

MEMS and Microsystem Packaging

NMI at INNOS June 2005



CONFIDENTIAL

Introduction

- **Background to MEMS and Microsystem Packaging**
- **Types of Packaging**
 - “Zero level” packaging
 - Primary packaging
 - Secondary packaging

Silicon IC Systems

- **Silicon IC systems have become:**
 - Incredibly complex
 - Amazingly dense

- **Standard packages have just about managed to keep up**
 - From early single analogue IC
 - To multiple stacked digital ICs

Packaging Diversification

- **Standard packaging is “fraying at the edges”**
 - System in Package
 - Complex chips: eg microprocessors
 - Power
 - MEMS

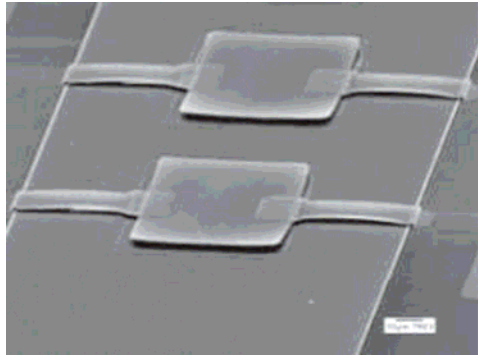
- **Package standardisation helped by:**
 - Single input/output media – electric signals
 - Mature worldwide industry
 - High volume and demand from products such as mobile phones etc.

MEMS and Microsystems Packaging

- **MEMS and Microsystems packaging is at the opposite side of the spectrum!**
 - Multiple input/output media
 - Immature, younger, fragmented industry
 - Only a few high volume products, such as inkjet, air bag sensor
- **Microsystems**
 - Photonics
 - Sensors
 - Inkjet print heads
 - RF switches

MEMS & Microsystems Input Media

- Heat



- Light

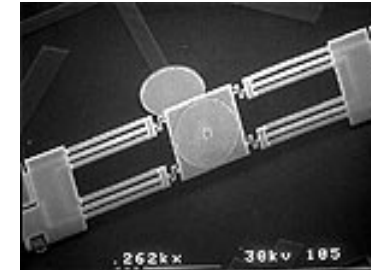
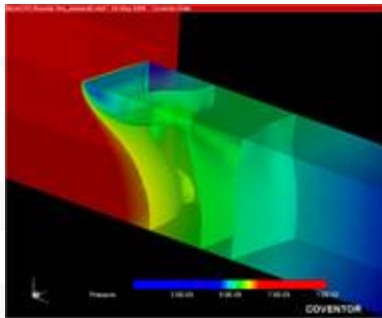
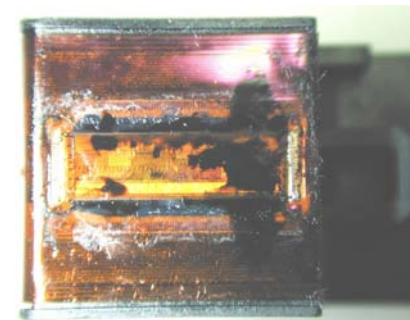


