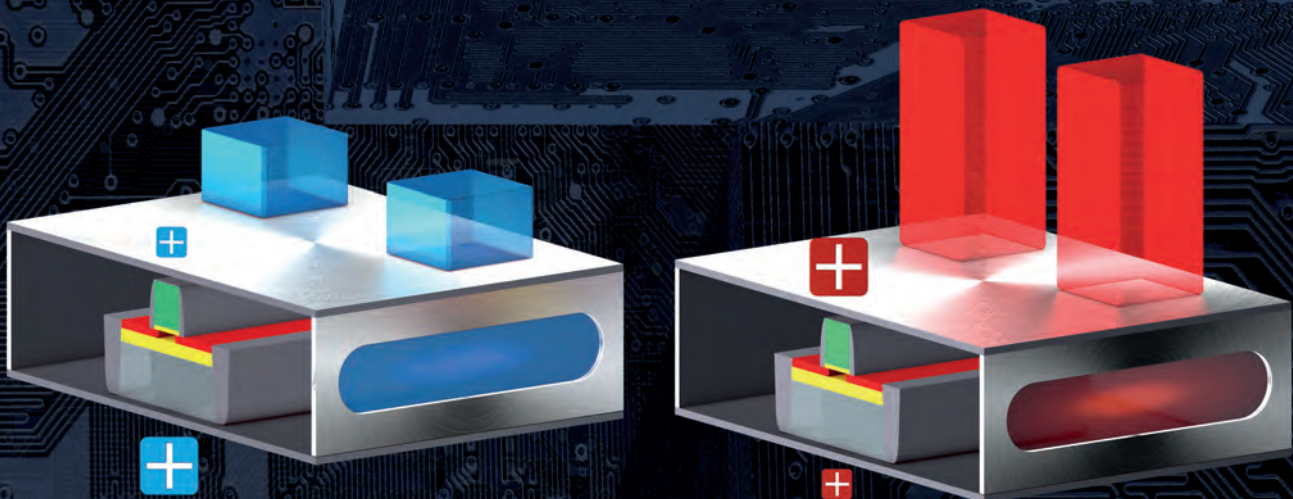
MAJOR ADVANTAGES

- 25% faster than equivalent transistors on solid silicon.
- 30 - 40% less energy consuming than equivalent transistors on solid silicon.
- Operating voltage reduced to 0.4 V and very low power dissipation.
- High reliability with calculation error rate 100 to 100 times less than solid wafer technologies.
- Very low variability of transistors on the same board because the silicon wafer is not doped and is very uniform.
- Competitive because its planar architecture allows production on standard microelectronics tools.

Low consumption

or

Speed



The FDSOI solution

FDSOI technology overcomes current leakage by using a thin film of silicon laid on a thin layer of insulating silicon oxide. Acting as a barrier, the latter insulating layer is deposited on the silicon wafer, which no longer requires doping.

The transistor performance characteristics can be enhanced by applying a voltage to its

rear face: this is called «rear face polarization». The combination of this voltage and the insulating oxide layer then becomes a second grid and, depending on the relative voltages applied to the transistor's front and rear faces, its properties can be altered as desired: the FDSOI transistor can either be very low energy or very fast.



Xiaomi watch integrating FDSOI technology and the FRISBEE circuit.

to build the entire technological and industrial environment for designing and manufacturing FDSOI components on a large scale. Leti and STMicroelectronics worked hand in hand to achieve this. The manufacturer, which wanted to develop its business in the “low-power” direction (low consumption applications such as telephony), decided to convert its 28-nm **node** platform to FDSOI. The goal? Components, whose speed-related performance characteristics can be boosted as required and when necessary (e.g. during a telephone call), but

Node

Characteristic unit node of the transistor grid to appreciate component miniaturizations.

which are also capable of going on standby or sleeping between two peaks of activity.

Ten to 15 Leti engineers were therefore dispatched to ST’s site in Crolles, where 300 employees were developing the platform, supported by 50 more Leti employees in Grenoble. “A technological change like that and the leap into the dark that accompanies it only happen once every ten years or so in the life of a manufacturer,” Andrieu notes. In concrete terms, the Leti and ST teams developed all the components (more than 20) required for producing an FDSOI-based circuit and, in particular, the voltage generators located on the components for ensuring “rear-face polarization”. They redesigned all the logic gates and cells obtained by connecting different transistors, in order to adapt them to a broad operating range. Furthermore, they imagined global control methods for dynamically

arbitrating the circuit operating point and checking that each component meets expectations even at very low electrical voltage.

