MEMS Micropackaging for Microsystems Integration

Sazzadur Chowdhury, G. A. Jullien, M. Ahmadi, W. C. Miller

Research Centre for Integrated Microsystems
Department of Electrical and Computer Engineering
University of Windsor
Windsor, Ontario, N9B 3P4, Canada

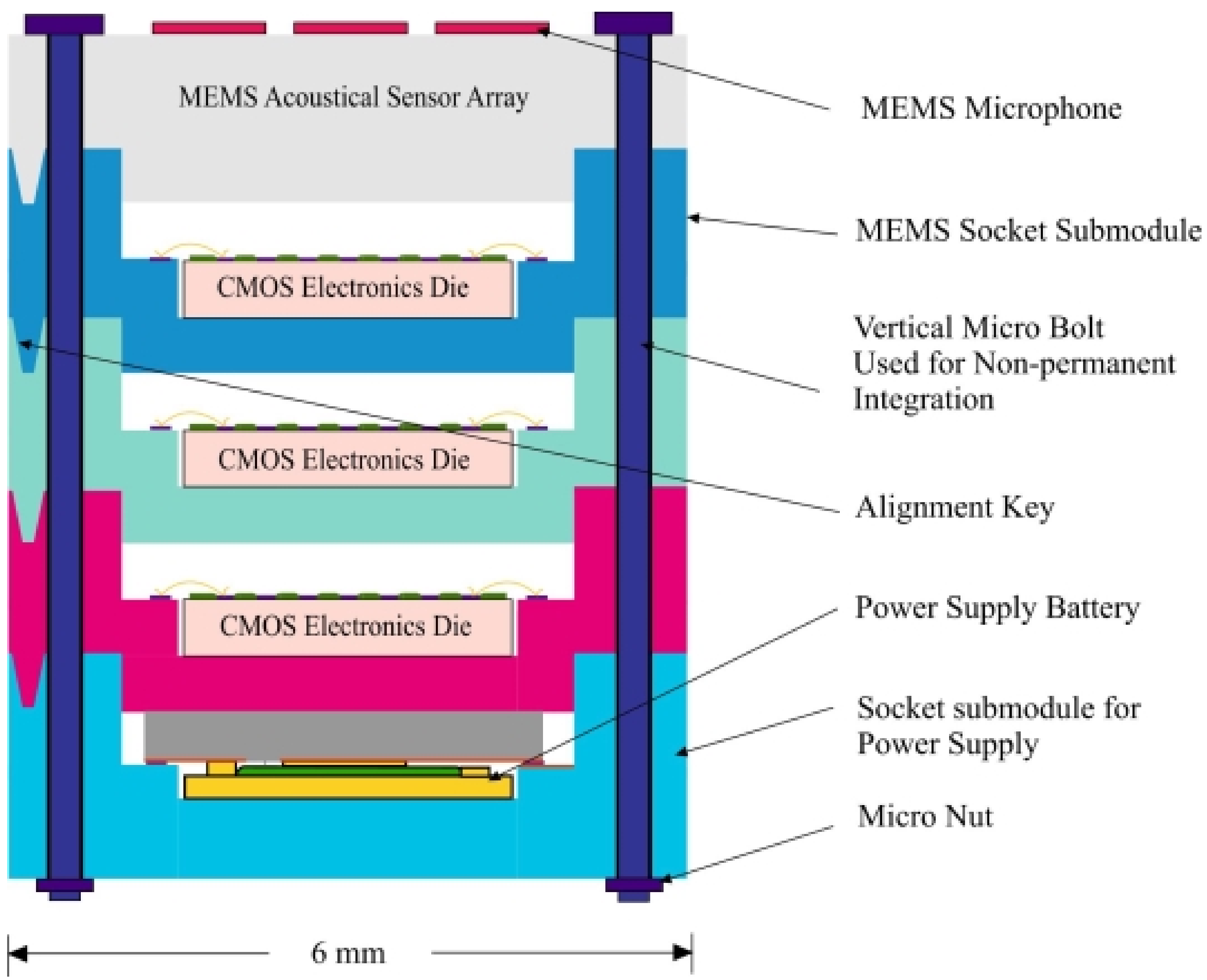
Abstract

- A modular MEMS socket system has been developed that enables a custom, application-specific micropackaging solution for diverse technology dies and devices
- Each socket submodule may contain a CMOS or non-CMOS die (MEMS, Photonics, RF, GaAs, BJT, etc.) or may itself be a sensor/actuator or microanalyzer
- An insertable/removable MEMS microbus card provides connectivity among socket submodules and slides into an interconnection channel prefabricated in all submodules
- The system can also be configured for testing of high density I/O SoC dies or diverse-technology systems using a solderless, pressure dependent cantilevered bridge-type microspring contact mechanism

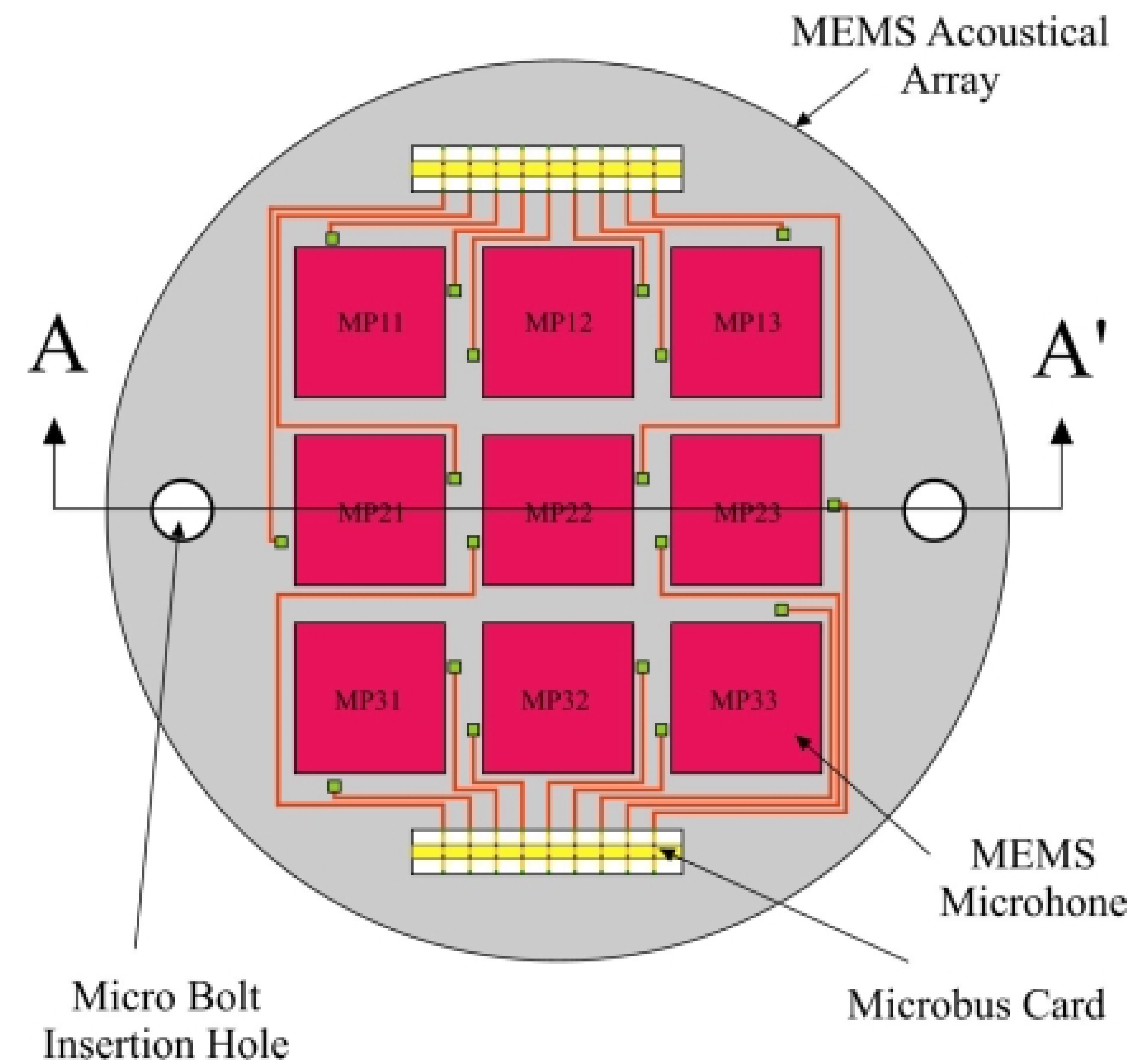
MEMS Micropackaging Solution: Major Design Features

- A complete working system in a package offering diverse micropackaging solutions
- Scalable single or modular micropackaging
- Permanent or temporary submodule integration
- Socket submodules to accommodate integrated circuit dies in custom fabricated housing pits
- A sensor can itself be a socket submodule or can be surface mounted in a socket submodule
- An insertable/removable microbus card provides custom inter-modular connectivity
- Heat deformed, gold coated cantilever microsprings on the microbus card connects to platinum coated microrail contacts inside the vertical interconnection channel in a submodule
- Gold wire bonding between Socket metal pads and die I/O pads
- Low impedance connectivity path
- Conduction type thermal management
- Cantilevered bridge-type microspring contact enables dies testing
- Easily modifiable connectivity using microbus card
- Batch fabrication using MEMS technology

