Advanced Packaging Techniques as enablers for the Health IoT ecosystem

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Presented January 25, 2016 to the SCV-CPMT Chapter
- IoT -> Health IoT
- Devices, Services, Specifics to Health
- Main challenges @ device level
- Packaging Technology Solutions
- Examples
- Outlook
Internet of Things

- Coined already in 1999, driven by the advent of electronic ID of devices
- Network enabled connection of objects („things“) with a multitude of other objects
- Allowing for multi-domain data transfer, interpretation and interfacing to both other objects and humans
- Autonomous (re)action of IoT objects based on connected information
- Paradigm Change from passive „Send/Receive“ towards active „Query/React“
- Needs: Unique ID, safe and secure data provisioning, trusted peer environment, hierarchy independent functions, regardless of protocol, domain and application
While originally, the IoT addresses physical objects exchanging information with each other and CPS offers real-world interaction of such IoT subsystems, today’s notion of IoT encompasses as a “network of networks“ with non-discriminatory data exchange and real-world interaction.

Smart Home Control with Grid Level Communication

Car2Car sensor communication and weather forecast

„cloud assisted gardening“ (MIT)
Health IoT

- IoT dedicated to health and well being
- „Wearables“ as catalyst but wearables are NOT the Health IoT!
- Connecting medical grade diagnostics devices capturing individual’s data …
- …merging with patient and population history data
- …merging with non-health meta-information (ambient data, smart home data, flu outbreak map, … )
- … building a patient individualized (and monitored!) therapy schedule
- … retrieving outcome information for further routine improvement
- … using data retrieval and interpretation tools to extract invisible information
Who talks to whom?

- Family
- Patient
- Doctor
- Clinics
- Caregivers
- Personal Devices
- Medical Care Devices
- Infrastructure Embedded Devices
- Research Databases
- Reimbursement Systems
- National Security Databases
Patient Expectations

Device -> Patient -> „all well with me?“
Device -> Doctor - > „all well with the patient?“
Device -> Family -> „Guys, I am well!“
Device -> Assisting Ambient -> „I need a stress redux“

Unobtrusive
Non stigmatizing
24/7 availability
Service and support
Doctor Expectations

Device -> Doctor

Pre-Evaluation System (PES) -> Doctor

Doctor -> Clinical Documentation System

Device and PES -> Reimbursement Documents

Doctor -> Patient

Device / Doctor -> Electronic Health Record (EHR)

NO ADDITIONAL WORKLOAD

Monitoring on Request
Info on Triggers
Assistance on Documentation
Hospital Expectations

Streamlined Processes

Happy Doctors

Cured Patients

No queuing, less stress to all

Device -> PES

Device -> Reimbursement Doc

Doctor/Device -> Clinical Documentation System + EHR

Device -> Scheduling and preventive action triggering

....
Reimbursers Perspective

Lower Cost
Lower Cost
Lower Cost

Preventive Care
Lifestyle adjustments
Tariff adaption

Device -> Data Mining System and Individualized Assessment
What kind of devices are we talking of...

- Augmented state of the art
  - Holter ECG
  - BIA Body Impedance Analysis
  - Handheld Glucose Meter
  - SpO2
  - Quick, Triply, HCO
  - Medication Bottles
  - Rehab/Training Devices
  - Blood Pressure Monitor BPM

- New devices
  - Connected Medication Blisters
  - „Wearables“
  - „Earables“
  - Body worn spirometry
  - Gait Monitors

- Augmented SoA
  - Blood Testing Lab
  - Clinical Monitoring Devices
  - Bed Side Therapeutic Systems (CPAP, Drug Dosing, O2, ..)
  - Implants

- Future devices
  - Glucose Monitoring Lens („Google Lens“)
  - Eye Pressure Contact Lens or IOL
  - Implanted Drug Dosing Chip

- New devices
  - PoCD
  - Vein Mapping
  - Medication Monitors
  - Insuline Patch Pump
  - ...