Among Leti’s achievements: the Leti-UTSOL digital model enabling simulation of component operation for generating the cell library from which circuits and processors are then designed. “This is the most effective model currently available on the market for the STMicroelectronics design environment and, today, for Samsung and its clients”, says Faynot. The FRISBEE circuit was its ultimate development in 2014. FRISBEE is capable of operating at voltages between 400 millivolts and 1.3 volts and at frequencies between 25 megahertz and 2.5 gigahertz. Embedded in an Ericsson smartphone, the circuit ensures five hours additional autonomy compared with competitive products. As Andrieu says, “This telephone was not commercialized in the end, but FRISBEE is important in the history of FDSOI as the industry’s first real product”. Then, in 2016, the Chinese company Xiaomi presented a smart sports watch featuring an embedded Sony GPS chip based on ST’s 28-nm FDSOI technology. Consuming less than 1.5 milliwatts, compared with approximately 10 milliwatts for conventional circuits, the Sony chip offers 25 hours autonomy in GPS mode, i.e. two-to-five times more than comparable products. NXP recently announced the production launch, at Samsung, of its new iMX multimedia application-processor platform based on 28-nm FDSOI technology.

**FRISBEE is important
in the history of FDSOI
as the industry’s first real product**

François Andrieu, Leti engineer

2001

Ideas Laboratory® established

2002

First 200 mm MEMS wafer
(accelerometer for Freescale Semiconductor)

2004

Spintronic technology (CEA/CNRS/UJF)
transferred to startup Crocus Technology

Ever-smaller nodes for ever-larger markets

The markets targeted by FDSOI technology are clearly those embracing mobile electronics: smartphones, tablets... objects for which the energy consumption issue is now crucial. "For these applications, FinFET processors, while performing better strictly from the processing speed standpoint, face serious challenges on the issue of energy consumption," Faynot says. Taking this a step further, FDSOI will probably become required in connected cars, in which processors will be required to combine data processing power with low energy consumption. Another targeted sector is the Internet of Things, an emerging market in which objects will be "conscious" of their environment in relation to exchanging information and performing functions in response to that information. The healthcare market also represents a vast outlet for FDSOI technology. The microelectronics giants were absolutely right: in its 28-nm version, FDSOI is now firmly established in the STMicroelectronics and Samsung catalogues. Yet, this is only a start!

In cooperation with ST, Leti's idea is to develop new functionalities for the 28-nm node: radiofrequency, embedded memory for chips, microcontrollers, etc. "The 28-nm node will have a long service life since it is very cost competitive and will meet the requirements of all the applications of the manufacturer's customers," predicts Andrieu. In parallel, this also involves demonstrating that FDSOI is compatible with transistor miniaturization. Leti, ST and IBM therefore started to focus on the 22-nm node from the end of the 2000s onwards. The outcome was that the technology was transferred to

GLOBALFOUNDRIES, the second-largest foundry company worldwide, in 2016. Leti's Grenoble lab dispatched a dozen personnel to the company's Dresden site to set up the corresponding platform. Moreover, last September, GLOBALFOUNDRIES announced an extension of its FDSOI platform to the 12-nm node. Its level of integration is unmatched. The objective is to produce the first circuits in Dresden in 2019. Is it enough to make FDSOI the new king of microelectronics technology? "It's not a question of overturning FinFET," Andrieu explains. "We're an alternative because even though Intel's technology remains unbeatable for high-performance computing applications, FDSOI is the solution for opti-

It is completely possible that this technology will end up capturing significant market share.

François Andrieu, Leti engineer

mizing the processing speed/energy consumption tradeoff on demand. FDSOI is in the challenger's position with respect to FinFET. But, from the market-development standpoint, it is completely possible that this technology will end up capturing significant market share."

As proof, GLOBALFOUNDRIES has not opted for one technology to the detriment of the other, but now offers both to its customers. In other words, FDSOI now appears to be essential and this is more than a turn of events. It is the long-term outlook! ♦

2007

Alliance with Caltech (California Institute of Technology) on NEMS

2009

3-party alliance with IBM and STMicroelectronics (FDSOI technology)

Startups on Top!

iskn



Solutions for enriching and facilitating interaction of physical objects and the digital world using a learning tablet, for example.