Illustration of Modular Integration of a MEMS Sensor and SoC Dies

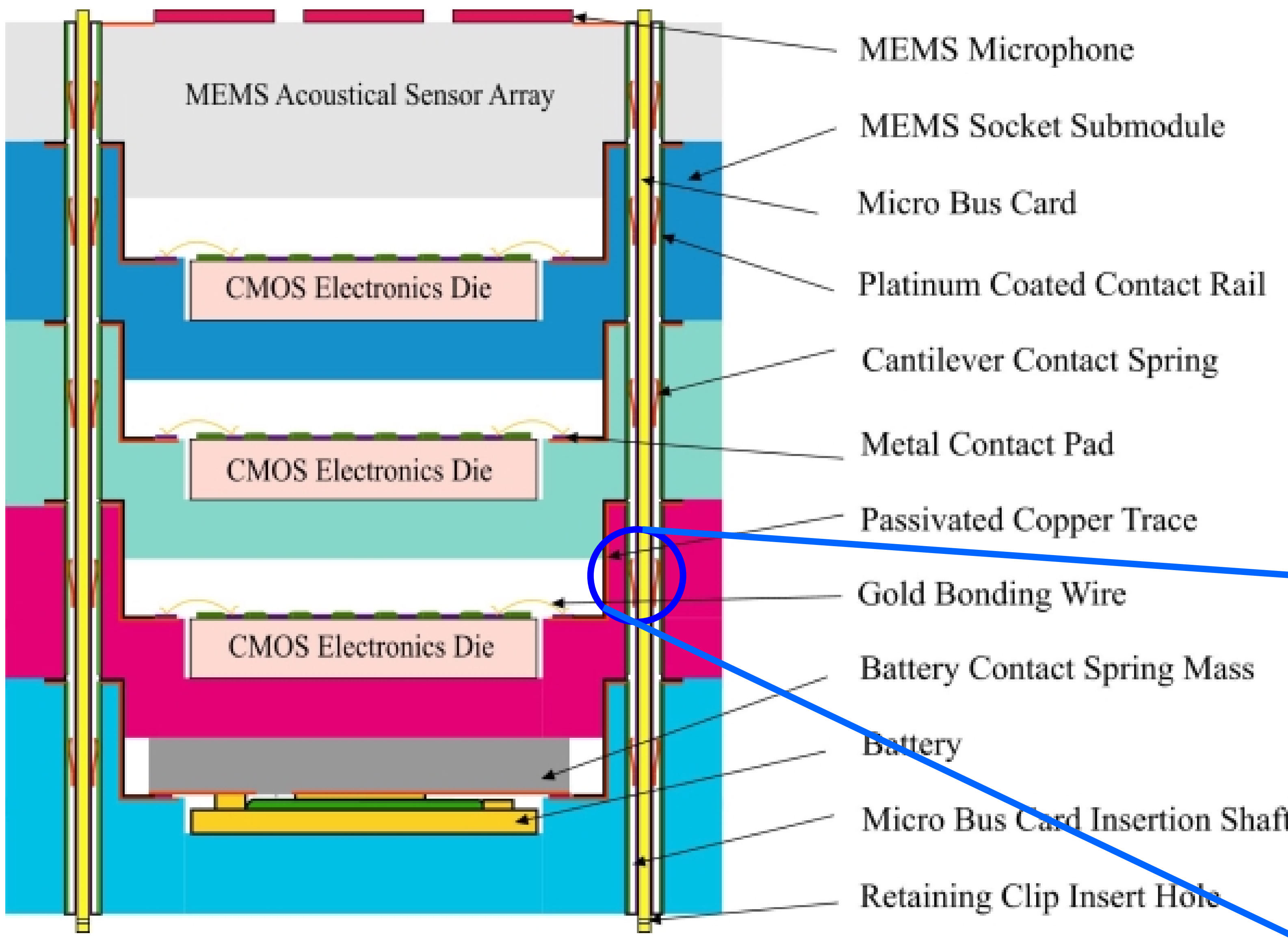


Section A-A’

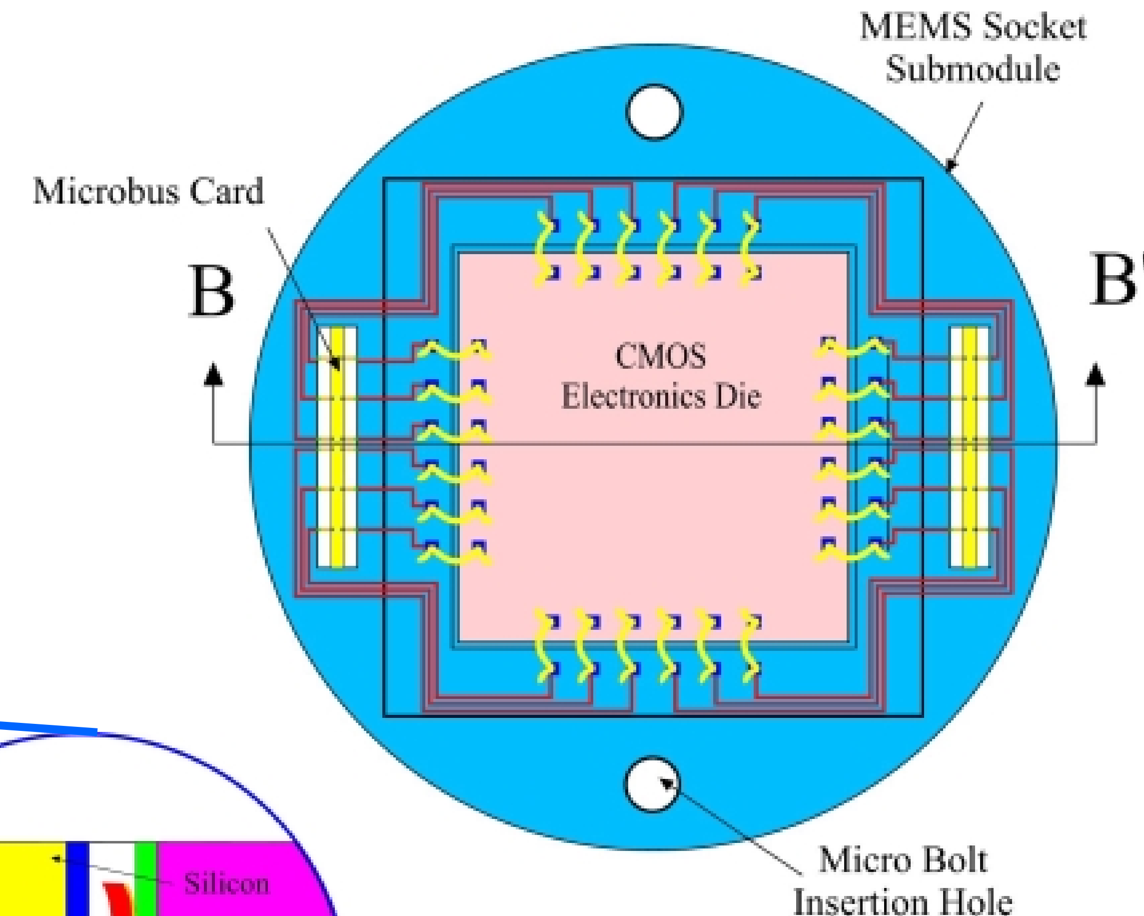


Top View

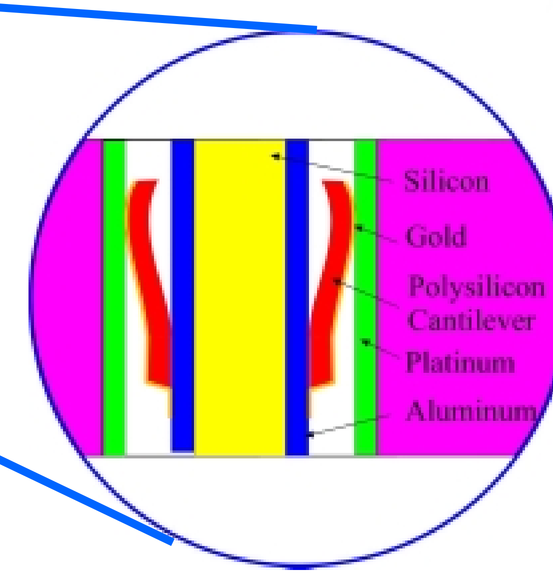
Illustration of Microbus Card Connectivity for Various Submodules



Section B-B’