- Augmented SoA
  - Blood Testing Lab
  - Clinical Monitoring Devices
  - Bed Side Therapeutic Systems (CPAP, Drug Dosing, O2, ..)
  - Implants

- Future devices
  - Temporary Implants
  - Enhancer Implants
  - Electronic Dosing Patches
Infrastructure Embedded Devices

- Oxygenators
- CT/MRI/SPECT/PES
- Fixed Assets
- Home Appliances
- Ambient Assisted Living Elements
- ...

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While in a „connected world“, IoT, likely 90+% of the devices will not have a dramatic impact if data failure/manipulation occurs, Health IoT MUST adopt right from the beginning safety/security concepts.

Safety/Security mandated by legislation and prerequisite for customer/patient acceptance

- Medical Devices governed by respective legislation
- Personal Devices still in a „gray area“

Data ownership is also a crucial aspect

- Medical Device Data in debate!
- Personal Device Data in debate!

OPEN but SAFE and SECURE Data concepts are will be a tipping aspect for a Health IoT success
Health IoT - Connectivity

- Devices will have –dependent on their use cases- different kinds of connectivity options (BAN, PAN, LAN, WAN), protocols and safety requirements

- Connectivity may result in a local, „fog“ or „cloud“ data processing and (re-)action, depending on preset, pre-learned or derived triggers

- „IFTTT“ approach with a human programmed connection cannot cope with the world of tomorrow…

  Elderly has measured previously low blood glucose,
  has not taken her medication,
  home indicates non-moving presence in living room
  ->
  Monitoring call,
  emergency call,
  unlock door upon arrival,
  flash ceiling light for presence indication
Health IoT Needs and Deeds

While Health IoT is from a ecosystem and IT point of view still in its infancy, the necessary hardware technology is not

- Sensors ✓
- Safety/Security Features ✓
- Calculating Power ✓
- Dynamically Configurable Memory (Hacking) ✓
- Connectivity ✓
- Energy Supply ✓
Good job.....

... but advanced packaging can do better!
Packaging Technologies for Personal Devices in an Health IoT EcoSystem are driven by the need to

- Smaller form factor
- Higher Integration
- Modularity
- Co-Design of Function, Component Packaging, System Packaging and User/Application-Centric Design
- Longer Battery Stamina
- Re-Configurable Wireless
- Re-Configurable Memory

- High Density Packaging
- Minimum Material Usage/Waste
- Modular Assembly Concepts
- Modular Design, Hardware Submodules, „Building Blocks“
- Integrated Batteries/Charging Concepts
- Novel Antenna Concepts, UWB circuits
- Nonvolatile low power memory modules
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- Ubiquitous Deployability
- Resource Efficiency
- Improved Fabrication and Cost
- Adaptability to use case
- Maintenance/Usability
- Adaptability to infrastructure
- Adaptability to required tasks
System in Package may drive the way…

… and both wafer and backend will contribute!
Application Specific Modularity

- Choose your sensors
- Choose your µC
- Choose your Crypto
- Choose your energy scenario
- Choose your wireless

*Proper SiP strategy allows for lot size 1…millions*
Application Specific Modularity

- Choose your sensors
- Choose your µC
- Choose your Crypto
- Choose your energy scenario
- Choose your wireless

Proper SiP strategy allows for low cost at high functionality, small form factor and optimal modularity
Packaging Options on the way towards ubiquitous IoT

- Mold Array Package
- Package in Package
- Package on Package
- Fan Out Wafer Level Package
- Panel Level Package

- Stacked Chips w/ Wirebond
- Stacked Chips with TSV and μ-Bumps
- Stacked Chips via Chip First Technology
Package Thickness & Technology Trends

- Memory Down Tablets/Ultrabooks
- Ultra Thin core
- Coreless
- POP Memory Phones/Tablets
- Thinner Die Thinner Core
- Thinner Die Coreless
- Thinner Die Embedded Coreless

Source: Intel
Chip Embedding – Production Format Comparison

Manufacturing on leadframes

- Leadframe technology
- Established process
- Many process options
- Cost optimised

~ 155 cm²

Fan-out wafer-level package

- Thin film technology
- Fast production ramp-up
- Today high I/O chips
- 3D under development

~ 730 cm²

Chip embedding in substrates

- PCB technology
- Begin of production
- Today low I/O chips
- Intrinsic 3D and power capability

