Yole Développement

From Technologies to Market
FIELDS OF EXPERTISE

Yole Développement’s 45 analysts operate in the following areas:

- RF
- Photonics
- MedTech
- Semiconductor manufacturing
- Advanced Packaging
- Batteries / Energy Management
- Power Electronics
- LED
- Compound Semi.
- MEMS & Sensors
- Imaging
4 BUSINESS MODELS

○ **Consulting and Analysis**
  - Market data & research, marketing analysis
  - Technology analysis
  - Strategy consulting
  - Reverse engineering & costing
  - Patent analysis

○ **Financial services**
  - Due diligence
  - Innovation financing
  - Maturation of companies
  - IP portfolio management & optimization

○ **Reports**
  - Market & Technology reports
  - Patent Investigation and patent infringement risk analysis
  - Teardowns & Reverse Costing Analysis
  - Cost Simulation Tool

○ **Media**
  - i-Micronews.com website
  - @Micronews e-newsletter
  - Communication & webcast services
  - Events

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www.bmorpho.com

www.i-Micronews.com/reports

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A GROUP OF COMPANIES

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Innovation financing
www.bmorpho.com

Manufacturing costs analysis
Teardown and reverse engineering
Cost simulation tools
www.systemplus.fr

IP analysis
Patent assessment
www.knowmade.fr
OUR GLOBAL ACTIVITY

40% of our business

30% of our business

30% of our business

Yole Korea

Yole Japan

Yole Inc.

BLUMORPHO
Paris

SYSTEMPLUS
Nantes

KnowMade
Nice

HQ in Lyon
SERVING THE ENTIRE SUPPLY CHAIN

Our analysts provide market analysis, technology evaluation, and business plan along the entire supply chain.

Integrators and end-users

Device makers

Suppliers: material, equipment, OSAT, foundries...

Financial investors, R&D centers

- Integrators and end-users
- Device makers
- Suppliers: material, equipment, OSAT, foundries...
- Financial investors, R&D centers
We are working across multiples industries to understand the impact of More-than-Moore technologies from device to system.

SERVING MULTIPLE INDUSTRIAL FIELDS

From A to Z...

- Transportation makers
- Mobile phone and consumer electronics
- Energy
- Automotive
- Medical systems
- Industrial and defense
Wearable applications and technology trends
MEMS & SENSORS ROADMAP

From More than Moore towards Beyond Law

MEMS & Sensors enable key functionalities ...

Current battleground of the industry

Industry competition

Moore

Processing

Information age

1980

IBM

Personal Computers

2010

Google

Linux

Laptop

2030

BOSCH

Sensing

Interaction age

Autonomous vehicles

2040

Robotic Servants

Actuating

Enhancement age

Telekinesis

Drones

Quantified self

Smart homes

Enhancement age

Acceleration
Where is the next growth relay?

...We are still strongly relying on the smartphone wave...

WILL IOT BE THE NEXT SEMICONDUCTOR WAVE?

Source: WSTS, Cisco, Gartner, Yole
MEMS is a semiconductor technology thus enabling miniaturization and lower cost manufacturing of existing products.

2016, gas sensors as the next MEMS success (?)
MEMS, SENSORS & ACTUATORS

**SENSORS**
- Movement
  - Accelerometers
  - Gyroscopes
  - Magnetometers
- Pressure
  - Sound (microphone)
- Environment
  - Gas
  - Humidity
  - Particles
  - Temperature
  - Micro bolometers
  - PIR & thermopiles
  - Ambient light sensor
  - Vision
  - Fingerprint
- Optical sensors
  - FLIR Lepton One
  - InvenSense MPU9250
  - STM pressure sensor
  - Infineon microphone
  - Bosch BME680

**ACTUATORS**
- Optical MEMS
  - Texas Instruments DEP
- Microfluidics
  - Debiotech micro pump
- RF
  - Avago FBAR Filter
- Micro structures
  - Spiromax Patek Philippe
  - Audio Pixels MEMS based speaker