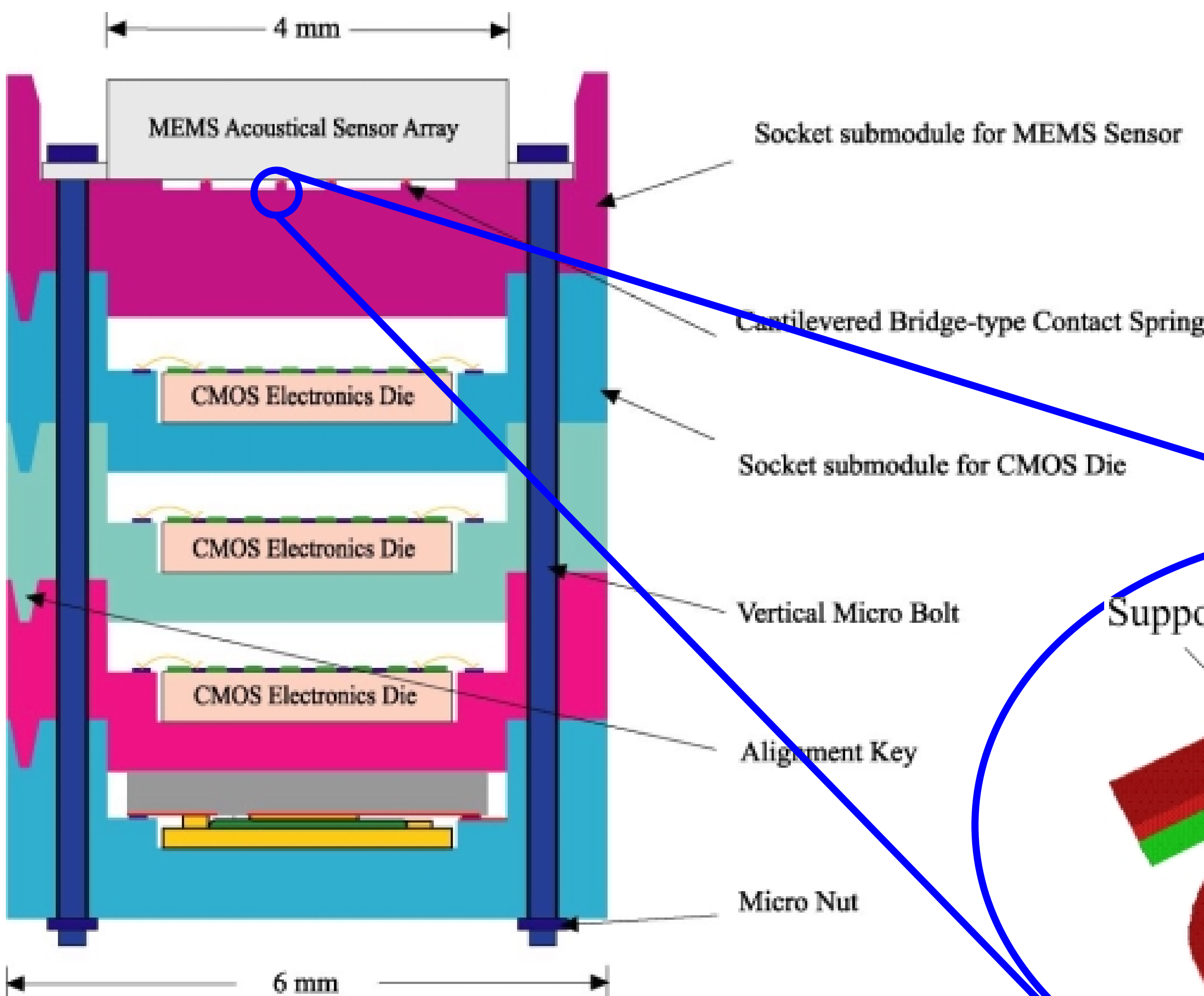


Top View of a die-container Socket submodule



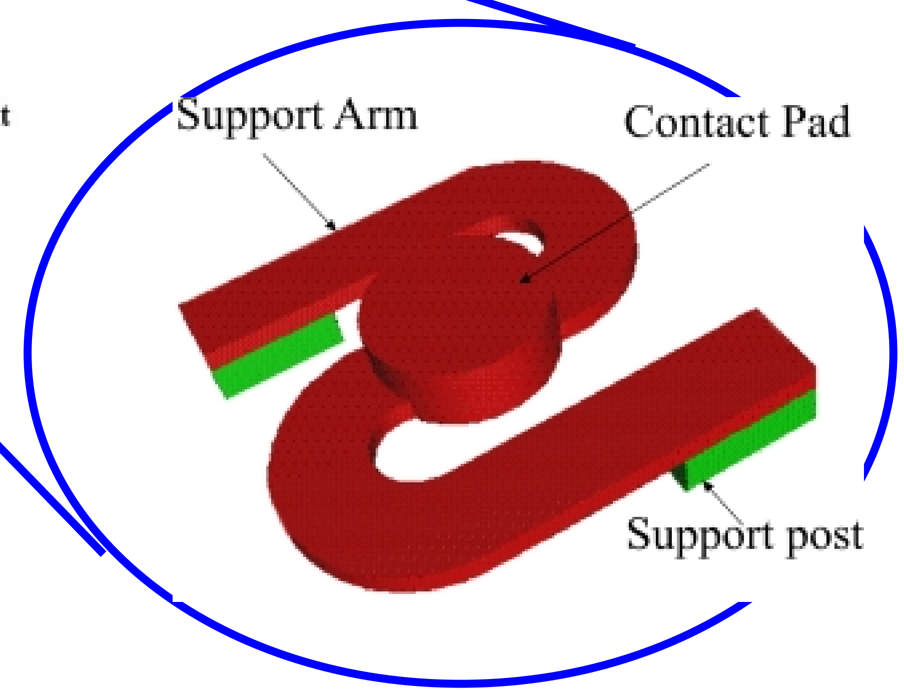
Exploded view of microbus card showing the spring contacts

Illustration of Temporary Connectivity Using Z-Shaped Microspring Contacts

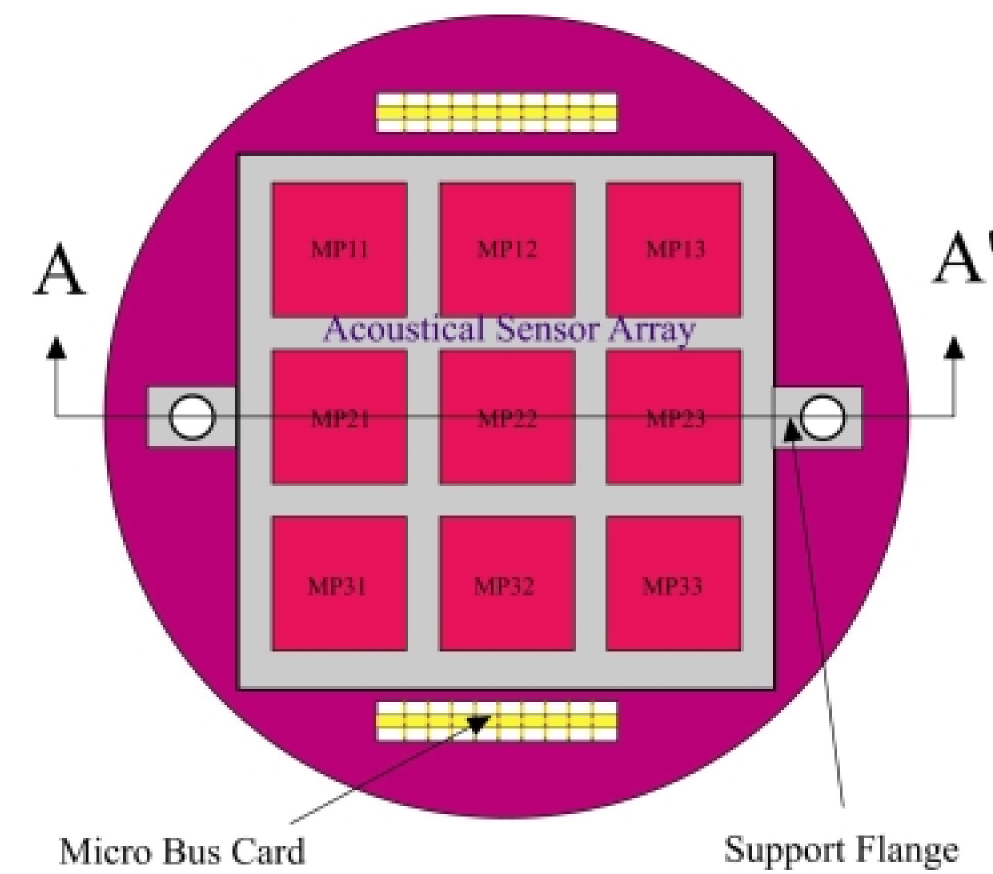


Section A-A’

The MEMS Sensor is surface mounted to a socket submodule

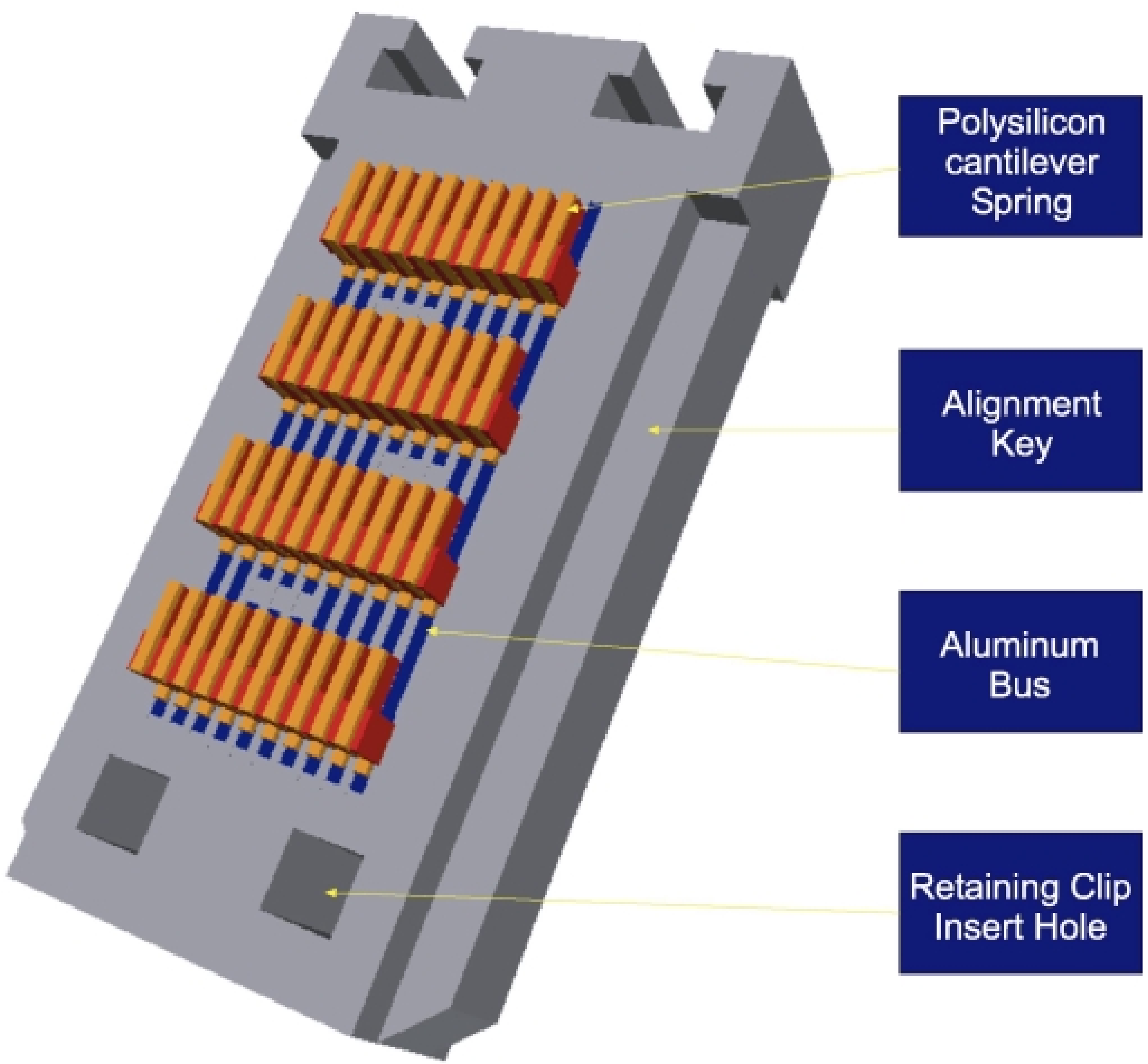


Microspring Contact’ (100 x 100 μm²)