Image: STS

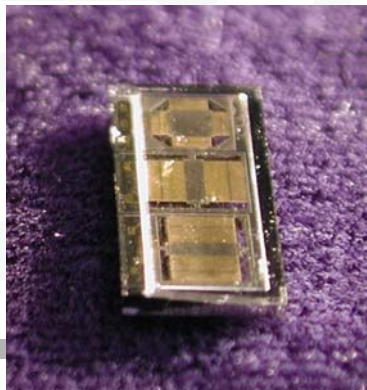
- Gas



- Liquid



- Motion



Microsystems with Inputs and Outputs in Other Medium

- **Micro fluidics**

Newer photonics are light to light

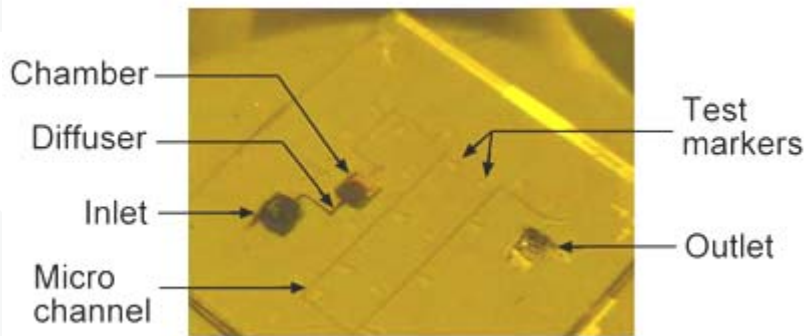


Image: Illinois University

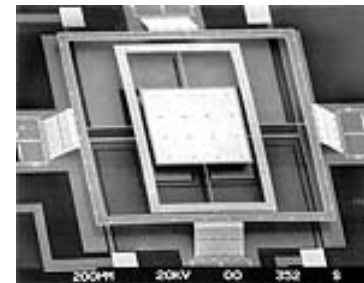


Image: STS, MEMScap, UCLA

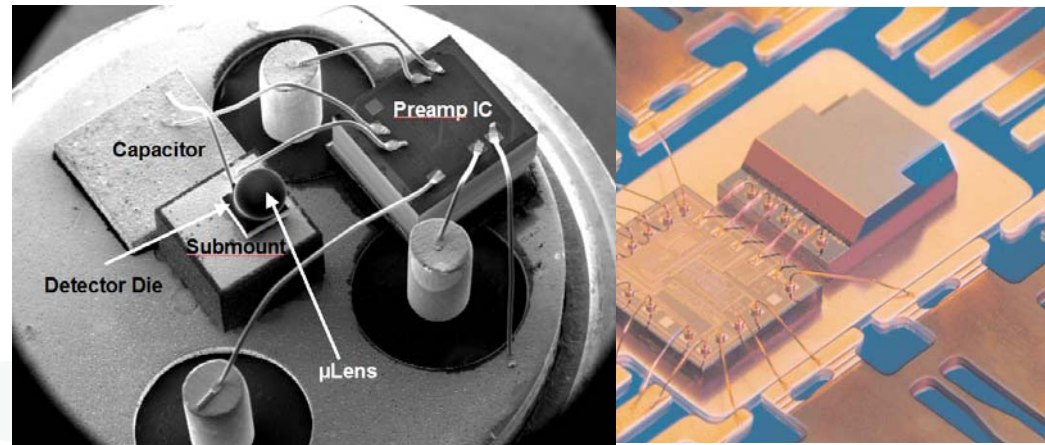
MEMS Interface Circuitry

- **MEMS devices tend to have low signal levels**

- Microphones
- Motion sensors

- **Or high frequency**

- RF switches
- Photonics



- **MEMS interface circuitry is often layout or package sensitive**

Cost

- **Advanced Packaging**
- **IC packaging 30 – 90% of item cost**
- **MEMS packaging 70 – 90% of item cost**



MEMSnet: Current Challenges

- **Most companies..... have very limited options for prototyping or manufacturing devices**
- **MEMS packaging is more challenging than IC packaging....**
- **Most companies find that packaging is the single most expensive and time-consuming task in their overall product development**

MEMS Packaging is a Challenge!

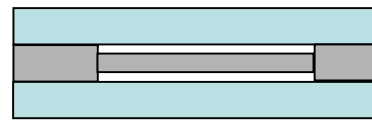
- **MEMS are difficult to:**
 - Design
 - Make
 - Find a supplier for
- **But, usually, packaging is the hardest task!**

MEMS Die Packaging Requirements

- **Mechanical structures often need altered environments**
 - RF switches, IR sensors/bolometers need high vacuum
 - Controlled atmosphere for capacitance sensing – accelerometers
- **Mechanical structures need a cavity**
- **Access for input/output medium**
- **Sensitive to packaging stresses**
- **Wafers can be thicker**

