MEMs Research Needs

A Packaging Perspective

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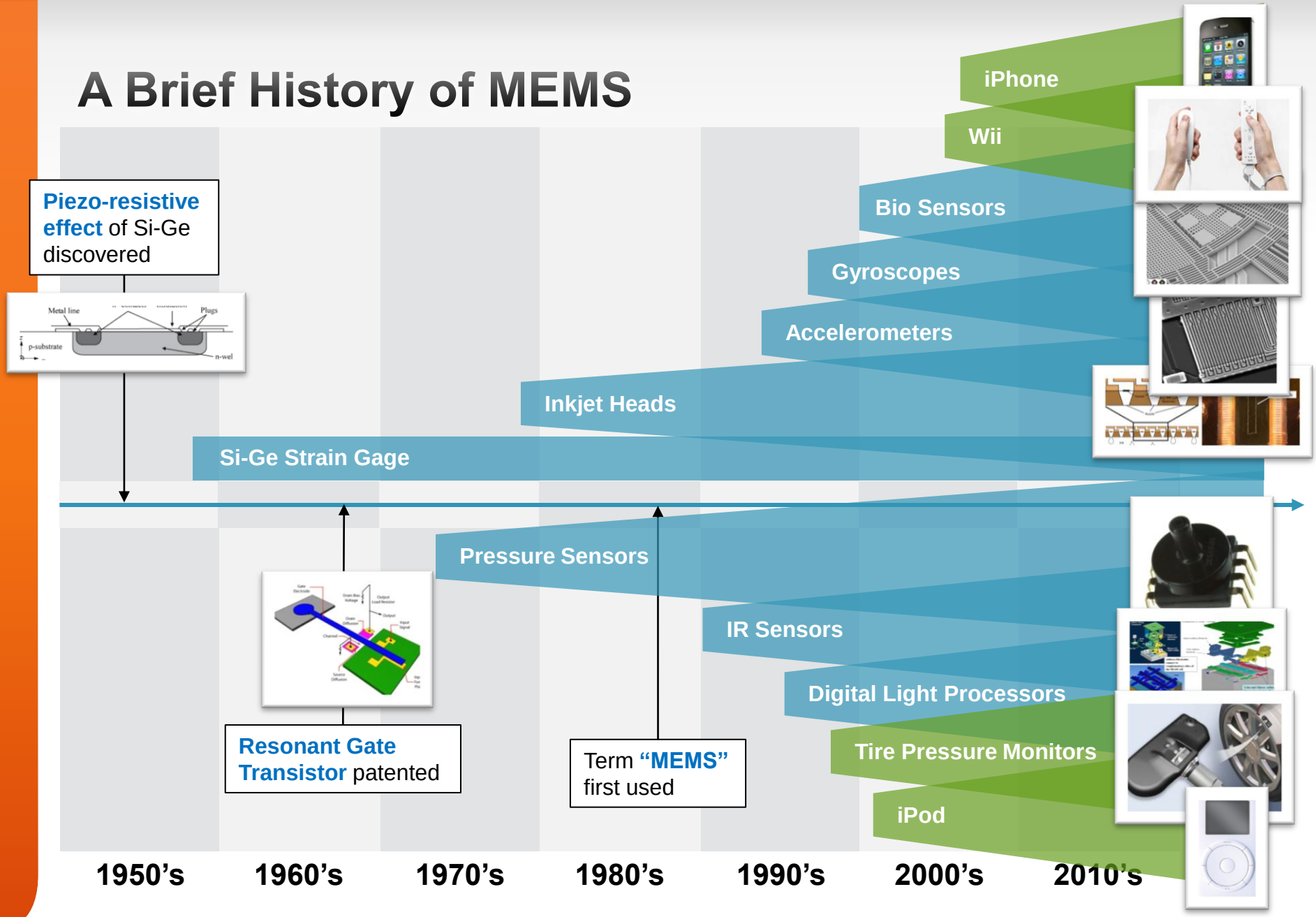
A Brief History of MEMS