Top View

Microbus Card Connectivity System



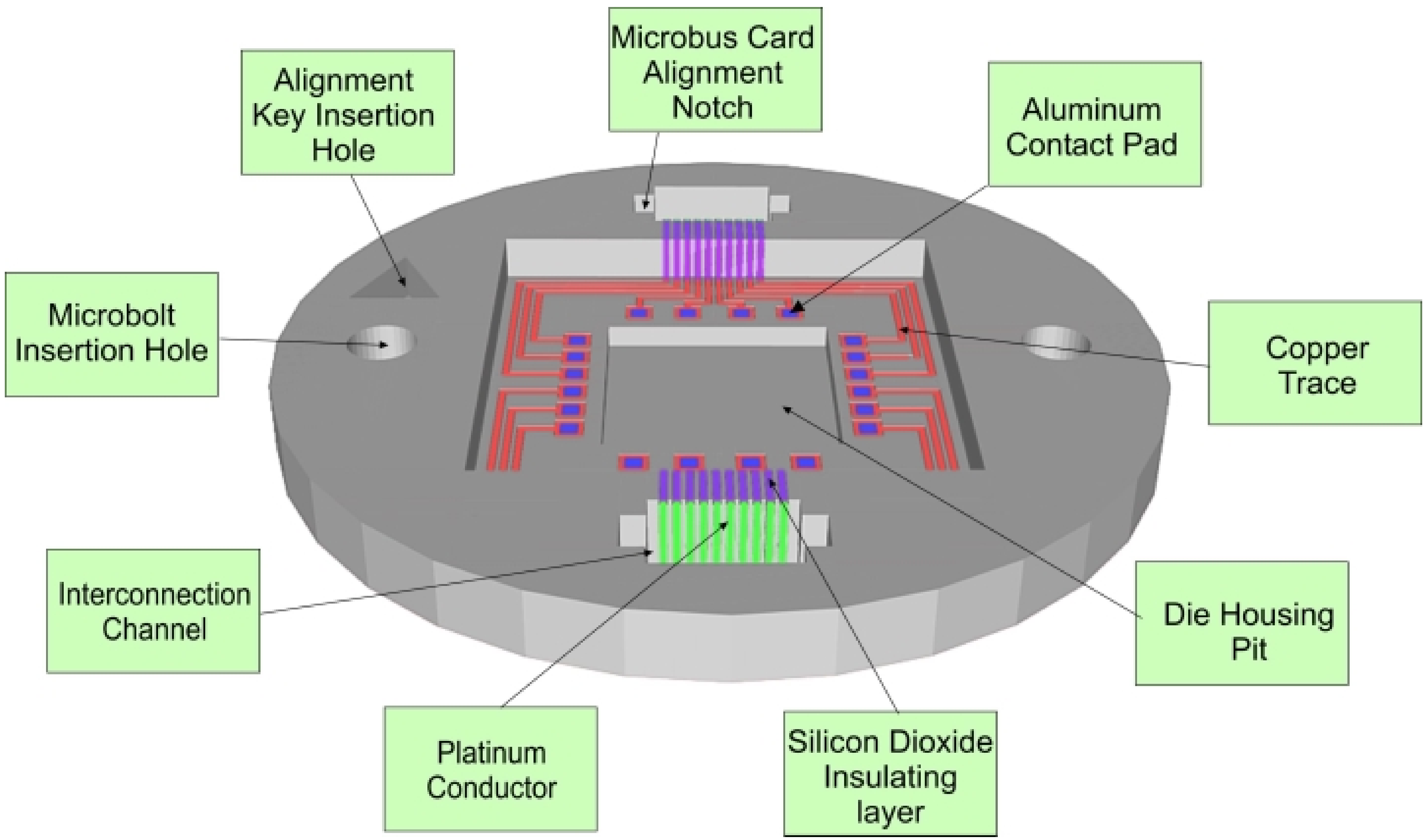
Microbus Card 3-D model Before Heat Treatment. Generated by IntelliSuite Design Tools Simulating Fabrication Processes

- The microbus card establishes Inter-modular connectivity when shoved in through an interconnection channel that is present in each socket submodule
- The microbus card is fabricated using MEMS technology
- The gold coated polysilicon cantilevers are heat treated after fabrication at 150-200^0 C to induce tensile stress so that the cantilevers bend upwards
- When shoved in, the bent cantilevers come in contact with vertical platinum coated microrails inside the interconnection channel and undergo deformation to generate necessary contact force

Major Design Specifications

- Polysilicon Cantilever Dimensions: 100 x 25 x 2 µm
- Gold Conductor Thickness: 200 nm
- Aluminum Bus Dimensions (W/T): 25 x 1 µm
- Retaining Clip Insertion Hole (L/W): 250 x 250 µm
- Microbus Card Dimensions (W/T): 2 mm x 400 µm
- Microbus card Material: Czochralski Silicon

MEMS Socket: Die Container Submodule

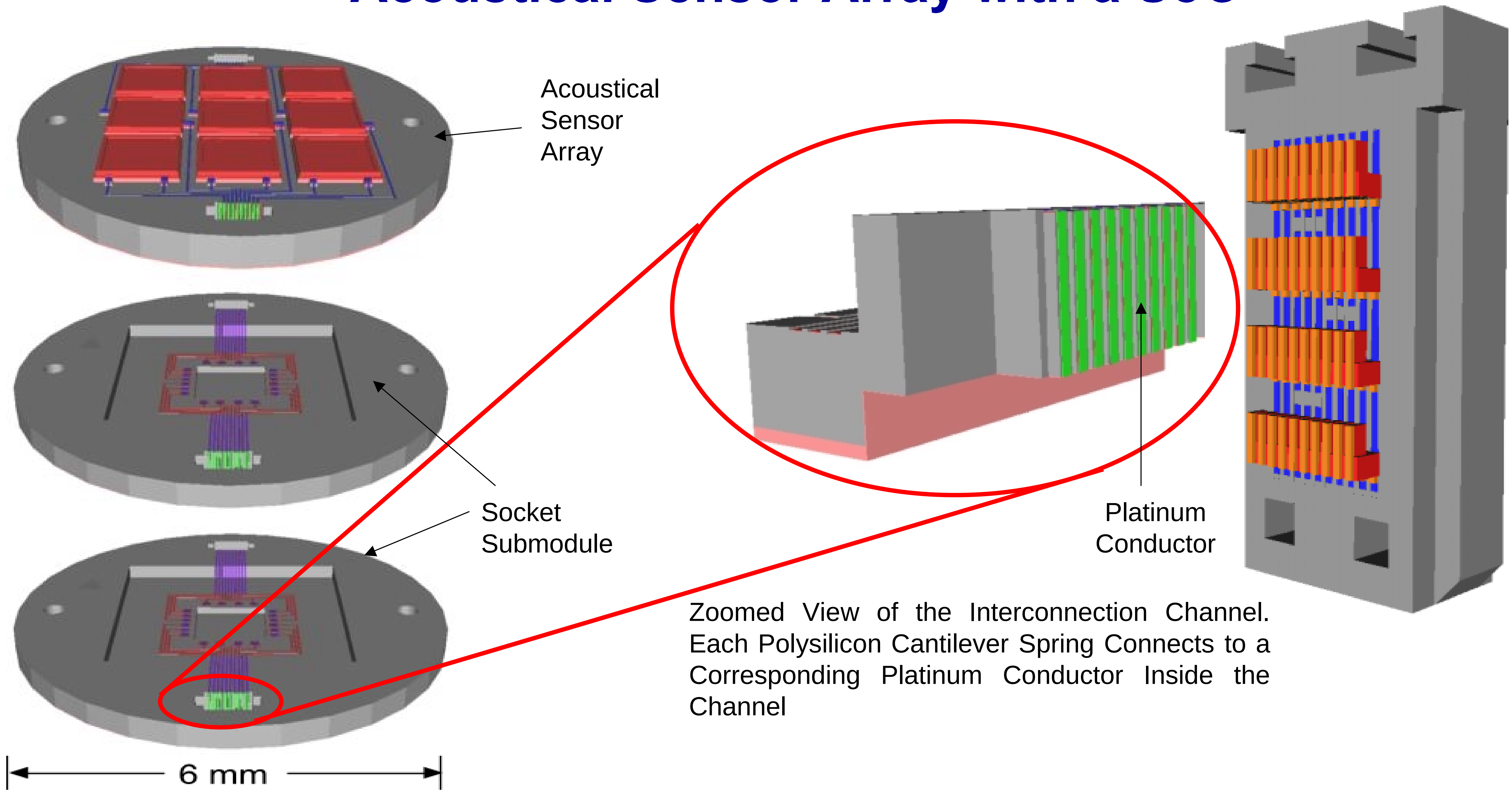


3-D model of a die container type MEMS socket submodule after simulating the fabrication processes using IntelliSuite design tools

Major Design Specifications

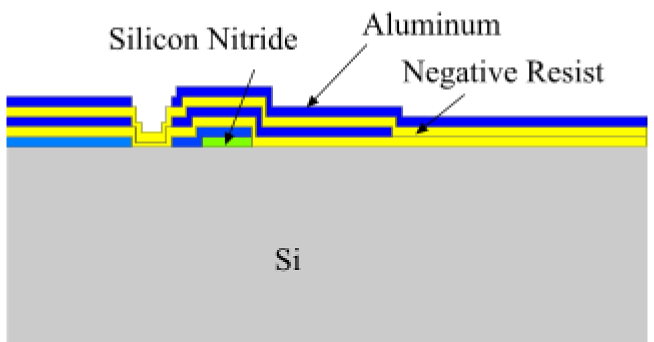
- Socket Submodule Thickness : 400 µm
- Depth of CMOS Die Insertion Pit: 100 µm
- Thickness of Backside Extrusion: 100 µm
- Microrail Dimensions (W/H): 25/200 µm
- Metal Contact Pad Area: 75 x 75 µm
- Micro Bolt Diameter: 400 µm
- Interconnection Channel Dimensions (W/T): 2 mm/400 µm
- Platinum Conductor Thickness: 200 nm

Micropackaging Example: Integration of an Acoustical Sensor Array with a SoC

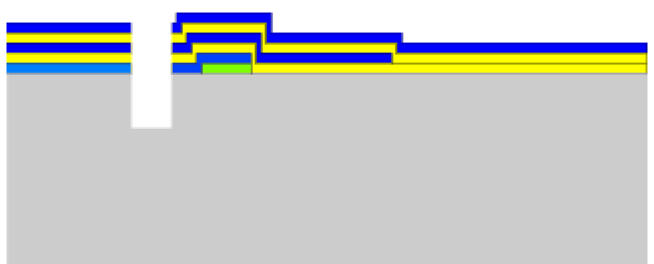


Zoomed View of the Interconnection Channel. Each Polysilicon Cantilever Spring Connects to a Corresponding Platinum Conductor Inside the Channel

MEMS Socket Submodule Fabrication Process

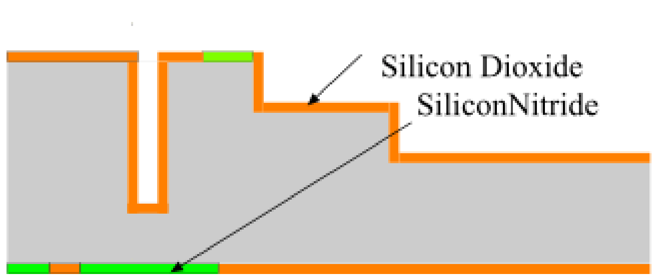


70 nm thick PECVD silicon nitride is deposited, patterned and etched on the top of a 400 μm thick silicon wafer. Three layers of aluminum-negative photoresist laminations are deposited.

