

Packaging and Assembly for Wearable Electronics

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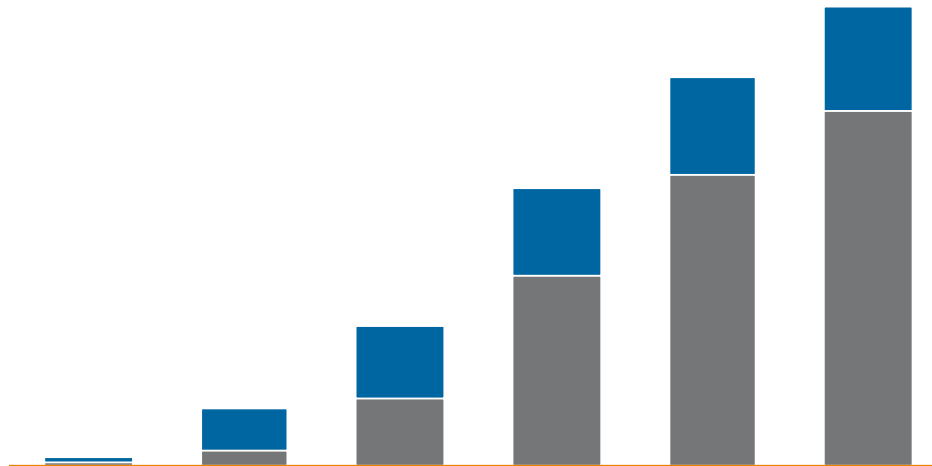
What's Wearable Electronics?

- **Wearable electronics not clearly defined today**
- **Products for consumer/fitness, medical, communication and fashion**
 - **Smart bracelets such as Nike's FuelBand and other fitness products**
 - **Products for wrist account for 34% of shipments**
 - **Smart watches such as Samsung Galaxy Gear smartwatch**
 - **Wearable medical devices such as portable blood pressure monitors, calorie trackers, heart rate monitors, etc.**
 - **Glass-based products, more than just Google Glass**