2014 / 11 Leti patents
and multiannual cooperation contract

MirSense



Quantic cascade, solid-state laser technology and unique silicon-based, medium infrared system for rapid, reliable identification of organic molecules.

2015 / Leti patents

Morphosense

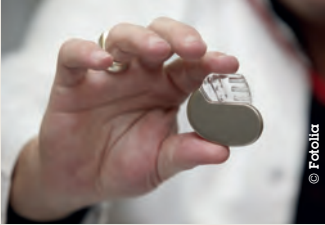


Solution for processing signals and merging data that are transmitted by MEMS sensors to monitor deformations and vibrations in critical systems.

2016 / Leti patents

A little Leti in so many industrial products

Silicon components



Miniature condensers in **IPDiA's** pacemakers or deep cerebral stimulators

Space

Infrared bolometers for the **ESA** Herschel satellite's photoconductor array camera and spectrometer (PACS)



Telecommunications



Technologies for **Radiall's** 5G communication systems and antennas

Cosmetics

Biodegradable nanovectors to encapsulate active ingredients in **Capsum's** Modernist Serum No.4®



Wireless communication with light



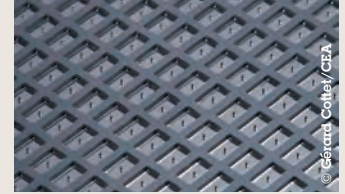
Low-cost, high-speed, LED-based LiFi technology for **Luciom**

Environment

Sensors for **Terradonna's** Cliiink® smart waste recycling containers



Medical



Large-scale production processes for **Debiotech's** 700 micron Debiotech microneedles

Equipment

RFID labels integrated into **Michelin** HGV tires for wear traceability



Microsystems



Movement detection MEMS for **Tronics'** dynamic smartphone and tablet displays

2010

First 3D stacked transistors: Coolcube™

2011

Construction of 240 m long white room link between Leti and Minatoc

2013

First clinical test at Clinatex



Arts-Sciences

Fresque #1, Digital "Aura"

While Larsen effects can hurt our ears, those depicted in Fresque#1 captivate the eye and unleash the imagination to better query the digital data flows that now shape our day-to-day. *by Aude Ganier*



© Antoine Conjard

When a microphone is too near to a loudspeaker, we're subjected to an ear-splitting whistle: the dreaded Larsen effect! Similarly, image pixels go hysterical when a camera is brought close to a screen. Fresque#1 is this type of Larsen effect "video", a visual that Lionel Palun "painted" with the artist's brush of today: networks, real-time computation and data flow. "I intervene between the camera and the screen by playing on the physical characteristics of image acquisition and by adding my own partition in the form of masks, grids and other filters. Above all, I invite the spectator to intrude upon this purely digital relationship by capturing his or her silhouette or face, furtively revealing a digital aura", explains the artist.

Illusion of network ubiquity

Fresque #1 plays out the illusion of ubiquity offered by networks. It gives resonance to two distant geographical and cultural spaces: in November 2017, the work will be

simultaneously exhibited in two public spaces in Japan and France. "These two locations will be interconnected through a Larsen effect video, which reflects ad infinitum the images of personal captures in these distant places. Lionel's visual partition, derived from real-time data, will ensure a sensitive restitution of these places and persons", explains William Guicquero, a Leti researcher involved in producing the work of art. Fresque#1 falls within the H2020 "Festival" research program, which brings together French, European and Japanese partners around coordinator Leti. Festival is dedicated to the Internet of Things and proposes new services capable of exploiting heterogeneous data. To achieve this, the researchers are developing an Internet platform, which makes available data collected in connected urban spaces (in partner cities), experimentation infrastructures and open data. The work is backed by Arts-Sciences, a workshop founded in 2007 by the Ideas Laboratory, a Leti creation, in conjunction with Hexagone Scène Nationale Arts Sciences - Meylan. Once again, Leti has been a pioneer in this area by initiating this first research laboratory common to artists and scientists in France.



© Fresque#1

WWW

Fresque#1 on YouTube
lionelpalun.com
www.festivalproject.eu/
www.atelier-arts-sciences.eu/

2014

First Earth-Moon high-speed laser communication in cooperation with ESA and NASA

2015

First STT-type MRAM in cooperation with Spintec

2016

- Joins Stanford SystemX Alliance
- Internet of Things cooperation agreement with Intel



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