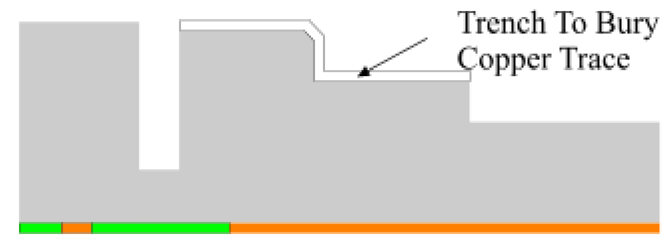


O_2 ashing of the negative photoresist is carried out by ICP-RIE method. The wafer is then successively ICP-RIE etched using Aluminum and negative resist laminations as delayed mask.

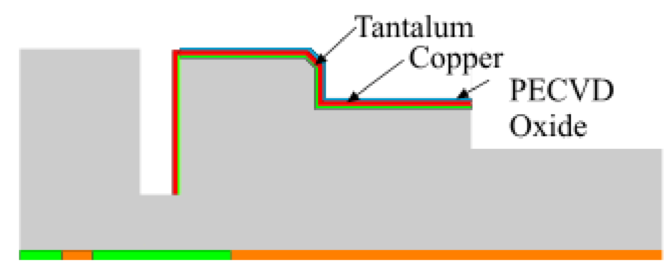
After the 3rd ICP-RIE process, the wafer patterning is completed. The 3rd Aluminum mask is then stripped.



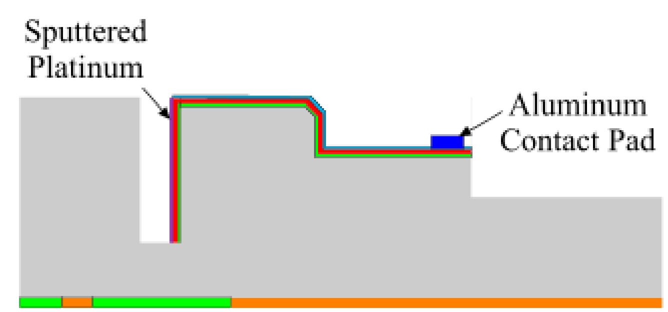
70 nm thick PECVD nitride is then deposited and patterned on the wafer backside. Thermal oxide is grown on both sides of the wafer and patterned.



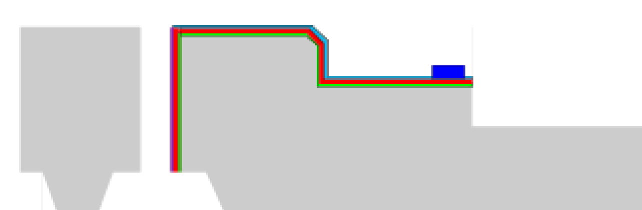
PECVD nitride on the wafer topside is removed. The wafer is TMAH etched to form the slant corner on the top. The wafer is then RIE etched to form 5 μm deep by 35 μm wide trenches.



Tantalum is sputter deposited and patterned in the trenches. 1.0 μm thick copper is sputtered and patterned. Finally a 3.5 μm thick silicon dioxide is PECVD deposited to protect the copper traces from oxidation.

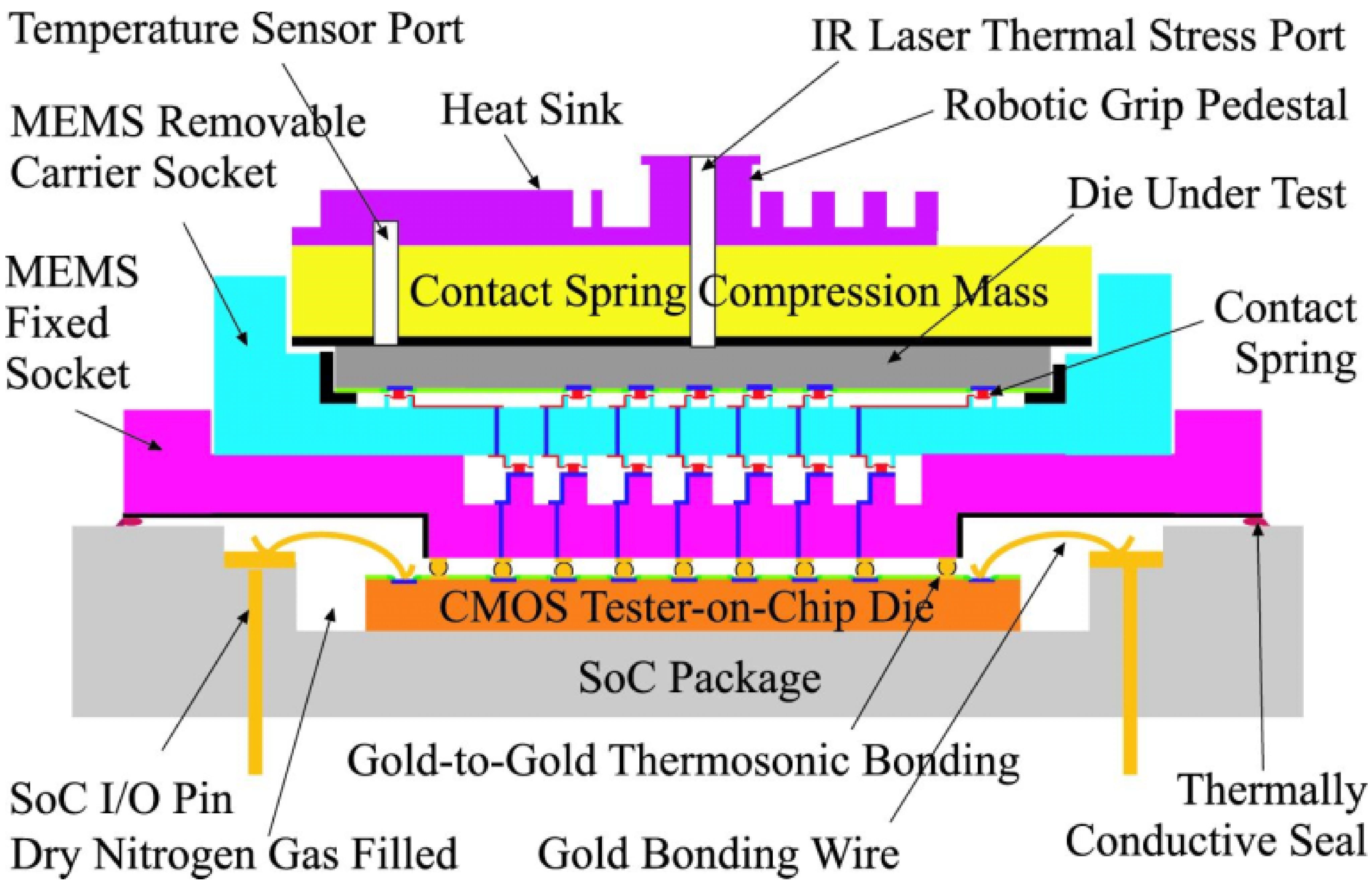


75x75 μm^2 Aluminum contact pads are then formed. 200 nm thick platinum is then sputter deposited in the interconnection shaft and pattered using an electrodeposited photoresist.