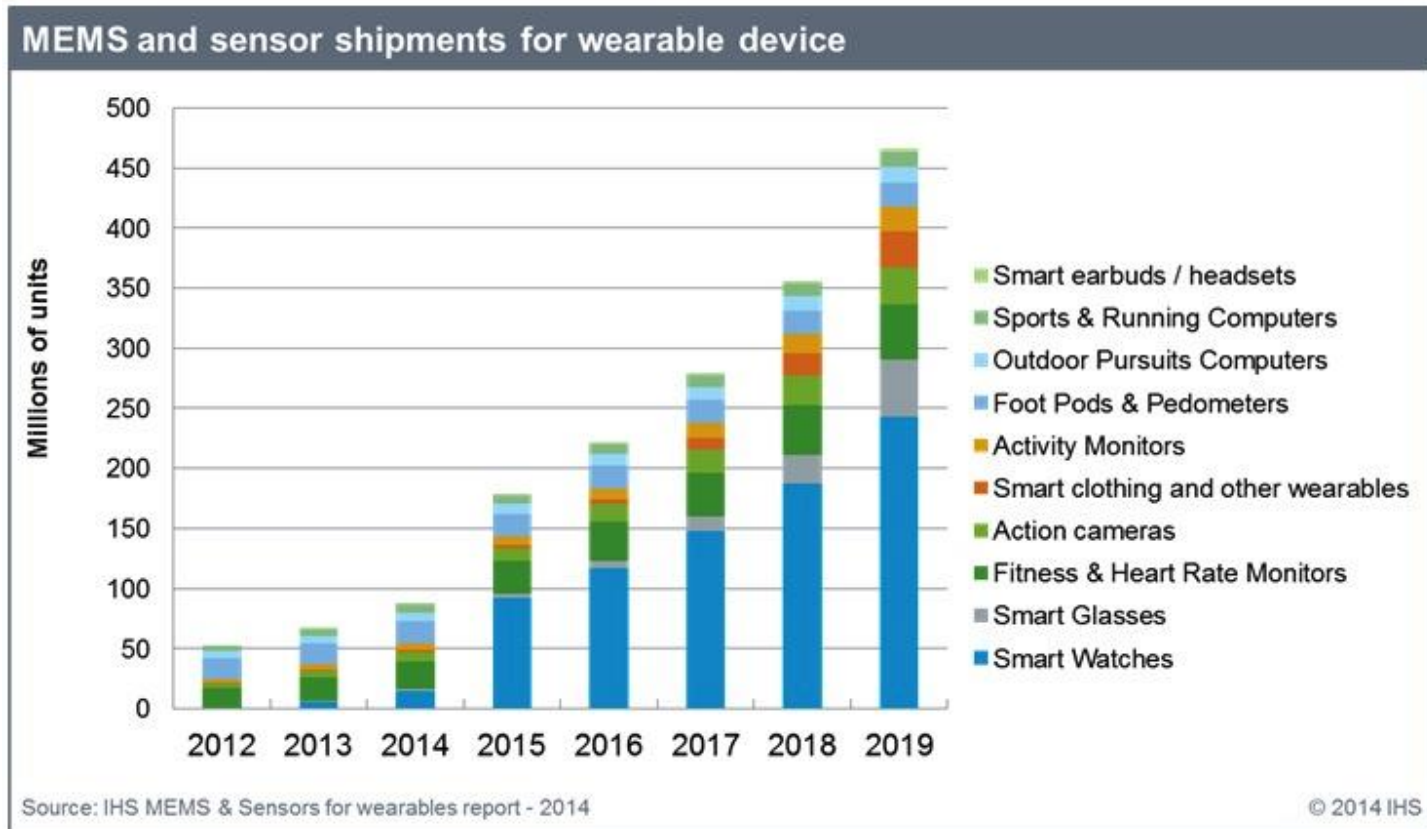


How Big is the Market?

- Market estimates for wearable electronics vary
- Industrial Economics and Knowledge Research Center (IEK) projects the global market value of wearable devices to be \$5.5 billion this year growing \$35 billion in 2018
- IHS predicts 10 fold increase from 2013 to 2018
- IDC projects >\$20 billion market in 2018
 - Global shipments projected to grow from 19 million units in 2014 to 112 million units in 2018



IoT Growth Includes WLP



- **MEMS and sensors growth driven by IoT**
- **Many different packages for wearable electronics**

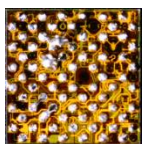
Wearable Product Requirements?

- **What are reliability requirements?**
 - Lifetime?
 - Environmental exposure (UV light, sweat, stress, washer/dryer, cleaning fluids, mud, dust, wafer, sunscreen, etc.)
- **Fitness activity bands**
 - Polymer encased electronics
 - Components must survive mold process temperatures
 - Must withstand twist, bend, flex compression
 - Must not react with bodily and environmental fluids
- **Printed circuit design require environmental protection**
 - Thermal management
 - Shock and vibration
 - Electrostatic discharge (ESD)
 - Bodily and environmental fluids
- **Fabrics for wearable electronics**
 - Weaving of metallized yarns
 - Lamination of circuit boards
 - Examples T-shirt for muscle stimulation therapy
- **Need special reliability tests**
 - Drop test (is it shock proof?)
 - Thermal stress (simulation)
 - Is it moisture resistant?

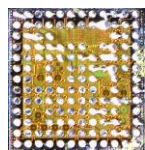


Package Choices: Which Ones Do I Use?

- Quad flat no-lead (QFN)
- Fine pitch ball grid arrays (FBGA) with laminate or flex circuit substrate
- Ceramic land grid array (CLGA)
- LGA (with laminate substrate), typically wire bond moving to flip chip
- Flip chip BGA (FC-BGA)
- Wafer level package (WLP)
- Fan-out WLP (FO-WLP)
- Stacked die package (WB, or FC and WB)
- Package-on-package (PoP)
 - Memory stack in top package
 - Logic in bottom package can be WB, FC, Embedded die, or FO-WLP
- System-in-Package (SiP)
- Integrated Passive Device (IPD)



