Multifunctional integration including Integrated Photonics and Flexible Electronics in the ECSEL programme

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Intro

Highlight project objectives/results that are related to the topic (chronological order)

- Integrated Photonics: Imaging sensor systems
- Integrated Photonics: Digital lighting solutions with LEDs
- Integrated Photonics: Novel packaging solutions
- Flexible Electronics
- Other relevant projects on sensors and MEMS

Conclusions

Integrated Photonics: Imaging sensor systems

- **EXIST (2014-1) Extended Image Sensing Technologies** CMOS image sensors; new design and technology (e.g. 3D stacking) for better and more pixels at higher speed, time-of-flight pixels, on-chip image processing; also extended sensitivity and functionality of the pixels: extension into infrared, filters for hyper-and multi-spectral imaging, better colour filters, programmable filters with LCD cells
- **ASTONISH (2015-1) Advancing Smart Optical Imaging and Sensing for Health** develops Near Infra Red sensors that will be miniaturized using Si Photo Multiplier technology; Tunable Fabry Perot optical filters will be developed for the acquisition front end of hyperspectral imagers to extend the sensing towards NIR and thermal IR wavelengths; Visible (Si) and NIR/SWIR (InGaAs) 2D sensors will be equipped with micropatterned optical filters, resulting in a hyperspectral snapshot camera sensitive over the full VIS/NIR/SWIR spectral range; Dedicated lenses and illumination designs for spectral imaging in the VIS-NIR-SWIR range
- **DENSE (2015-1) aDverse wEather eNvironmental Sensing system** develops Gated short wave infrared camera with pulsed laser illumination (SWIR camera); Short-wave infrared LIDAR (SWIR Lidar).

Integrated Photonics: Imaging sensor systems

- **VIZTA (2018-1) VIZTA sounds for Vision and Identification Z-sensing Technology and Applications**. The key differentiating 12-inch Silicon sensing technologies developed during VIZTA are: Innovative Single Photon Avalanche Diode and lock-in pixel for Time of Flight architecture sensors; Unprecedent and cost-effective NIR and RGB-Z filters on-chip solutions; complex RGB+Z pixel architectures for multimodal 2D/3D imaging. For short-range sensors : advanced VCSEL sources including wafer-level GaAs optics and associated high speed driver. These developed differentiating technologies allows following highly integrated prototypes demonstrators: High resolution (>77 000 points) time-of-flight ranging sensor module with integrated VCSEL, drivers, filters and optics; Very High resolution (VGA min) depth camera sensor with integrated filters and optics. For Medium and Long range sensing, VIZTA also adresses new LiDAR systems with dedicated sources, optics and sensors.
- **HELIAUS (2018-2) tHErmaL vIsion AUgmented awarenesS** development of a novel chip architecture together with on-chip integrated functions to make the IR sensor as easy to use as visible sensor leading to low cost, high performance Long Wavelength Infra Red module

Integrated Photonics: Digital lighting solutions with LEDs

DELPHI4LED (2015-1) From Measurements to Standardized Multi-Domain Compact Models of LEDs
AI-TWILIGHT (2020-2) AI powered Digital twin for lighting infrastructure in the context of front-end Industry 4.0

Integrated Photonics: Novel packaging solutions

ADMONT (2014-2) Advanced Distributed Pilot Line for More-than-Moore Technologies Integration of OLED on CMOS for micro-sensing and diagnostic systems; smart energy RGB true-colour-sensor smart system; ....
EuroPAT-MASIP (2016-2) European Packaging, Assembly and Test Pilot for Manufacturing of Advanced System-in-Package Enabling sensor/MEMS and optoelectronic integration in fan-out wafer-level packaging technology packaging platform: footprint reduction of existing packaging solution for optoelectronic and imaging devices by 30 %; denser system integration to enable more functionality in less space, demonstrated in imaging array with inside package die-to-die distance below 100 µm (reduced from state-of-the-art 150-200µm).
MICROPRINCE (2016-2) Pilot line for micro-transfer-printing of functional components on wafer level Functional components like processed III/V devices, optical filters, and special sensors are transfer printed to demonstrate the capabilities of the technology and pilot line.

Integrated Photonics: Novel packaging solutions

POSITION-II (2017-1) A pilot line for the next generation of smart catheters and implants packaging and SIP technologies that will allow complex electronic imaging systems to be folded into or wrapped around the millimetre size tips of minimal invasive instruments, will require the best of Europe's technologies in the area's of: TSV's, integrated passives, functionalized SOI substrates, biocompatible coating technologies, die stacking technologies, all brought together on dedicated assembly platforms, and will leverage these technologies also towards non-medical applications.