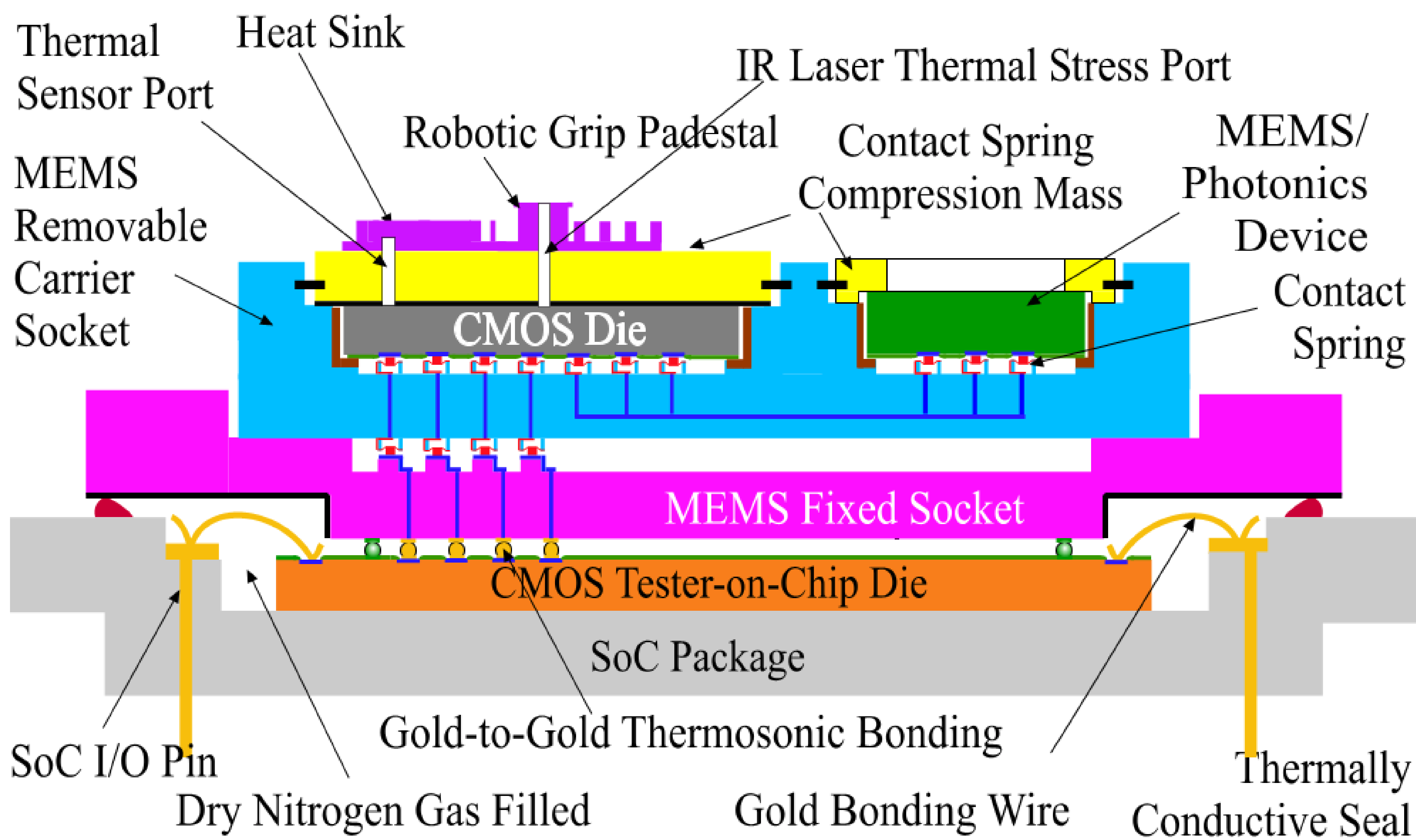


Wafer backside nitride is stripped. Anisotropic etching is performed on the wafer backside using TMAH to complete the fabrication process.

CMOS Die Testing Configuration: Concept

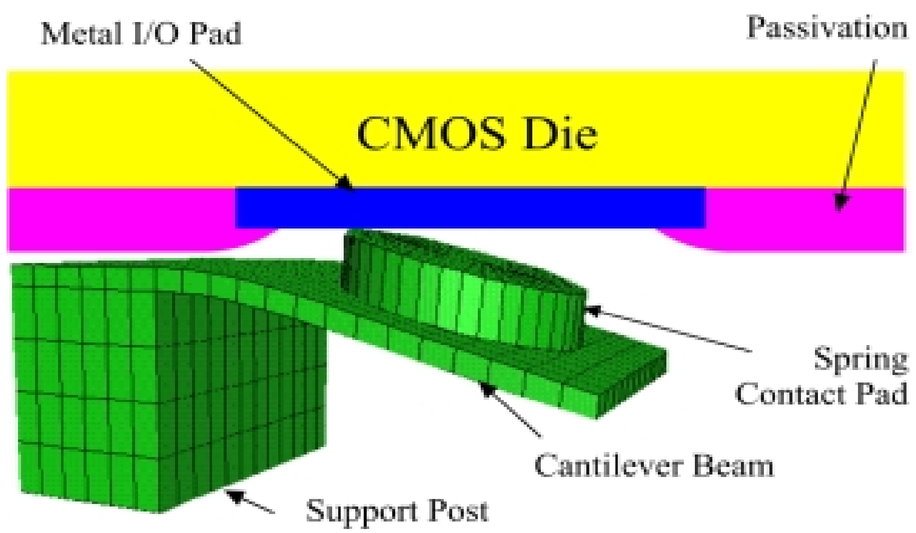


Multiple Technology Devices or Systems Testing Configuration



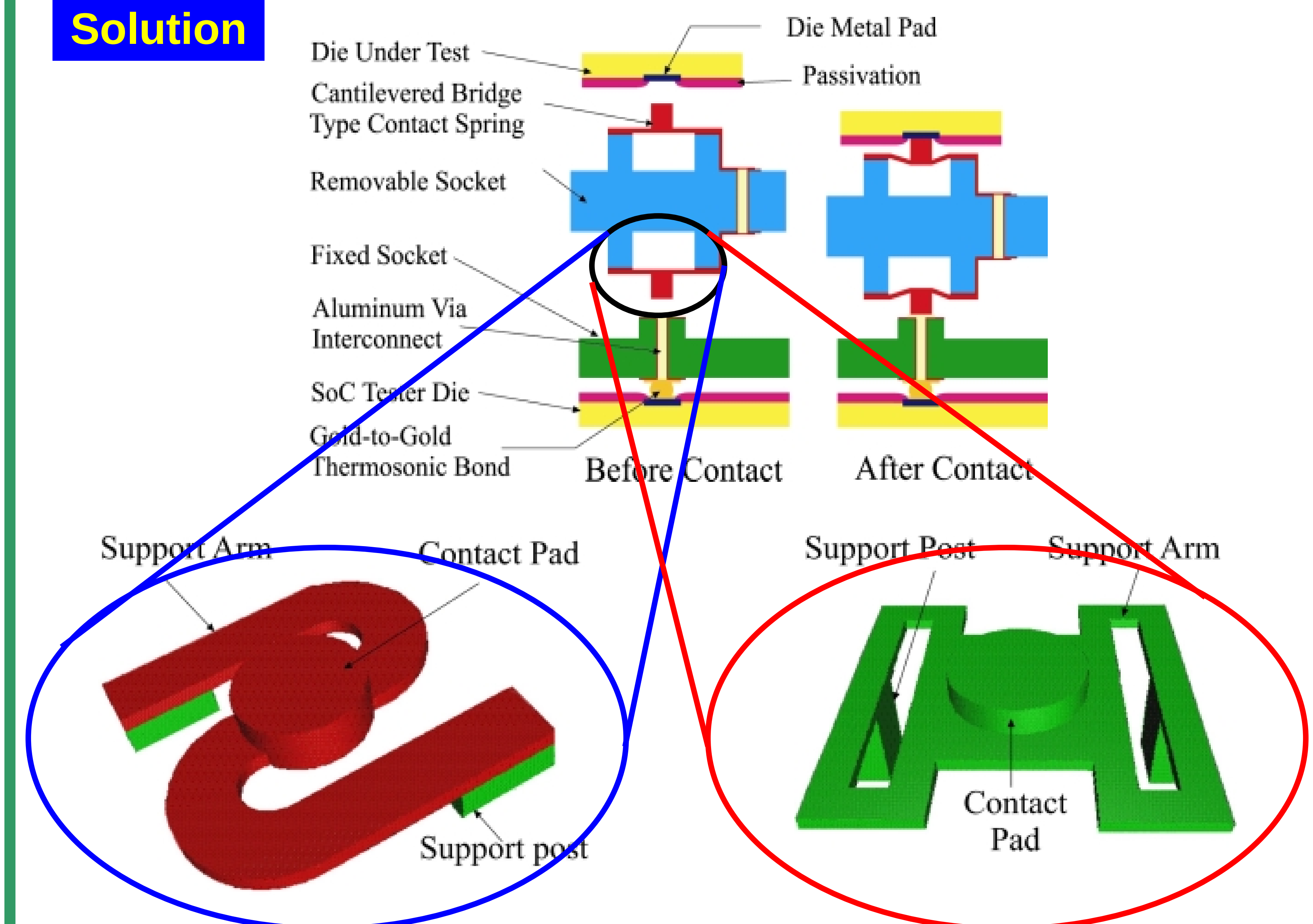
Microspring Contact Design Considerations

Problem



- Due to a uniform pressure applied on the top, the contact pad undergoes a torsional deformation that results in a curved top surface
- The whole contact pad surface does not come in contact with the die metal pad
- The result is a higher resistance line-type (arc) contact

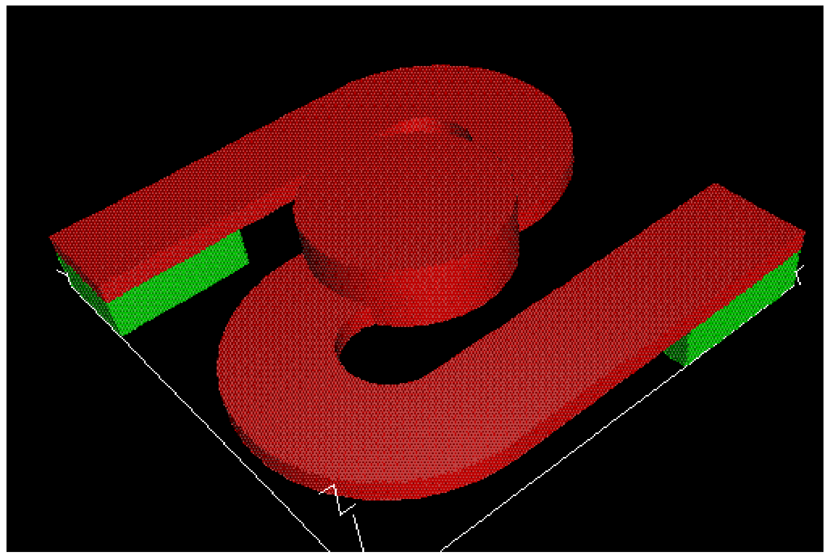
Solution



Z-Shaped - High Force Application

Square-Shaped - Low Force Application

Microspring Contact Design specifications

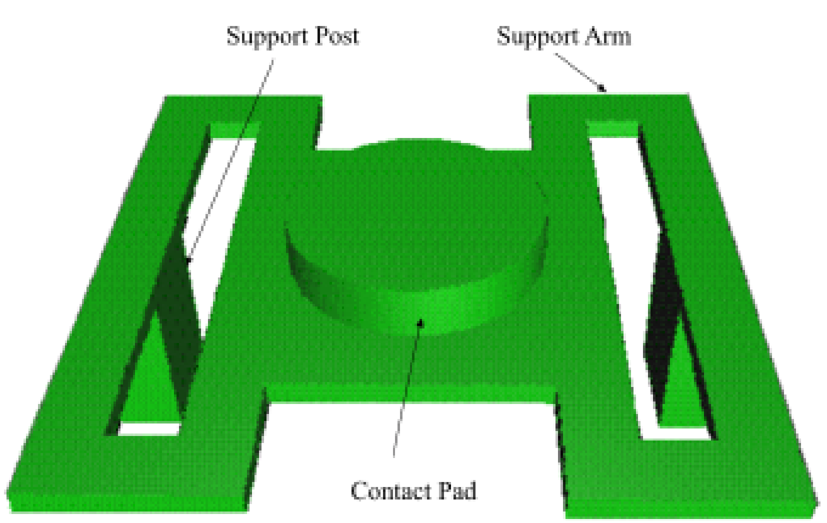


Z-shaped Geometry

- Spring area: 100 x 100 μm^2
- Contact pad diameter: 40 μm
- Contact pad height: 10 μm
- Support arm thickness: 5 μm
- Support arm width: 20 μm
- Contact force: 5 mN
- Spring material: Copper