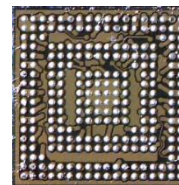
WLP



FO-WLP



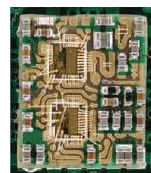
PoP



FC-BGA



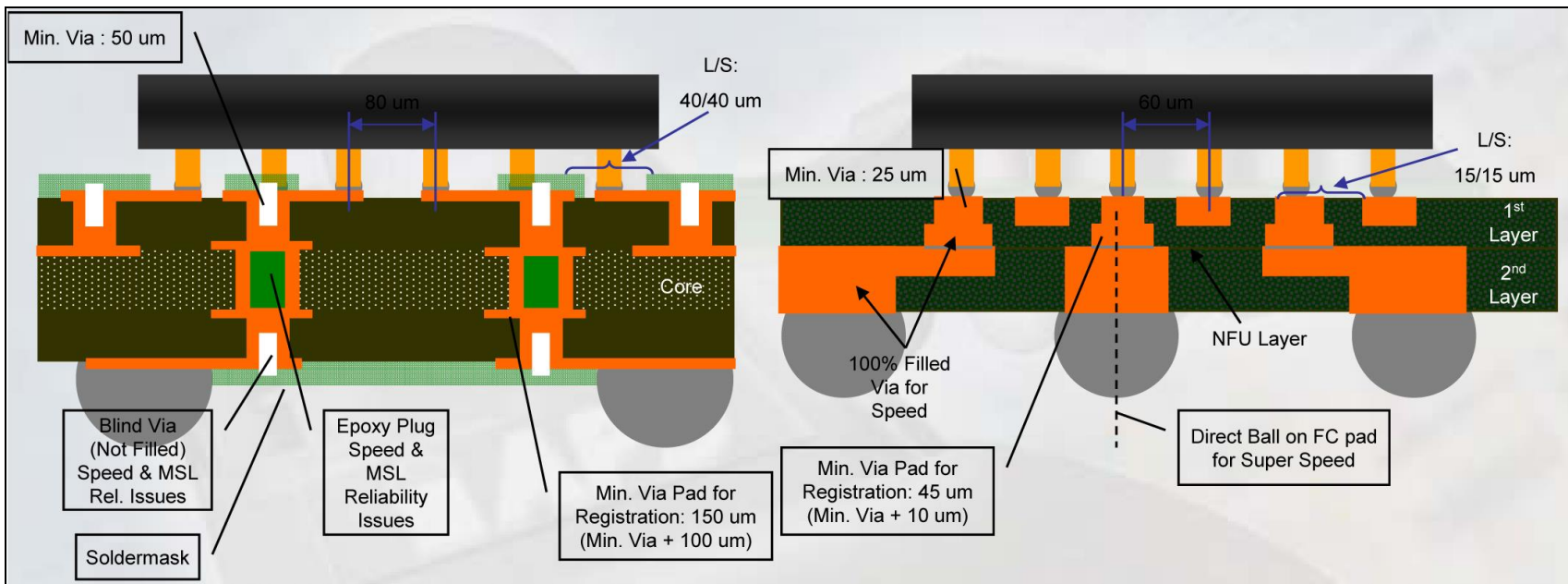
QFN



LGA module

Flip Chip on Leadframe

MIS Coreless Substrate with Flip Chip



Source: APS.

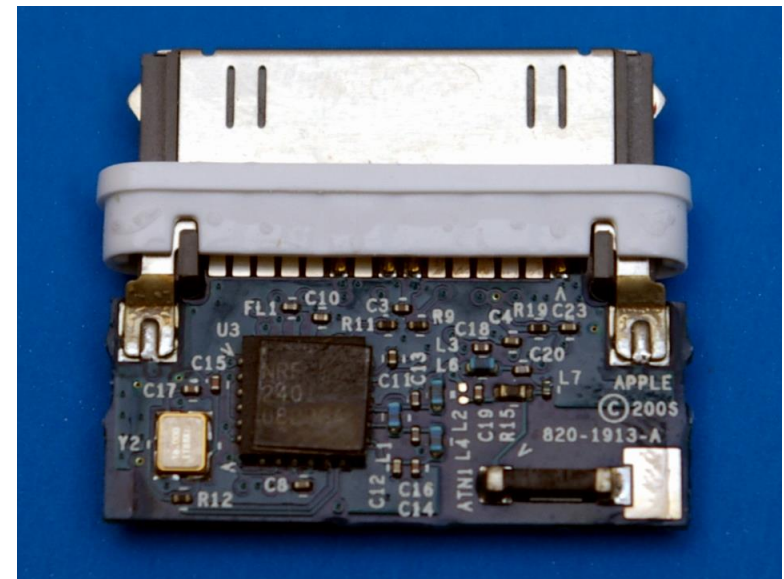
- **Potential low-cost flip chip solution**
- **Conventional 1-2-1 substrate (left)**
- **Two-layer MIS substrate (right)**
 - **Direct filled microvia down to 50μm diameter for improved routing**