~ 2790 cm²
FanOut Wafer Level Packaging: FO-WLP

- Single function device packaging at small footprint with PCB compatible I/O pitch
- Multi function device combination at smallest footprint with intrapackage interconnect and PCB compatible external I/O pitch
- Reconfiguring of wafer sized platform (mechanical and/or electrical)
- Overmolding
- w/ w/o balling
- Dicing
### FoWLP Process Flow Options

#### Mold first
- Apply thermal release tape on carrier
- Die assembly on carrier
- Wafer overmolding
- Carrier release
- RDL (e.g. thin film, PCB based, …), balling, singulation

#### RDL first
- Apply release layer on carrier
- RDL (e.g. thin film, PCB based, …)
- Die assembly on carrier
- Wafer overmolding
- Carrier release, balling, singulation
Panel Level Packaging: PLP

Panel-Size FO WLP

- Large-area molding 18" x 24"
- Through mold vias for 3D
- Interconnects using PCB materials & technology
- Mold embedding of sensors

PCB Embedding - ECPLP

- Use of new polymers / laminates
  - Thin layers (10 µm) for high density
  - High breakthrough (>40 kV/mm) for power
- Improved resolution for interconnects
  10 µm ➞ 5 µm ➞ 2 µm
- Processes to reduce warpage
FO-PLP Process Flow Options => identical for FO WLP but much larger sie!

**Mold first**
- Apply thermal release tape on carrier
- Die assembly on carrier
- Wafer/panel overmolding
- Carrier release
- RDL (e.g. thin film, PCB based, …), balling, singulation

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Pressure Sensor-ASIC Package
Embedded Component Panel Level Packaging (EC-PLP)

ECP Process

Component
Pre-process

Laser Drilling
of fiducials + overlay

Dielectric Printing

Assembly

Component

Layup & Pressing

Laser Drilling

Mechanical Drilling

Desmearing

Metallization

Imaging

Copper plating

Stripping + Etching

Automatic Inspection

Onward Processing
Organic Substrate

courtesy AT&S

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EC-PLP: Active and Passive Components

Embedding (Modular Micro Camera)

Bare Die and Packaged Components can be used

Electronic and Thermal Design

Reliability Co-Design

Very complex systems can be realized in EC-PLP technology

(13 active components from 8 different manufacturers)
MoMiCa – Modular Micro Camera

Modular camera with integrated 32 bit image processor and memory
Antenna

Patch Antenna on medium resistivity silicon / Wafer Level Processing

Gain_{\text{max}} = -4 \text{ dBi}
Antennas

Antennas on FOWLP SiP Packages

- Make components from substrate metal layers and dielectrics
- Electrical characteristics of embedded passives are strongly dependent on parasitic elements
- Parameterized RF models are needed to reduce design cycle
IoT, especially Health IoT has from an IT point of view still a lot of challenges to be addressed evolutionary.

Hardware concepts become ready to fulfil the needs for Health IoT with respect to modularity, ubiquity, cost and reliability aspects.

Co-Evolution of IC and Package with consideration of IoT aspects in mind right from the beginning set the path for our next generation digital world.

Don’t expect monolithic silicon to fix IoT needs.
Expect large area packaging to do the job 😊
IoT, especially Healt IoT has the potential to revolutionize the medicine, the hospitals and the kind of relationship between physician and patient as well as nurse and patient.

Better knowledge, eliminating time-consuming routine, prevention of waste, increasing the efficiency of processes (after analyzation)

But the technology should not be used to speed up the processes for the personal. We should use it to have more time for the interpersonal relationships.

Healthfulness is a holistic approach and the smart little electronic helpers could be a contribution but not more.
Program Overview

1st day  Technical Tours, e.g. guided IFA-Tour, Get Together
2nd day  Opening, Keynotes, Sessions, Evening Reception
3rd day  Speed Networking, Sessions, Provoquium, Workshops
4th day  Sessions, Panel Discussion, Closing Session

Location  Dahlem Cube / Seminaris CampusHotel, Berlin
Chairman  Prof. Dr. Klaus-Dieter Lang
Schedule  Call for Contributions (Deadline 15th Feb 2016)
Website  www.electronicsgoesgreen.org

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