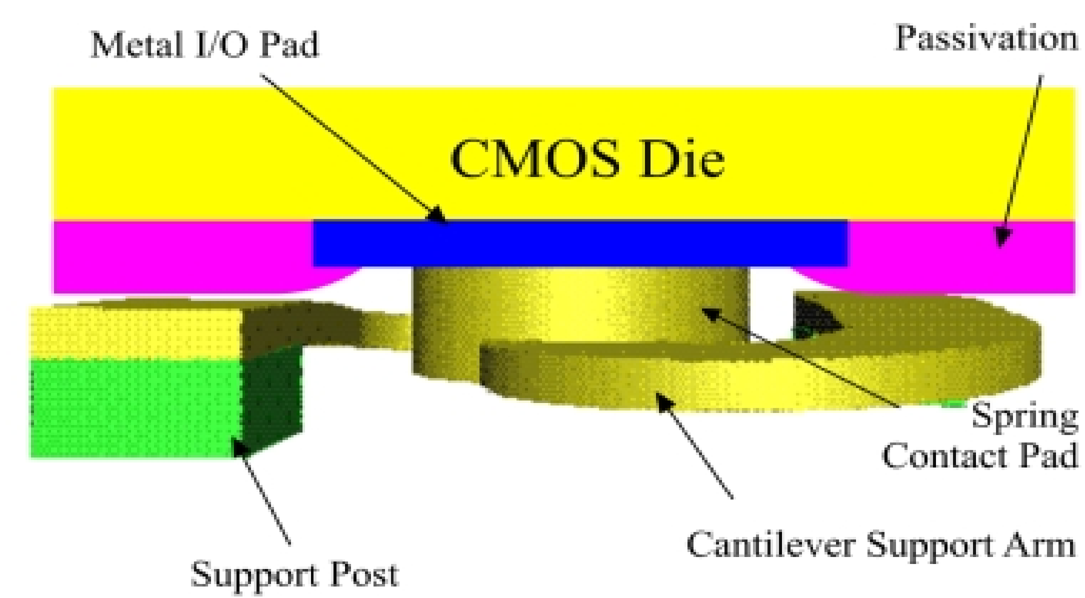
Major Design Features

- 150 μm pitch
- 30 μm tolerance in both X and Y directions
- Excellent elastic properties
- 19.3 mΩ contact resistance
- Excellent thermal properties at 150 ^{0} C
- Further down scalable



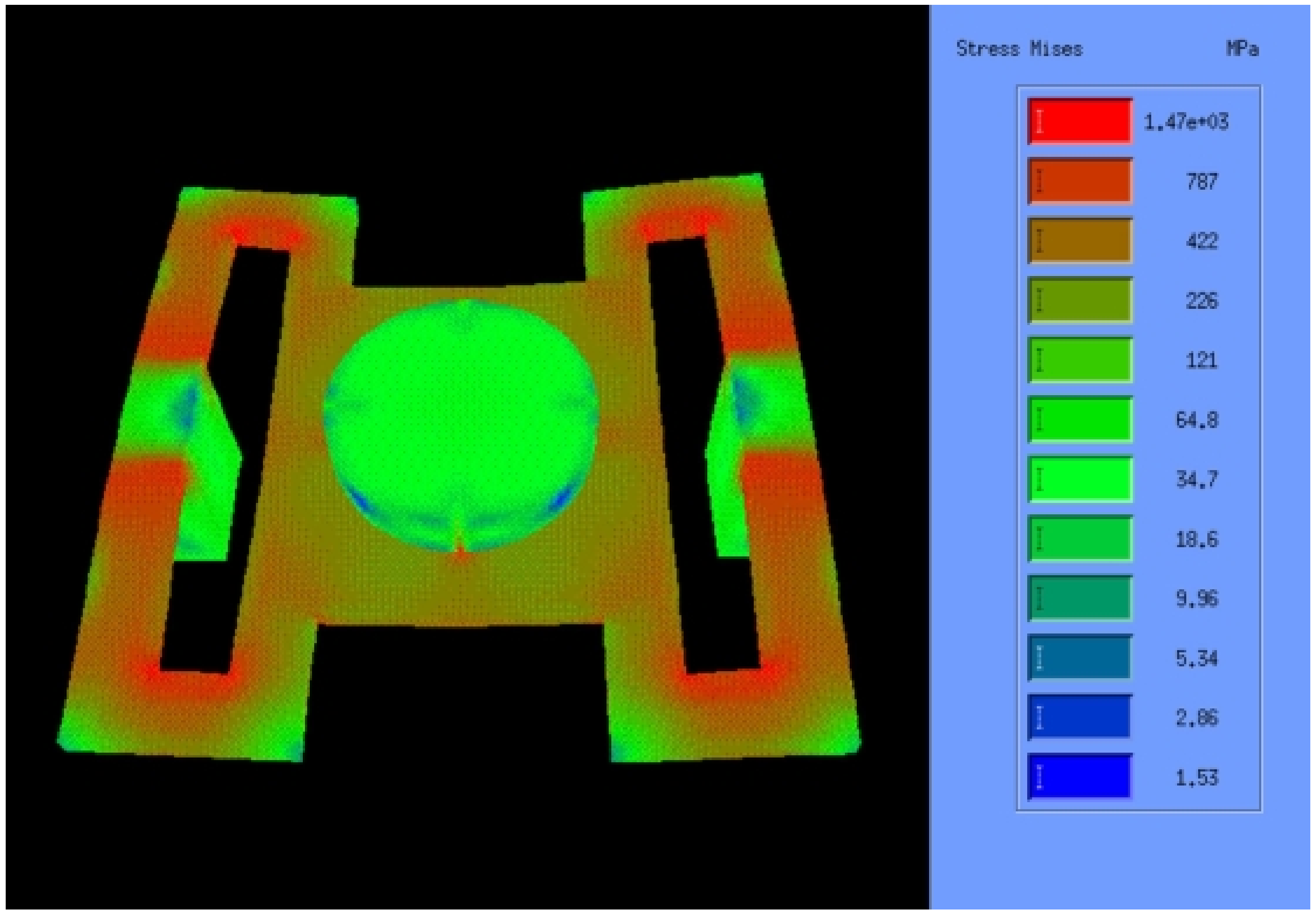
Square Geometry

- Spring area: 100 x 100 μm^2
- Contact pad diameter: 40 μm
- Contact pad height: 5 μm
- Support arm thickness: 2 μm
- Support arm length: 70 μm
- Contact force: 1.35 mN
- Spring material: Copper

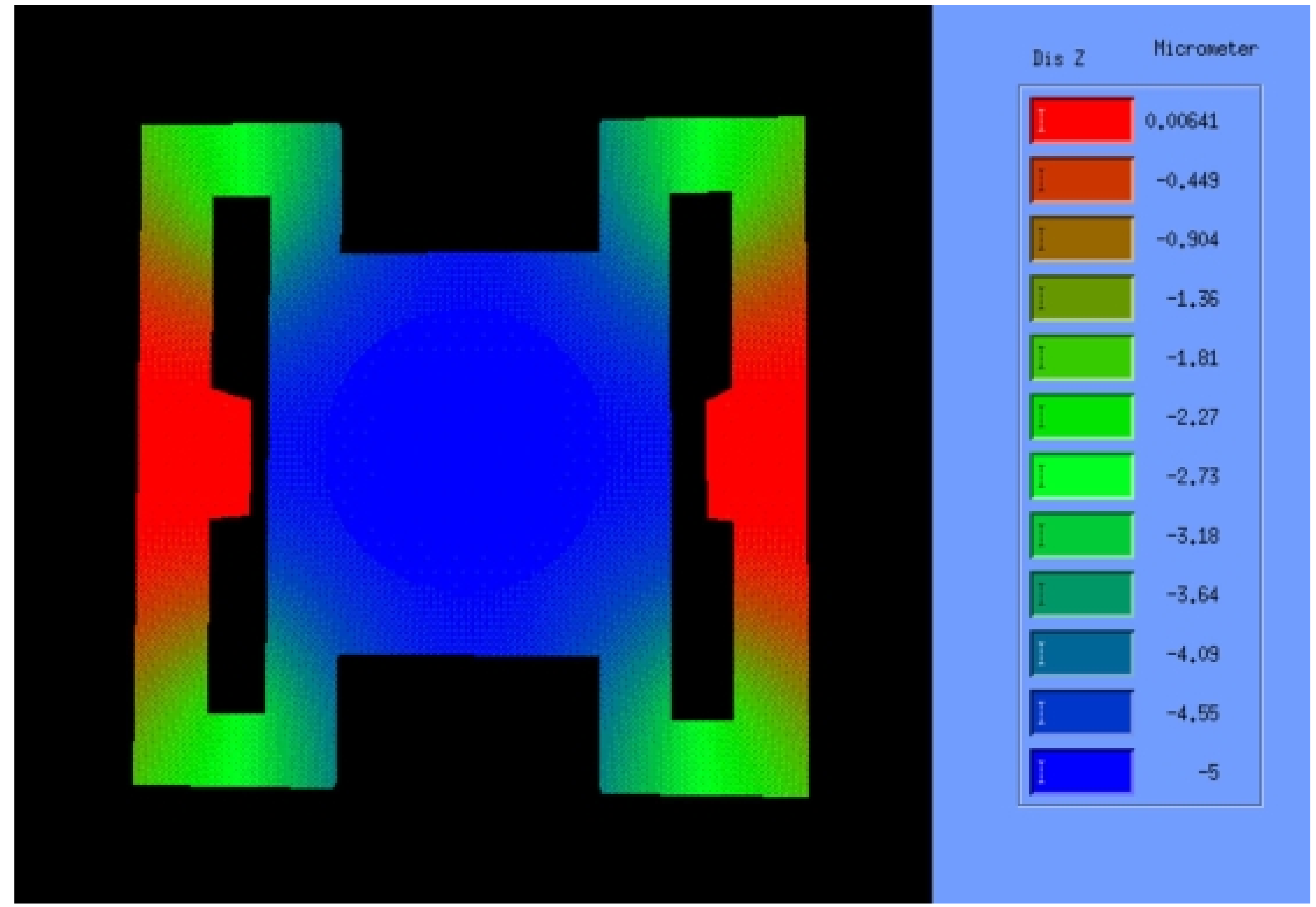


Result: Excellent Connectivity

FEA Simulation Results: Square-Shaped Microspring Contact



Von Mises stress (Max. 1.47 GPa)