No One Solution for Wearables

- Packaging options (found in today's products)
 - BGA, FBGA
 - Flex circuit CSP
 - LGA (including MCM)
 - Chip-on-board (COB)
 - PoP
 - Stacked die CSP
 - Leadframe packages such as QFN, SOP, TSOP
 - Ceramic packages
 - Integrated passive devices
 - WLP
 - Embedded die
- Packaging options (emerging)
 - FO-WLP
 - MIS package (leadframe versions with mold compound as underfill and substrate)
 - SiP
- Cost/Performance trade-off determines adoption, but **Cost** and **Form Factor** are key

Product Board Options

- **Flexible circuit**
 - Many medical products
 - CHECKLIGHT head impact monitor from MC10
 - Wrist bands
- **Rigid flex**
 - Wrist bands
 - Smart watches
- **Printed circuit board**
 - Pedometers
 - Smart watches



Source: TPSS.

Wearable Electronics Enabled by Flexible Circuits

- **Flexible substrates**
 - Materials such as polyimides, LCP, Teflon, etc.
 - Thin substrates
 - Fine pitch features
 - Multiple die
 - Embedded active die and passives possible
 - Folded assembly
- **Low-cost processing**
 - Roll-to-roll
 - Flexibility
- **Reliability proven historically**

NIKE FUEL™ BAND

Key functions

- Monitor activities and provides metrics



Overmolded rubber

Integrated USB

Polymer Lithium-ion battery x 2

BT antenna in FPC

Rigid FPC

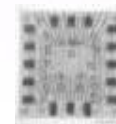
LED array

Tactile switch



Magnesium battery cover

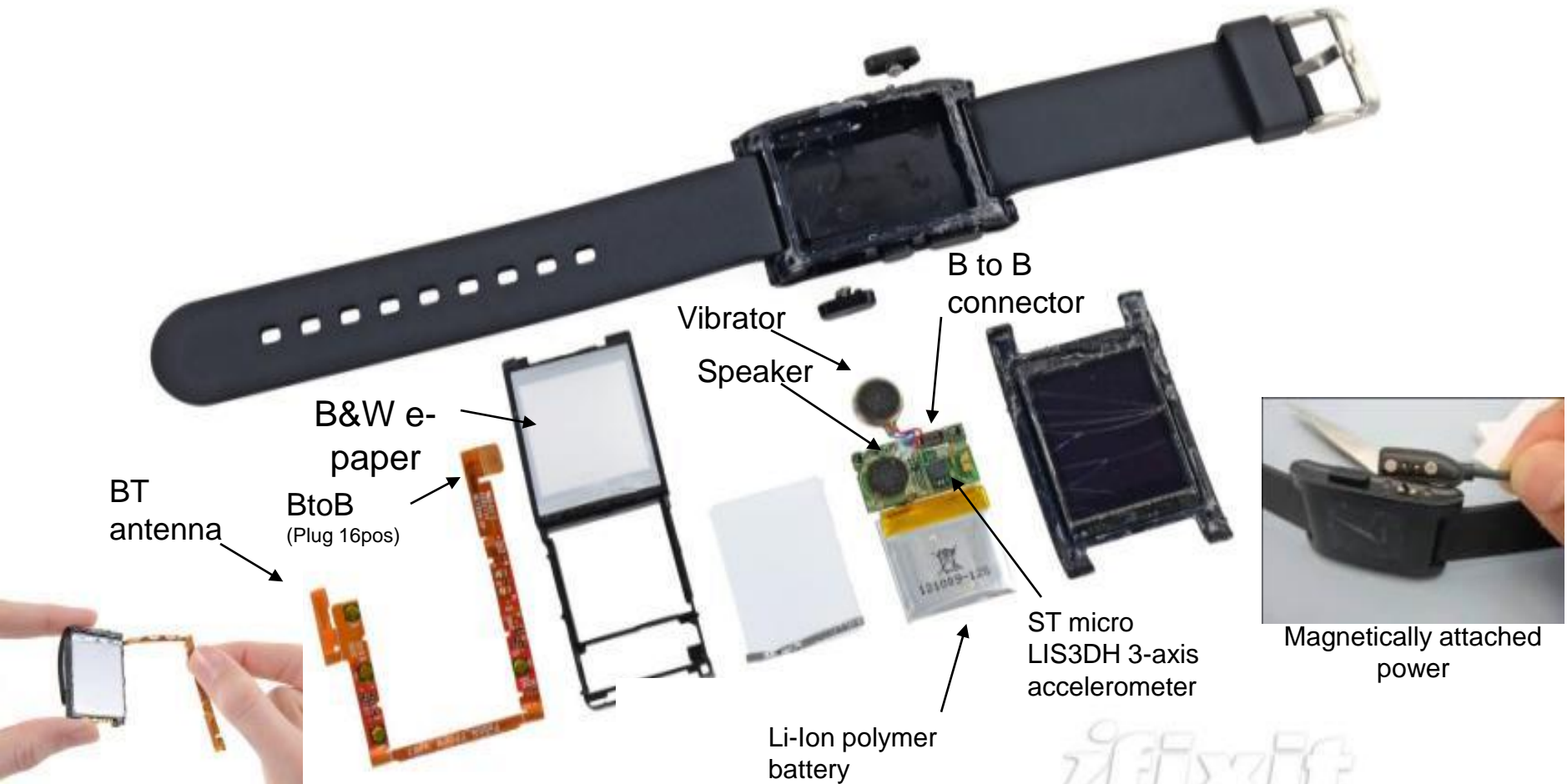
USB adapter cable



C3H MEMS Accelerometer
STMicroelectronics

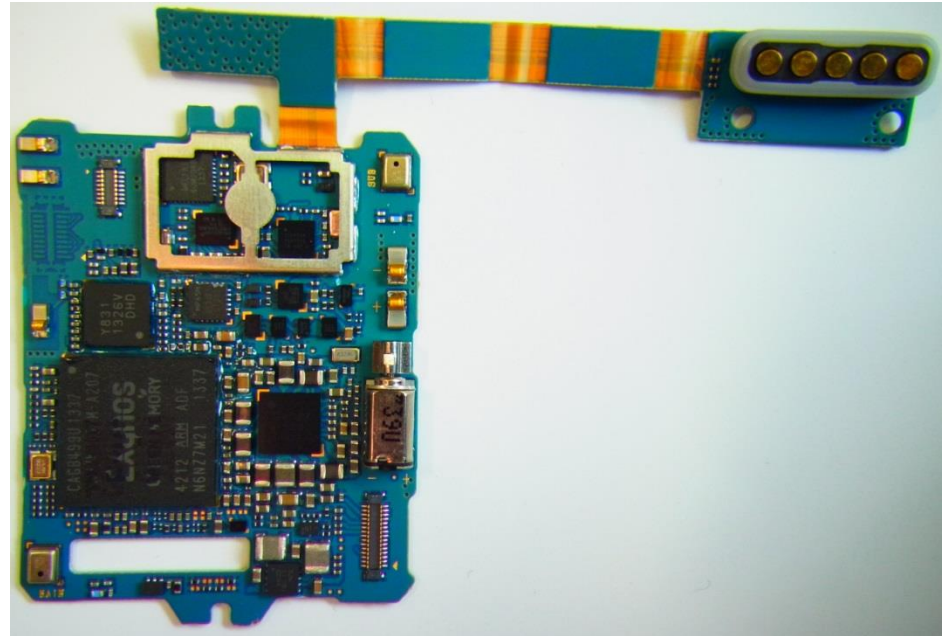
Source: TEConnectivity.