“Zero Level” Packaging

- **Additional glass or silicon wafers bonded to MEMS wafer**
- **Composite wafer sawn into “die”**



Glass
MEMS
Glass

- **Advantages**

- Cheaper – bulk wafer scale process
- Protects MEMS from saw slurry
- Compatible with standard IC packages
- Provides environmental control, cavity and protects MEMS

Types of “Zero Level” Processes

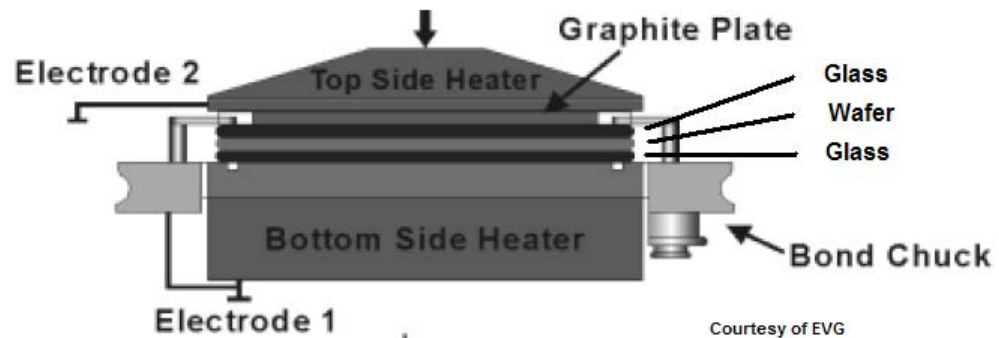
- **Direct bonding**
 - Anodic bonding of glass
 - Wafer-to-wafer bonding

- **Indirect bonding using a “glue”**
 - Eutectic bonding – gold/silicon
 - Solder
 - Glass frit
 - BCB, epoxy – polymer