**“open” package environmental combos**
- “closed” package 6 to 11 DOF combos

**Notes:**
- MUs (6 to 9 DOF)
- IMUs (6 to 9 DOF)
- 6 to 11 DOF combos

**Components:**
- Ambient light sensor
- Fingerprint Vision
- Optical combos
- “open” package
- “closed” package

**Manufacturers:**
- FLIR
- InvenSense
- STM
- Infineon
- Bosch
- Texas Instruments
- Debiotech
- Avago
- Spiromax
- Patek Philippe
- Audio Pixels

@2016 | www.yole.fr | EPIC Workshop | Cambridge 2016
Many MEMS devices sensors are in the growth phase, and even more are emerging. Many growing MEMS and sensors could benefit to wearable...
MEMS & SENSORS TRANSITIONING TOWARDS 3 MAIN HUBS…

**INERTIAL**
- Accelerometer
- Gyroscope
- Magnetometer
- IMU (Inertial Measurement Unit)
- 6 DOF (Degrees of Freedom)
- 9 DOF

**ENVIRONMENTAL**
- Gas / Particle
- Pressure
- Temp/Humidity
- Microphone

**OPTICAL**
- Visible
- Proximity/ambient
- 3D
- 3D vision
- Multi spectral

Closed Package Hub

Open Cavity Hub

Optical Hub

Six key attributes that make a big difference

Hands-Free

Ecosystem/Development Platform

3rd party apps
API partners
Accessories

Low Power consumption
Instant wake
Background working/sensing

Always-On

Attention-Getting

Voice/Gesture recognition

Less distracting with notifications
Short interaction
Invisible - useful data

Connected

Environmental sensor

Wi-Fi
Cellular
Bluetooth
NFC

Environment-Aware

Source: MIT, KPCB

Accelerometer
Gyroscope
IMU
Compass
Camera
Microphone
Environmental sensor

@2016 | www.yole.fr | EPIC Workshop | Cambridge 2016
### Applications, Systems and Sensors

#### Market
- **Consumer**
  - Infotainment
  - Wellness
  - Life style
  - Home automation
  - Gaming
- **Healthcare/Medical**
  - Comfort
  - Safety
  - Patient monitoring
  - Activity monitoring
  - Disease Prevention
- **Industry/Defense**
  - Worker Safety
  - Worker productivity
  - Activity monitoring
  - Soldier efficiency
  - Soldier monitoring

#### Use Case
- **Consumer**
  - Precise time
  - Mobile payment
  - Assisted walking
  - Activity monitoring
  - Intelligent personal assistant
- **Healthcare/Medical**
  - Glucose monitoring for diabetes
  - Amplify surrounding signals for disabled
  - Heart monitoring
- **Industry/Defense**
  - Augmented reality to improve productivity
  - Environment monitoring for firefighters
  - New vision for training
  - Hands-free patient care

#### Systems
- **Consumer**
  - Smart glasses
  - Smart watch
  - Fitness band
  - VR headset
  - Smart clothing
- **Healthcare/Medical**
  - Hearing aids
  - Blood pressure
  - Pulse oximeter
  - Glucose monitoring
  - Fall detection
  - ECG monitor
  - Posture monitoring
- **Industry/Defense**
  - Smart glasses
  - VR headset
  - Smart clothing
  - Hand-worn terminal

#### Sensors
- **Consumer**
  - Accelerometer
  - Gyroscope
  - Magnetometer
  - IMU
  - Photodetector (HRM)
  - Environmental (Temp, Hum, Gas, Pressure)
  - Microphone
  - NFC
- **Healthcare/Medical**
  - Accelerometer
  - Pressure
  - Photodetector
  - Biochemical
  - (sweat, galvanic skin, EEG, ECG,…)
  - Microphone
- **Industry/Defense**
  - Accelerometer
  - Gyroscope
  - Magnetometer
  - Pressure
  - Environmental
  - Biochemical
  - (sweat, galvanic skin, EEG, ECG,…)
  - Microphone