.**APPLAUSE (2018-1) Advanced packaging for photonics, optics and electronics for low cost manufacturing in Europe** supports this by building on the European expertise in advanced packaging and assembly to develop new tools, methods and processes for high volume mass manufacturing of electrical and optical components to be demonstrated in Industrial Use Cases, related to: 1. Substantially smaller 3D integrated ambient light sensor for mobile and wearable applications 2. High performance, low cost, uncooled thermal IR sensor for automotive and surveillance applications 5. Novel manufacturing platform for optical and other MEMS requiring open access cavities 6. Optical water measurement modules with cost-effective packaging of components.

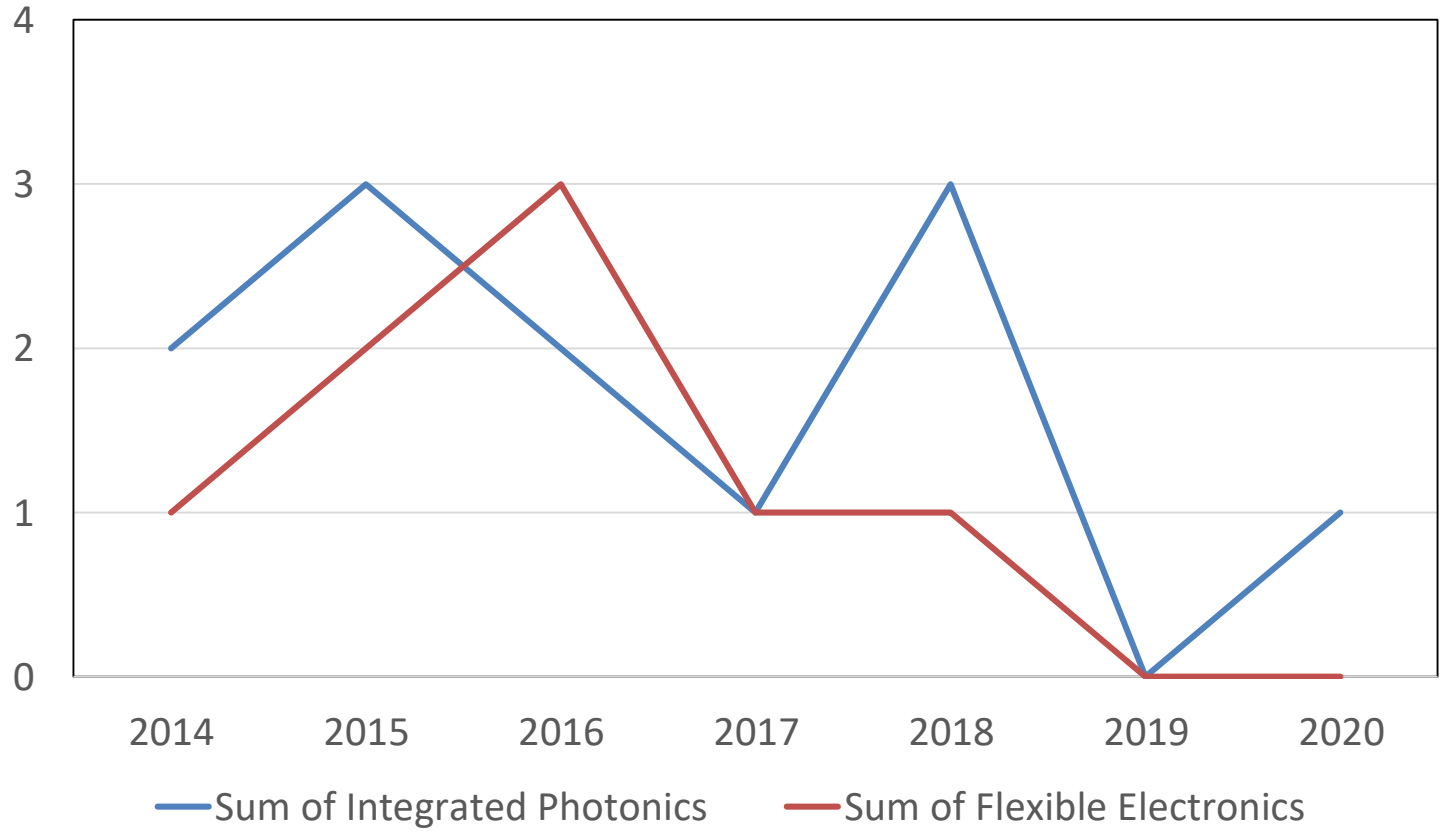
Flexible Electronics

- **ADMONT (2014-2) Advanced Distributed Pilot Line for More-than-Moore Technologies** Integration of Organic - LED on CMOS for micro-sensing and diagnostic systems
- **DELPHI4LED (2015-1) From Measurements to Standardized Multi-Domain Compact Models of LEDs** novel LED fixtures build on flexible substrates
- **EnSO (2015-2) Energy for Smart Objects** Develop and demonstrate high density, low profile, shapeable, long life time, rechargeable micro battery product family
- **SILENSE (2016-1) (Ultra)Sound Interfaces and Low Energy iNtegrated SEnsors** Integration of large 2D array of sub-wavelength ultrasound sources and receivers on flexible foils including drive and readout systems partitioned between foil and CMOS.

Flexible Electronics

- **EuroPAT-MASIP (2016-2) European Packaging, Assembly and Test Pilot for Manufacturing of Advanced System-in-Package** Enabling sensor/MEMS and optoelectronic integration in fan-out wafer-level packaging technology packaging platform; handling thin silicon wafers, chip embedding in reconfigurable wafers and embedding in flexible foil packaging in applications such as mobile, IoT etc., where low package forms and heights are the key parameters
- **MICROPRINCE (2016-2) Pilot line for micro-transfer-printing of functional components on wafer level** µTP for silicon photonics, optical sensors and LEDs and on flexible substrates
- **POSITION-II (2017-1) A pilot line for the next generation of smart catheters and implants** Flex-to-Rigid (F2R) is an interconnect platform designed to bring heterogeneous electronic components together in extremely small form factors and consists of tiny silicon islands of arbitrary shape, connected by extremely thin and flexible interconnects.