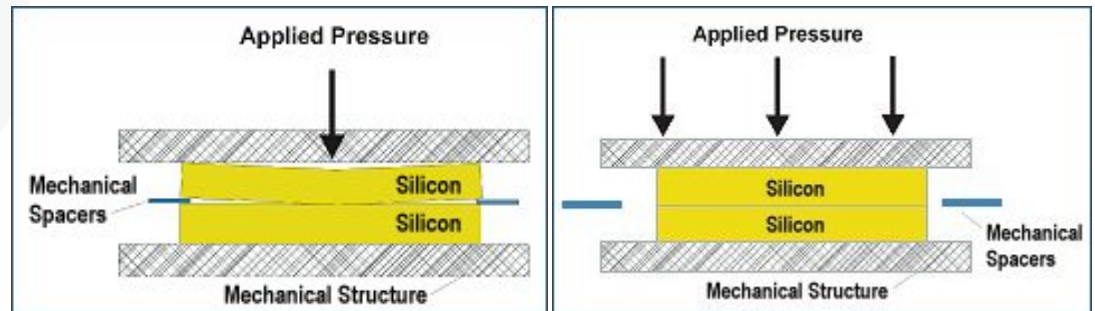
Direct Bonding

- **Anodic bonding**

- Glass/wafer/glass

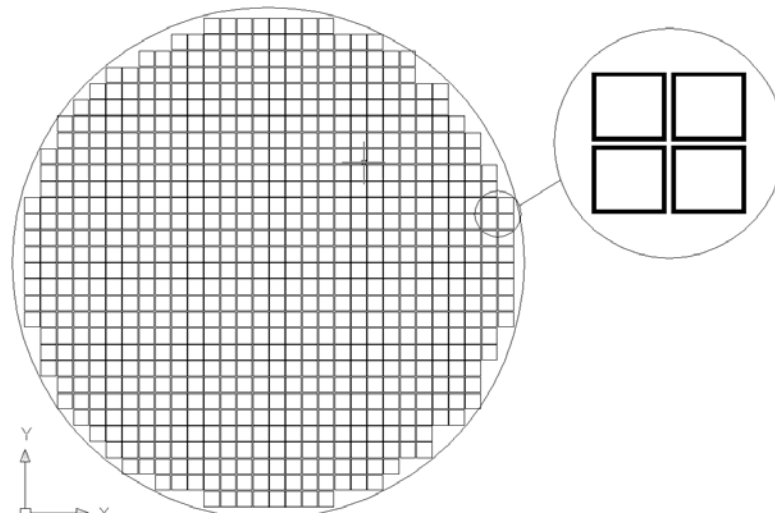


- **Wafer-to-wafer bonding**



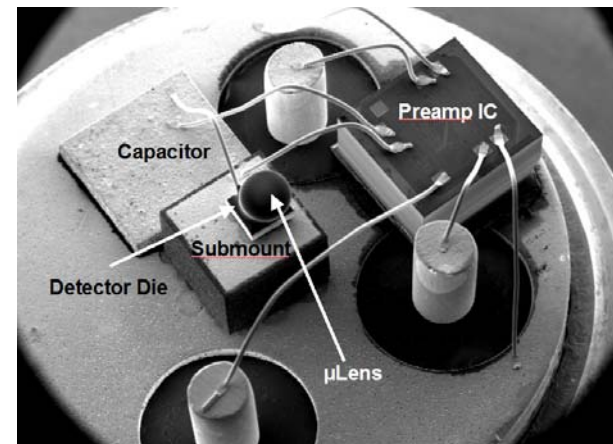
Indirect Bonding

- **Apply “glue”**
 - Sputter/etch eutectic
 - Screen print glass frit
 - Spin on/photo pattern BCB
- **Apply cap**
- **Heat treat**
 - Reflow/cure

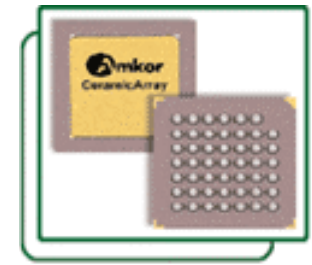


Micro System Often Requires a System in a Package

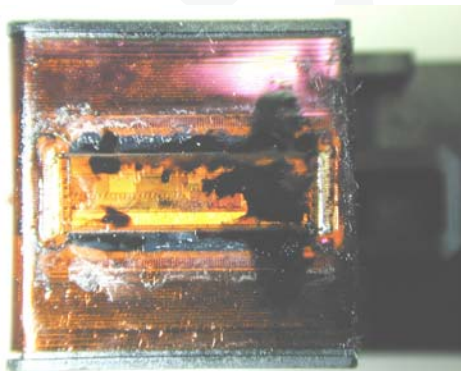
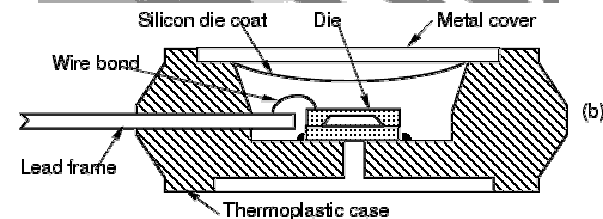
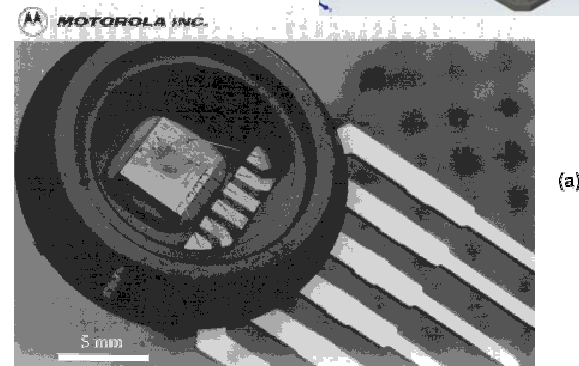
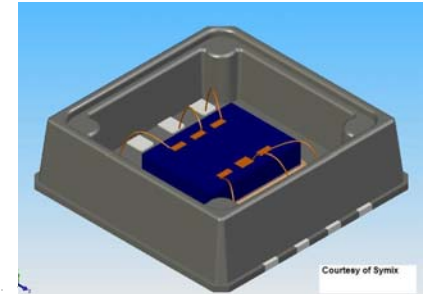
- **Interface circuitry**
 - Either In primary packaging
 - Or layout sensitive in secondary packaging
- **“System in a Package” is a Zarlink speciality**