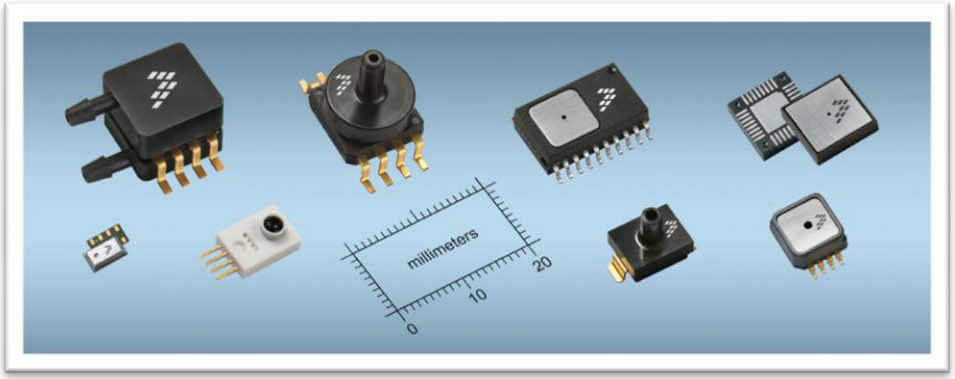
SOURCE: Southwest Center for Microsystems Education (SCME), *History of MEMS Learning Module*, 2001

MEMS Trends & Packaging Implications

- **Increasing Accuracy**
  - Increasing precision is desired/demanded over time
  - Isolation: stable packages that isolate sensor from extraneous stresses

- **Increasing Integration**
  - More functions, more chips in a single sense unit
  - Integration: expanding SiP, PiP, PoP complexity

- **Miniaturization**
  - Handheld device space constraints fix maximum volumetric envelope
  - Miniaturization:



Freescale Pressure Sensor Portfolio

- **Increasing Diversity**
  - Expanding applications and markets
  - Customization: Each package customized for the application, market, and environment. Pressure, inertial, optical / consumer, automotive, medical. . .
  - Design: accuracy required to do all the above well.

- **Cost, Cost, Cost**
  - Leverage existing capabilities (test & pkg) and integration, standardization.

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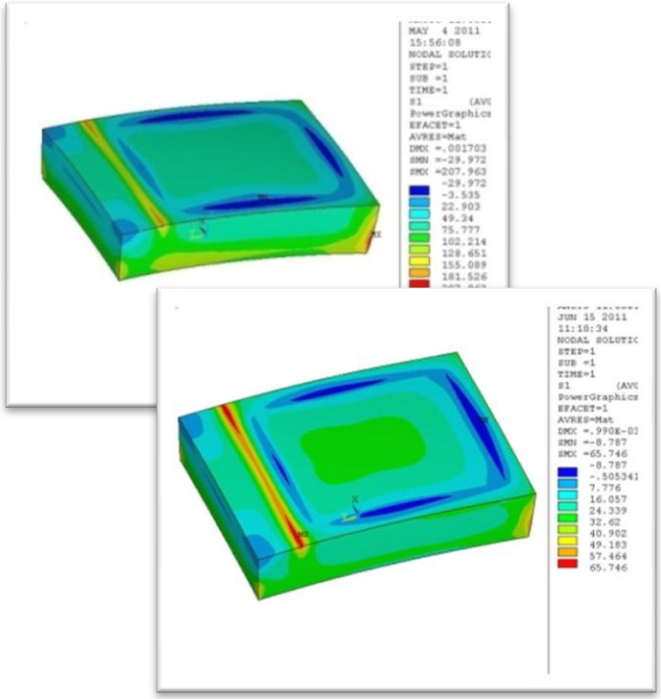
Key Focus Areas for Research

- **Design Accuracy**
- **Isolation Improvement**
- **Cost**
- **Applications**

Design Accuracy

- MEMS designs sometimes experience many revisions.
  - Inherent functionality
  - Fabrication process variation
  - Assembly and board mounting stresses
  - Environmental conditions



- Current analytic and finite element modeling approaches are insufficient to achieve "first time right" design objectives.