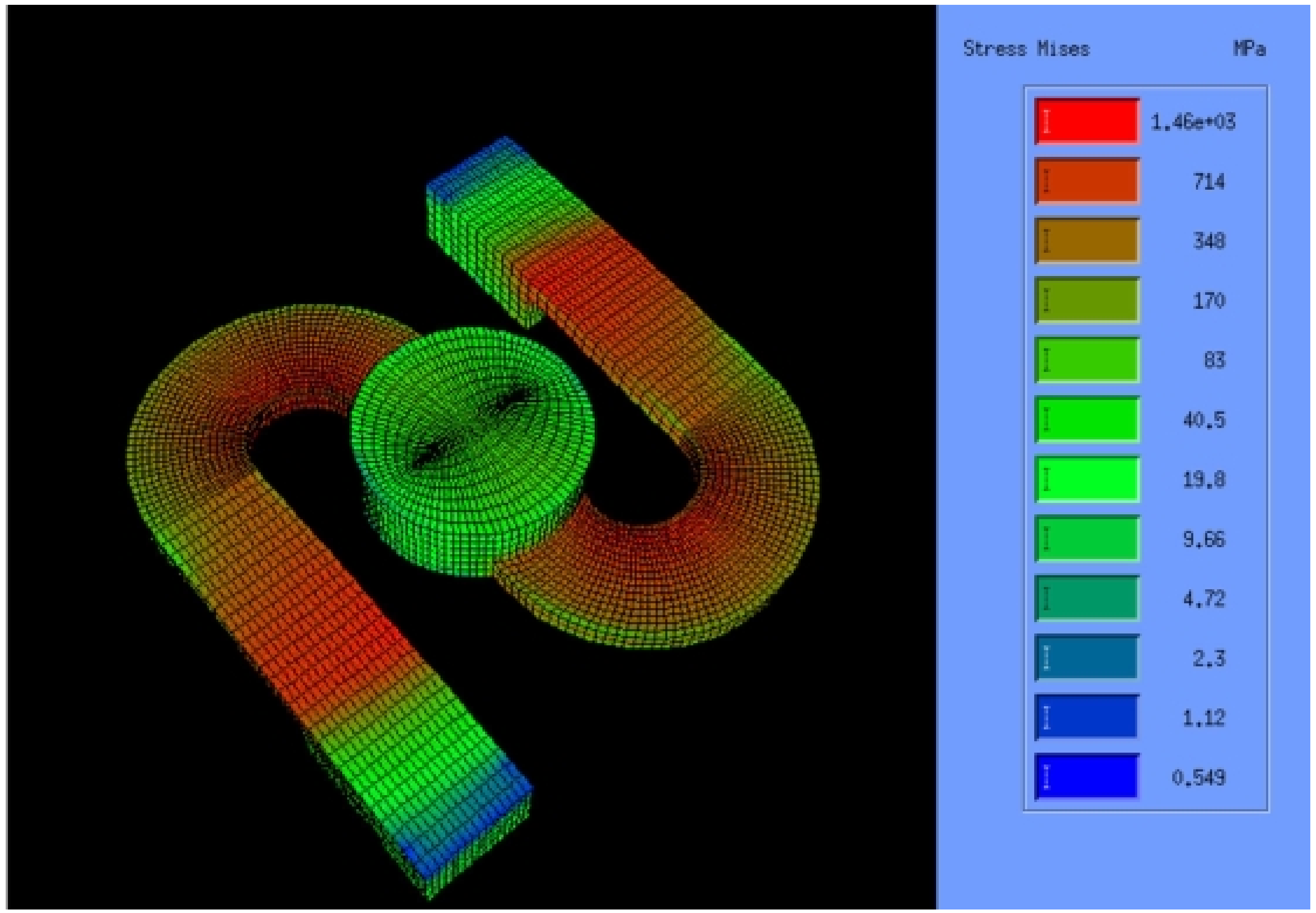
Z-axis displacement is uniform throughout the contact pad area

The Von Mises stress is within the elastic limit of copper with a reasonable safety margin for the desired Z-axis displacement

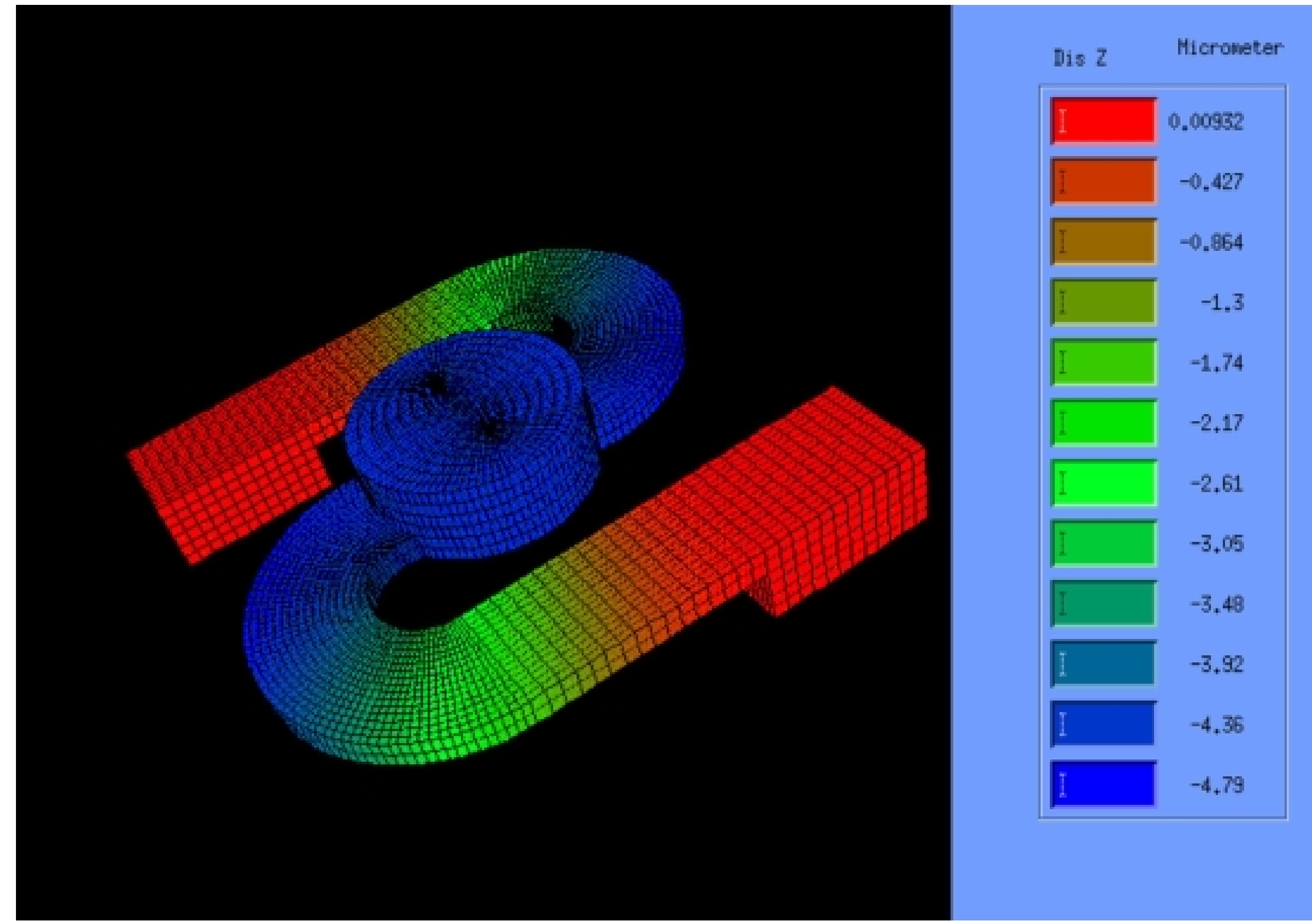
Applied force: 1.35 mN

Max. Z-axis displacement: 5 µm

FEA Simulation Results: Z-shaped Microspring Contact



Von Mises stress (Max. 1.46 GPa)



Z-axis displacement is uniform throughout the contact pad area

The Von Mises stress is within the elastic limit of copper with a reasonable safety margin for the desired Z-axis displacement

Applied force: 5 mN

Max. Z-axis displacement: 4.8 µm

Conclusions

The design of a MEMS micropackaging system is presented that enables SoC integration. Major components of the system consist of MEMS socket submodules and insertable/removable microbus card(s). The system demonstrates advantages over conventional packaging systems in terms of: (a) easy removal or integration of a new die/device; (b) permanent or non-permanent module integration; (c) reconfigurable connectivity using microbus card, and; (d) an application specific custom packaging geometry that can be batch fabricated using MEMS technology.

Acknowledgements

The research has been made possible by the interest and support provided by the Gennum Corporation of Burlington, Ontario. The authors greatly acknowledge the generous support of the following partners: CMC, MICRONET and NSERC. The Research Centre for Integrated Microsystems at the University of Windsor would like to acknowledge the access to the outstanding MEMS technology provided by the IntelliSense Corporation, 16 Upton Drive, Wilmington, MA 01887, USA as part of a collaborative partnership.

References

1. Yoshio Mita, Makoto Mita, Agnes Tixier, Jean-Phillipe Gouy and Hiroyuki Fujita, “Embedded-Mask-methods for mm-scale Multilayer Vertical/Slanted Si Structures”, *Proceedings of MEMS 2000 Conf*., Miyajaki, Japan, pp. 300-305.

2. Agnes Tixier, Yoshio Mita, Satoshi Oshima, Jean-Phillipe Gouy and Hiroyuki Fujita, “3-D Microsystem Packaging for Interconnecting Electrical, Optical and Mechanical Microdevices to the External World”, *Proc. of MEMS 2000 Conf.*, Miyajaki, Japan, pp. 698-703.

3. H. GoldStein, “Packages Go Vertical”, *IEEE Spectrum*, August 2001, pp. 46-51.