**Wearables open clear opportunities for providers of MEMS and other sensor devices**
MARKET DRIVEN BY 4 TYPE OF SYSTEMS

In this report, we cover 4 categories of wearable systems involved in the 3 markets described previously, consumer, healthcare and industry/defense markets. These 4 systems have been forecasted for the next 5 years, including sensors that are integrated.
MARKET SEGMENTATION

3 SEGMENTS, SHARED SENSORS…

Consumer is a high volume market at low price, whereas industrial and defense is a low volume market at high price – for now, although the landscape could change rapidly.
To be successful, investments are needed in technology but also in marketing, but above all, the use case is the enabler.
CHALLENGES FOR THE WEARABLE MARKET

Wearables have specific technical requirements

Some requirements are relevant to sensors

4 Requirements

Accuracy
- Reliable data
- Low noise

Ultra Low Power
- Low power consumption

Useful insights / Sensor fusion
- Multiple parameters
- Non-invasive sensing

Sensors’ Packaging
- Small size, almost invisible
- Reliable and low cost

No specific challenge! No technological breakthrough
Two markets are mature to perform well.

DRIVERS FOR MOBILE CARE APPLICATIONS

- Level of integration
- Time

- Wearable and Mobile Care
- Everywhere Care
- Point of Care
- Hospital Care
- Smartphone & Tablet revolution
- Feature Phones
GLOBAL MINIATURIZATION ROADMAP

Wearable for an improvement of the quality of life

- **Anywhere, Anytime monitoring**

- **Home Care**
  - Point of care

- **Mobility**
  - Hospital and Lab Care
  - Portable
    - IVD
    - Point of care
    - Infusion and drug delivery
    - Respiratory monitoring
  - Benchtop
    - Anesthesia
    - Ventilators
    - Medical monitoring

- **Quality of Life**
  - Wearable
    - Glucose monitoring
    - Kidney dialysis
    - Theranostics
    - Activity monitoring
    - Patient monitoring
    - Smart pills

- **Anywhere Care**
  - Medical requirements
    - Only for chronic diseases and for medical safety reasons
  - Implantable
    - Pacemakers
    - Neurostimulators
    - ECG
    - Cochlear implants

@2015 | www.yole.fr | Wearable Electronics | November 2016
WEARABLE FOR HEALTHCARE: PART OF INTERNET OF THINGS HYPE

The human starts to be a connected object

<table>
<thead>
<tr>
<th>Sense</th>
<th>Collect and transmit (&amp; store)</th>
<th>Analyze + Services</th>
</tr>
</thead>
</table>

- Devices
- Applications
- Measurements

- Biometrics
- Medical Data

- IBM Watson

Video conference, Email, SMS, Mail, Phone

Feedback
Many sensors are already used in their specific application.

- Accelerometers
- Barometer
- Electrochemical biosensor
- Flow sensors
- Gyrosopes
- Humidity sensors
- IR Temperature Sensors
- Magnetometer
- Microfluidic chip

- Microphones
- Photodetectors
- Pressure sensors
- Proximity IR sensors
- RF MEMS
- RFID
- Strain sensors

SENSORS FOR THE WEARABLE MARKET

New sensors are coming?
COMPONENTS OF WEARABLES

- Sensors
  - Inertial
  - Biosensors
  - Environmental
  - Microphone
  - Others (Haptics…)

- Connectivity
  - Bluetooth
  - Wi-Fi
  - GPS

- Battery
  - Button Cell
  - Battery Li-Ion
  - Flexible
  - Energy Harvesting

- Interfaces
  - Speech Recognition
  - Haptics/Touch
  - Gesture Recognition

- Materials/Algorithms
  - Electronic textiles
  - Flexible Displays
  - Algorithm for accurate data

Sensor module regroup a fragmented offer… Packaging issues
Some blocks are ready, but use case will drive the organization of the upper layers...