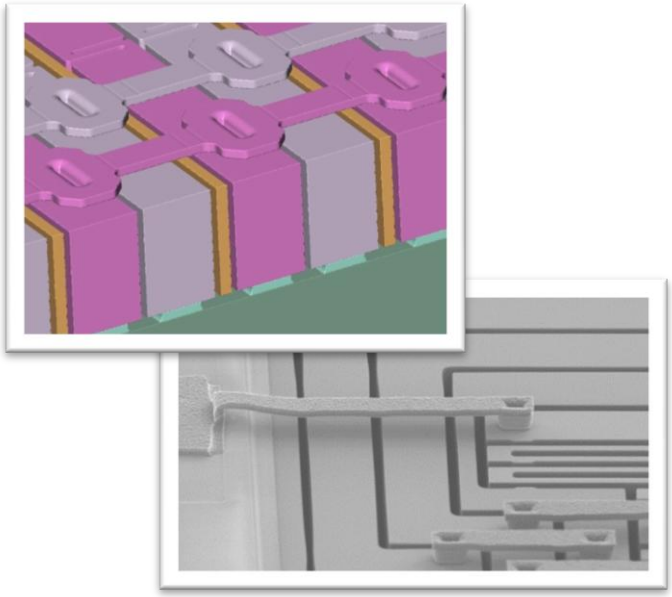
- Research Needs
  - **Automation / Simplification**
    - To enable modeling of statistical variation and complex systems without added labor.
  - **Definition of model boundary conditions**
    - To improve design accuracy and better predict actual performance

Isolation Improvement

- Conventional wisdom: ceramic as a stable foundation for the system.
  - But, it is unaffordable and not scalable to miniaturization needs.

- Conventional microelectronics packaging materials (lead frames, substrates, mold compounds, etc.) have attractive pricing but create and transmit more extraneous stresses to the sensor.
  - Increasing sensitivity requirements are revealing the limitations of applying these packages to MEMS.

- Research Needs
  - **Materials**
    - Create a cost-effective ceramic-like base suitable for many form factors.
  - **Physical Isolation**
    - Design robust sensors that are immune to extraneous stress fields.
  - **Compensation / Trimming**
    - Develop more sophisticated methodologies that cancel-out extraneous stresses.



Cost

- Cost Hierarchy:
  - Conventional microelectronics paradigm: **chip > package > test**
  - Emerging MEMS paradigm: **test > package > chip**

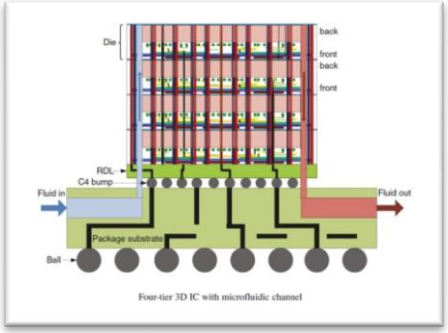
Courtesy of SPEA

- Despite the changing cost paradigm, the overwhelming majority of R&D attention, effort, and dollars are directed towards improving the chips to deliver more sensitivity, integration, etc.

- Research Needs
  - **MEMS Design-for-test / Self-test methodologies**
    - To eliminate the need for custom actuation-based testers & handlers and leverage existing digital tester/handler infrastructure.
  - **Isolation Improvement**
    - To enable leverage of existing digital packaging technologies & cost structures.
  - **Standardization & Integration**
    - ~~One product / one process / one package~~. Multi-function products = fewer pkgs.

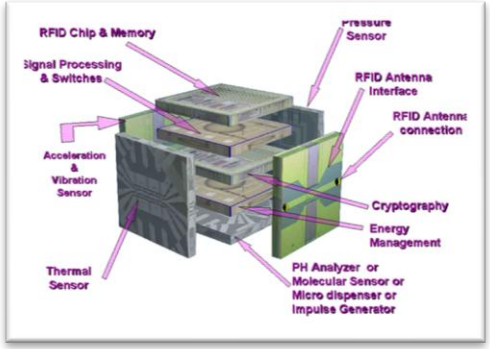
Emerging MEMS Packaging Applications

- **Micro-fluidics**
  - Medical and implantable devices, drug delivery, lab-on-chip, etc.
  - Cooling 3D chip stacks



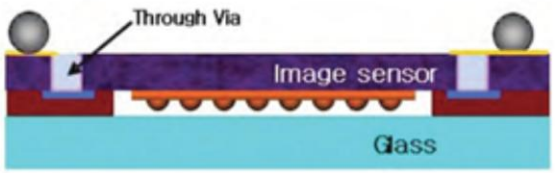
Four-tier 3D IC with microfluidic channel

- **2-D and 3-D Packaging Integration**
  - Sensing "node" concepts for aerospace and military
  - Volumetric shrinks
  - More function in constant volume



Courtesy of 3D Plus

- **Wafer-level Packaging**
  - ASIC-as-cap-wafer, TSV chip/wafer stacks
  - Optical packaging: dispensed lenses, etc.



Structure of ISM WLP with TSV interconnection.

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