IR AND MEMS SENSORS

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Outline

• History
  • From niche to mainstream

• New enabling technologies

• Examples of today's sensors
  • Mix of old and new technologies

• Future needs
  • More of the same, or new trends? Some perspectives for the future
SOME HISTORY

Where did we start?
Niche applications

• R&D in silicon sensors since 1961
  • The IC-development would become too low cost...
  • Piezoresistive based beams/membranes
  • Radiation sensors for high-end products

• Low and medium volume production since 1979
  • IR-emitter and pressure sensors among first MEMS products
  • Market primarily driven by the oil and gas industry

\[ P. \ Ohlickers \ and \ H. \ Jakobsen, \ Microelectronics \ Journal, \ vol. \ 29, \ pp. \ 587-600, \ Sep \ 1998. \]

\[ S. \ Moe \ et \ al., \ S&A \ 2000 \]

IR-emitter, for detection of hydrocarbons and CO₂
Automotive, aerospace, space

- 1965 AME founded
  - 1972 Accelerometer AE864, military application
  - 1980 AE880 Pressure sensor
- 1985 SensoNor spun off
  - 1992 SA20 Low cost accelerometer
  - 1998 SP13 Tire pressure sensor
  - 2003-2009 Infineon, TPMS
  - Now: STIM300 etc...
- 2002 Memscap acquired Capto, from SensoNor (SP82...)
Design modifications introducing DRIE
Wellbeing and health

• A selective gas sensor for CO$_2$ detection based on a pulsed IR-emitter and a miniature photoacoustic gas sensor
  • Gas filled cavity, temperature increase for absorbed light, change in amplitude measured

• Memscap, blood pressure measurements
  • Simple design, originally from 1965
  • Redesigned for lower cost manufacturing

O. Schulz et al., Eurosensors XIX 2005


Ingelin Clausen et al., JMM 2012
Shrunk to a minimum

- Pressure sensor for bladder examination
- Can avoid life-threatening situations after spinal injuries
- Clinical trials

http://geminiresearchnews.com/2014/04/lifesaving-sensor-for-full-bladders/
ENABLING TECHNOLOGIES

Solutions enabling steps closer to more widespread applications
MOEMS, optics and MEMS united

- Diffractive optical elements
- Tunable Fabry Perot structures
- Mirrors

Thor Bakke and Ib-Rune Johansen, Optical MEMS and Nanophotonics conference 2012
Industrial applications, light diffraction

Titech Visionsort

- Waste sorting

GasSecure, a Dräger company

- Detect hydrocarbons

www.gassecure.com

www.sintef.com
Piezoelectric material, PZT

- Innovative designs
- High volume manufacturing
  - Process integration
- Reliable performance in daily environment
Aotofocus lens

• SINTEF patent from 2006
• poLight is one of the pioneers in high volume piezoMEMS fabrication
  • High speed and ultra low power

http://polight.com/technology/how-does-it-work/
Micropumps

• For microfluid system activities

Tofteberg, Hannah Rosquist; Bakke, Thor; Vogl, Andreas; Mielnik, Michal Marek; Østbø, Niels Peter.
Micropump with active valves based on thin film PZT. piezoMEMS 2014; 2014-10-28 - 2014-10-29
Microphones, a good one – and many

• Trend: Request for very high signal-to-noise ratio
  • Challenge of arrays: Need matched sensitivity and phase
    • Arrays for noise cancellation/directionality
    • But also for gesture detection and as gyros, and ...?
  • Vesper: Piezoelectric (AlN) rather than capacitive, SNR 68 dB

• Readout based on infrared optical technology
  • SNR 80 dB demonstrated
  • The sensor "sees" the sound
    • SINTEF, Norsonic, Norsk Elektrooptikk, Cisco, Forskningsrådet


Cost reductions through polymers

- Not hermetic
- Not strong
- Not stable
- Even harmful.....

- But **LOW COST**
- And flexible, formable, ...
Valves, silicon integrated in polymer

- Direct integration of fluidic MEMS in polymer
- By injection molding
Assembly of sensors to flex

• Hybrid integration, roll-to-roll
  • Smart tags with sensors, display, NFC, ... food control, medicines
  • Similar challenges for assembly and interconnects

http://thinfilm.no/technology-printed-electronics/
THOUGHTS ABOUT THE FUTURE

Which niche device will be the next consumer product and which enabling process will bring us further?
Megatrends

• Assist ill/elderly at home

1980s: Demonstrated
Now: Level 2, feet off
2025: Level 3, hands off
2030: Level 4, eyes off

• Autonomous cars

"Scientifically automated amoral cars will be much safer than the average drunk/tired/old/inexperienced/text messaging driver. Pick your choice."

Yole, October 2016

Spectroscopy, a candidate for upscaling

• Analysis of
  • The air we breath in
    • and breath out
  • The food we eat
    • Allergens
    • Quality and readiness
    • Toxicity
  • The ground we walk or drive on

SINTEF Foto: Geir Mogen
Mirrors/filters, cost reductions ongoing

- Reflect or remove light
  - Tunable and low cost in combination with MEMS
  - Photonic crystals for "super" mirrors
- Pico-projectors
  - For sharing phone experience

http://www.ericpickersgill.com/removed

http://www.lab4mems2.ite.waw.pl/overview.html
Pressure sensors, tactic sensors

• Improved granularity of GPS in height
  • From avionics (height detection) to elderly (fall detection)

• Feedback to robots
  • From industry robots to service robots
Enabling, but diverged, processes

- Magnetic layers
- Piezoelectric layers
- Hydrogel layers
- Nanoparticle layers
- Graphene/CNTs

An ecosystem needed

- Design (institutes/universities)
- Control of wafer compatibility
- Secure shipping/processing of wafers
- High throughput @ high quality
- Or - the winner takes it all?
  - Apple, Alphabet/Google, Qualcomm/NXP, AMS, TSMC?
The gap between 1980s and 2030?

- Manufacturability and cost
  - Robustness of design and in production
- Computing power
- Reliability

http://www.formtrends.com/driver-less-car-design-sleepwalking-into-the-future
Packaged in polymers, sensors merged

- How to reduce cost by hybrid integration, computing at the EDGE
- MEMS in Fan-out wafer level packaging (Keep Out Zones)

Incoming probed wafer w/ KGD; Wafer diameter independent; Wafer material independent.

WLFO – RECONSTITUTION on mold carrier; Compression molding on mold carrier; Recon panel ready for REDISTRIBUTION.
Small energies for small things

• Energy harvesting is the most elegant

• But - batteries are still used
  • Utilized so efficiently that they last the lifetime of the devices
    • Even for years of operation
  • Can be printed and be environmentally friendly
    • Products that only need to last some months

• Batteries in large wireless sensor networks
  • A perfect challenge for mathematical optimization
Summary

- Development has been, and is (?), from niche to consumer markets
- New enabling technologies keep coming and move us further
  - Integration becomes more challenging
  - Reliability gets less predictable
- Polymers solve cost issues, but adds reliability issues
  - Merging of sensors will come
  - Energy consumption can be made smarter
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Technology for a better society