Use case will lead the organization of connectivity (blocks (interface and algorithms) have to be adapted to the use case). For now, it’s not the case, wearable are thus limited.

Lower blocks are ready to be implemented, only upper layers are still under construction.
APPLE WATCH TEARDOWN

Sensors for Wearable are close to smartphone ones...

Broadcom
Wi-Fi/Bluetooth/NFC/FM BCM43342

Skyworks
Wi-Fi LNA + switch and PA

STM IMU
LSM6DS0/3

ADI Touch Controller
AD7149

Maxim Integrated
Audio Codec
Audio Amp

IDT
Wireless charger
P9022

AMS
NFC Signal Booster
AS3923

NXP
NFC controller

Elpida
512Mb SRAM Memory
F440AAC

CPU Apple APL0778

Toshiba/SanDisk
8Gb Flash Memory

STM µC
STM32

Skyworks
Wi-Fi LNA + switch and PA

Dialog
Power Management Unit
D2238A

NXP
NFC controller

Toshiba/SanDisk
8Gb Flash Memory

Broadcom
Wi-Fi/Bluetooth/NFC/FM BCM43342

ELPIDA
512Mb SRAM Memory
F440AAC

CPU Apple APL0778

Toshiba/SanDisk
8Gb Flash Memory

NXP
Interface device

Maxim Integrated
Audio Codec
Audio Amp

IDT
Wireless charger
P9022

AMS
NFC Signal Booster
AS3923

NXP
NFC controller

Toshiba/SanDisk
8Gb Flash Memory

QFA
Interface device

Source: ABI Research/Chipworks
Pictures courtesy of Apple Inc.
Fitness tracker is a fragmented and competitive market.

Apple will disrupt the market...

2013 Smartwatches market share (Munits) - Total: 3.5 Munits
- Samsung
- Sony
- Pebble
- Others, Counterfeit & Unlicenced

2014 Smartwatches market share (Munits) - Total: 6.5 Munits
- Samsung
-Sony
-Pebble
-Motorola (Google)

2015 Smartwatches market share (Munits) (Forecasts)
- Samsung
- Sony
- Pebble
- Motorola (Google)
- Apple
- Others, Counterfeit & Unlicenced

2016 Smartwatches market share (Munits) (Forecast) - Total: 23.9 Munits
- Apple 47%
- Samsung 10%
- Huawei 7%
- Sony 3%
- Garmin, Polar, etc. 3%
- Others, Counterfeit & Unlicenced 30%

Over-estimated 2015 sales ~18 Munits
EVEN FOR THE MOST POWERFUL CONSUMER TECH COMPANY…

…The wearable market is still a tough market

iPhone sales - Forecasts 2015-2018

Apple Watch sales - Forecasts 2015-2018
The 3 phases for integration (the infra red case study)

Integration in a smart/phone is generally going through 3 phases:
1. Socket type: at home or bulky system a few dm³
2. Plug-in: external module to be plug to a smartphone/tablet …
3. Embedded: integration into the smartphone (must be < 9 mm thick today)
FUTURE PACKAGING SOLUTION FOR MEMS & SENSORS

Multiple sensors integrated in one small patch

Printed & Flexible electronic will make future electronic seamless

Source: Smart Tag flexible, mc10, luxcapital
CONCLUSION

Wearable wave is already starting…but…

Main technologies for wearable are already on the market, but suffer from several issues:

- High power consumption for few sensors
- Reliability of measurement
- Packaging issues (robustness, size, …)

Future trend:
First step, could be sensor fusion between sensors embedded in the wearable and the smartphone, before a full autonomy of wearable devices at long term.

There are still some issues, but improvement done thanks to smartphone will accelerate the adoption of sensors for wearable
Stay tuned in 2017 →
on
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