Primary Packaging

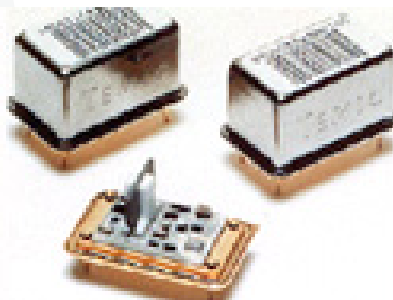
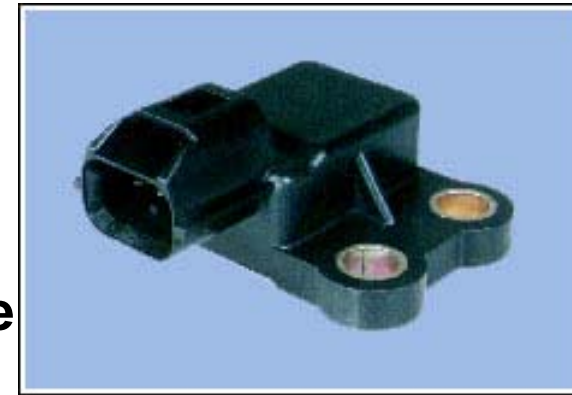


- Hermetic ceramic packaging instead of zero level
- Zero level package thickness
- Environmental access
- All levels of packaging merge



Secondary Packaging

- Usually a mechanical and electronic structure
- Designed by the customer (or strong input)
- Multidisciplinary project
 - Specialist engineering knowledge for application
 - Mechanical engineering
 - Package engineering



What Level of Package Integration

- **Package integration driven by**

- Cost (NRE or part cost)
- Application
- Electronic requirements

- **Levels of integration**

- Fully integrated MEMS + interface circuitry “System on a Chip”
- MEMS + interface in Primary packaging “ System in a Package”
- MEMS + interface circuitry as components on a PCB

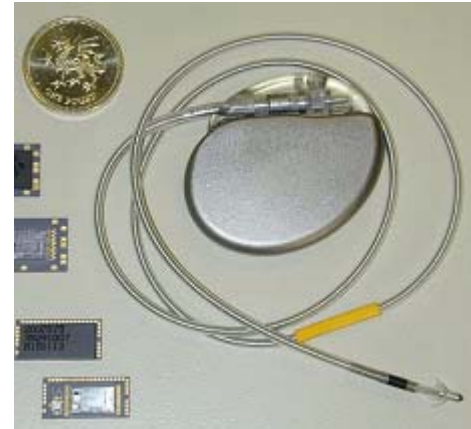
Self-Powered Systems

■ Current systems

- Battery: pacemaker lasts 10 years
- Photo cell power: supermarket shelf RF driven LCD price labels

■ Future self-powered system components

- Micro fuel cells, MEMS energy harvesters
- Low-power wireless cells
- E grains, intelligent dust



Design and Manufacturing Systems

- **Profusion of medium**
- **Non-standard processes**
- **Customers who know their business but not Micro systems**
 - Bio-chips: do you understand biology, do they understand silicon ?
- **Multi-company and multi-disciplinary projects**
- **Shared design rules, EDA and fabs are a long way off**
- **A consultants dream!?**
- **Will we have to choose a niche, will it be difficult to swap niches?**

NO WONDER MEMS PACKAGING IS NON-STANDARD!

SIMPLY COMMUNICATING



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