- **APPLAUSE (2018-1) Advanced packaging for photonics, optics and electronics for low cost manufacturing in Europe** flexible, stretchable patch for multi-modal measurement for cardiac monitoring; flexible/stretchable substrate handling tools and methods suitable for mass manufacturing; Integration of thin dies on flexible patch; Ultra-thin chips embedded in flexible substrates

Evolution


4
3
2
1
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2014
2015
2016
2017
2018
2019
2020
Sum of Integrated Photonics
Sum of Flexible Electronics

Other relevant projects: sensors, MEMS

3Ccar (2014-1) Integrated Components for Complexity Control in affordable electrified cars developped new semiconductor-based systems, like System-on-Chip (SoC), System-in- Package (SiP), embedded systems and Cyber Physical Systems (CPS) e.g. novel, robust MEMS scanning mirrors suitable for automotive use.

InForMed (2014-2) An integrated pilot line for micro-fabricated medical devices is a pilot line for micro-fabricated medical devices consist of a number different components, all made in specialized technologies, like: CMOS, sensor technologies and micro-fluidics ; using advanced assembly techniques to form truly heterogeneous systems.

IoSense (2015-2) Flexible FE/BE Sensor Pilot Line for the Internet of Everything consists of three pilot lines: (1) FE wafer level pilot manufacturing for integrated sensor technologies, (2) FE wafer level pilot manufacturing for discrete and special material sensor technologies and (3) Assembly and Packaging pilot manufacturing; that are aiming to

- Increase the manufacturing capacity of sensor/MEMS components
  - directly in the involved pilot lines by factor of 10 and
  - indirectly by increased demand at existing sensor manufacturers by a factor of 10 in a long term time frame (10 years+),
- Improve manufacturing cost by highly effective process technologies by 30%,
- Improve manufacturing time by flexible FE/BE processes and easy reuse by 30%,
- Improve time for idea-to-market for new sensor systems down to less than one year.

A typical IoT node consists of sensors (40% cost share), communication and security (23% cost share), power management and control (14% cost share), energy harvesting and storage (10% cost share) and the required integration (13% cost share).

Other relevant projects: sensors, MEMS

CONNECT (2016-1) Innovative smart components, modules and appliances for a truly connected, efficient and secure smart grid. developed Autonomous sensing network for energy consumption monitoring based on energy harvesting ASICs for autonomous current sensors and capillary smart meter integration.