PEBBLE Smartwatch



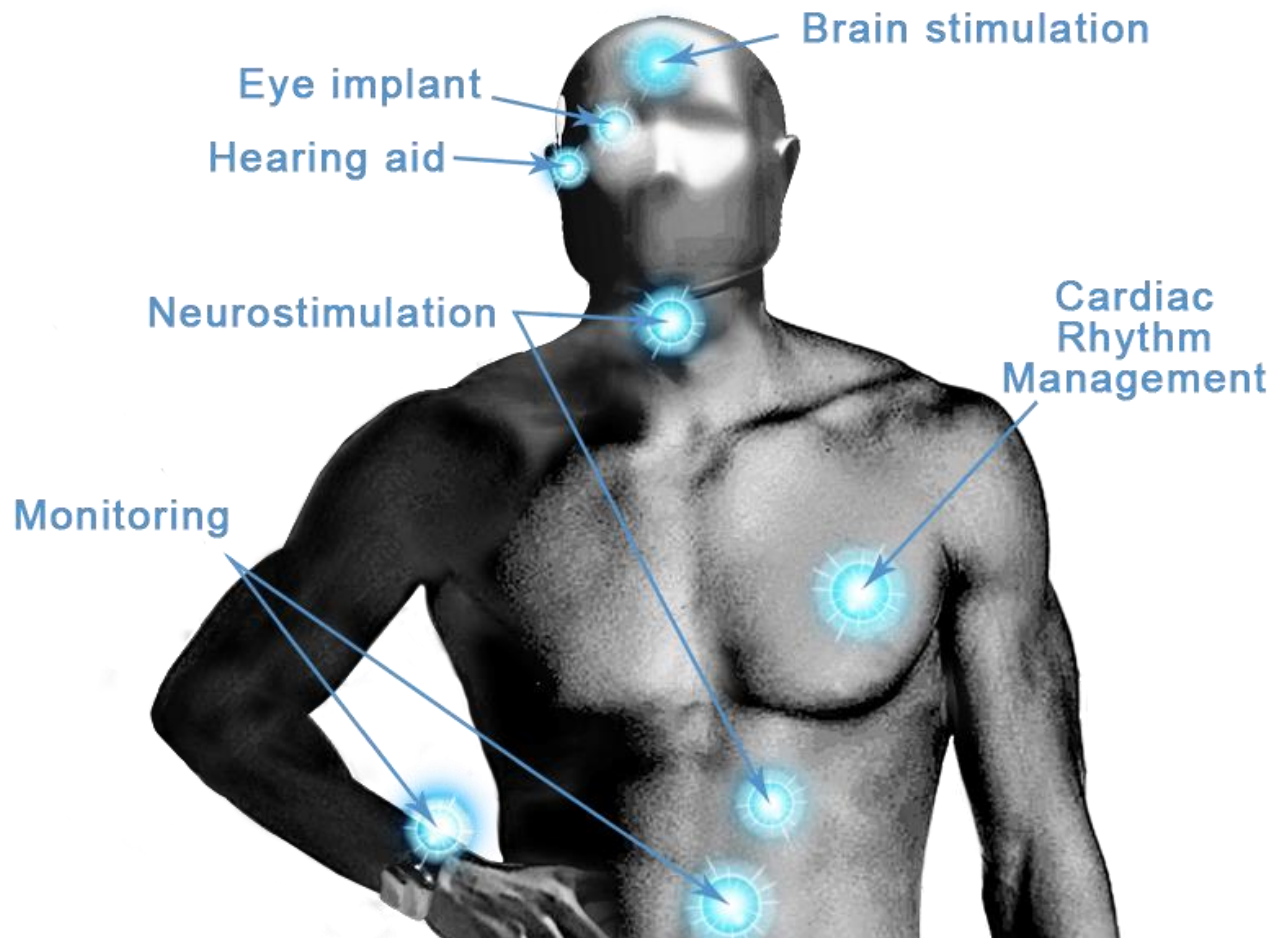
Samsung Galaxy Gear

- Many different components
 - WLP
 - FC-CSP
 - QFN
- Mounted on rigid flex board
- Flex circuit inside
- Display: OLED



Source: TPSS

Medical Devices with IPDiA Integrated Passives



Source: IPDiA.

Conclusions

- **Many different products**
- **Many different types of boards/substrates**
- **Many different package types**
- **Need many different reliability tests**
- **Need new materials to achieve realization of future product designs**