I-MECH (2016-1) Intelligent Motion Control Platform for Smart Mechatronic Systems developed a *smart Instrumentation Layer* gathering visual and/or sensor information from supplementary instrumentation installed on the moving parts of the controlled system to enhance the achievable performance of the system,

SCOTT (2016-2) Secure COnnected Trustable Things focussed on wireless sensor and actuator networks and communication in the areas of mobility, building & home / smart infrastructure as well as health

PRYSTINE (2017-2) Programmable Systems for Intelligence in Automobiles had as one of its obectives: Enhanced reliability and performance, cost and power of FUSION components that provides for:

- 25% less data communication required compared to state-of-the-art
- 30% less false-positive detections compared to separate sensing approach
- Fail operational sensor compound vs. fail silent individual sensing approaches
- Power reduction of 25% through semiconductor material improvements and functional convergence in sensor modules
- Up to 30% cost reduction and 10% margin improvement for perception sub-systems

Other relevant projects: sensors, MEMS

NewControl (2018-2) Integrated, Fail-Operational, Cognitive Perception, Planning and Control Systems for Highly Automated Vehicles had as one of its obectives: Increase the accuracy and robustness of algorithms, E/E architectures for adaptive perception

- Enable FMVW LIDAR technology for automotive, aeronautic and environmental survey
- Demonstrate 2D non-macro mechanical scanning for high reliability
- Demonstrate LIDAR prototypes which enable at high volume production:
  - cost of parts and assembly below 100 €;
  - life time of > 10,000 hours operation without failure
- Increase perception performance by adapting sensor operation to real-time conditions – reduce data rates by 50% through adaptive control of sensor compounds

CHARM (2019-1) Challenging environments tolerant Smart systems for IoT and AI designs and demonstrates new solutions from sensors and packaging to cybersecurity and decision making, enabling the exploitation of embedded technology also in harsh environments. By focusing into the very demanding topic of harsh environments, CHARM helps to develop the know-how and competences of the partners, helping them to strengthen a commanding position in their fields.

Other relevant projects: sensors, MEMS

Moore4Medical (2019-1) Accelerating Innovation in Microfabricated Medical Devices some results: Use biocompatible and soft encapsulated MEMS ultrasound transducers to effectively and safely transfer power in the form of acoustic pressure to implants deep inside the body and selectively stimulate nerves; Development of autonomous smart well plate platforms that are suitable for many organ-on-chip devices and complements them with the necessary infrastructure in terms of sensing, perfusion and powering, all in a standard multi well plate format; Develop a platform that combines state-of-the-art electronics with actuation, sensing and wireless connectivity to administer drugs and provide feedback to caretakers if, when and how the medicines are administered; Use the modern adaptable 2D array MEMS ultrasound transducers in closed loop configuration with AI algorithms to assist in image acquisition and interpretation without the need for a skilled sonographer; Develop a platform that uses state-of-the-art sensors to monitor people during their sleep. Transfer that data to the cloud and develop advanced algorithms based on AI to detect anomalies.

ADACORSA (2019-2) Airborne data collection on resilient system architectures develops: Functionally safe sensors for sense-and-avoid (Radar, LiDAR, Time of Flight - ToF) for drones in VLL airspace, with low weight, size, power and cost. Flight demonstrations that include automated takeoff and landing, risk mitigation, and navigation

NextPerception (2019-2) NextPerception - Next generation smart perception sensors and distributed intelligence for proactive human monitoring in health, wellbeing, and automotive systems provide novel remote sensing technologies to distinguish people, capture their behaviour and observe their physiological parameters. State of the art radar, LiDAR and time of flight cameras will be enhanced with new features to enable new applications and capabilities beyond their current ones. Complementary sensors will solve major challenges;

Progressus (2019-2) Highly efficient and trustworthy components and systems for the next generation energy supply infrastructure has as one objective: to enhance sensing technologies and methodologies

Conclusions

- Integrated Photonics
  - 13% of the ECSEL projects have a “Integrated Photonics” component
  - three topics: imaging sensor systems, Digital lighting solutions with LEDs, Novel packaging solutions
  - geared towards Internet of Things, Cyber Physical Systems, autonomous driving, Medical Technology
  - projects tackle components to include them in systems
- Flexible Electronics
  - 9% of the projects have an “Flexible electronics” component
  - some overlap with previous
  - mostly flexible substrates and packaging for MEMS and optoelectronic devices integrated with other electronics
- Other projects
  - tackle challenges related to sensors in particular environment for particular purposes