ENGENIUSMICRO

Development of Electronic Packages with Integrated Environmental Mitigation

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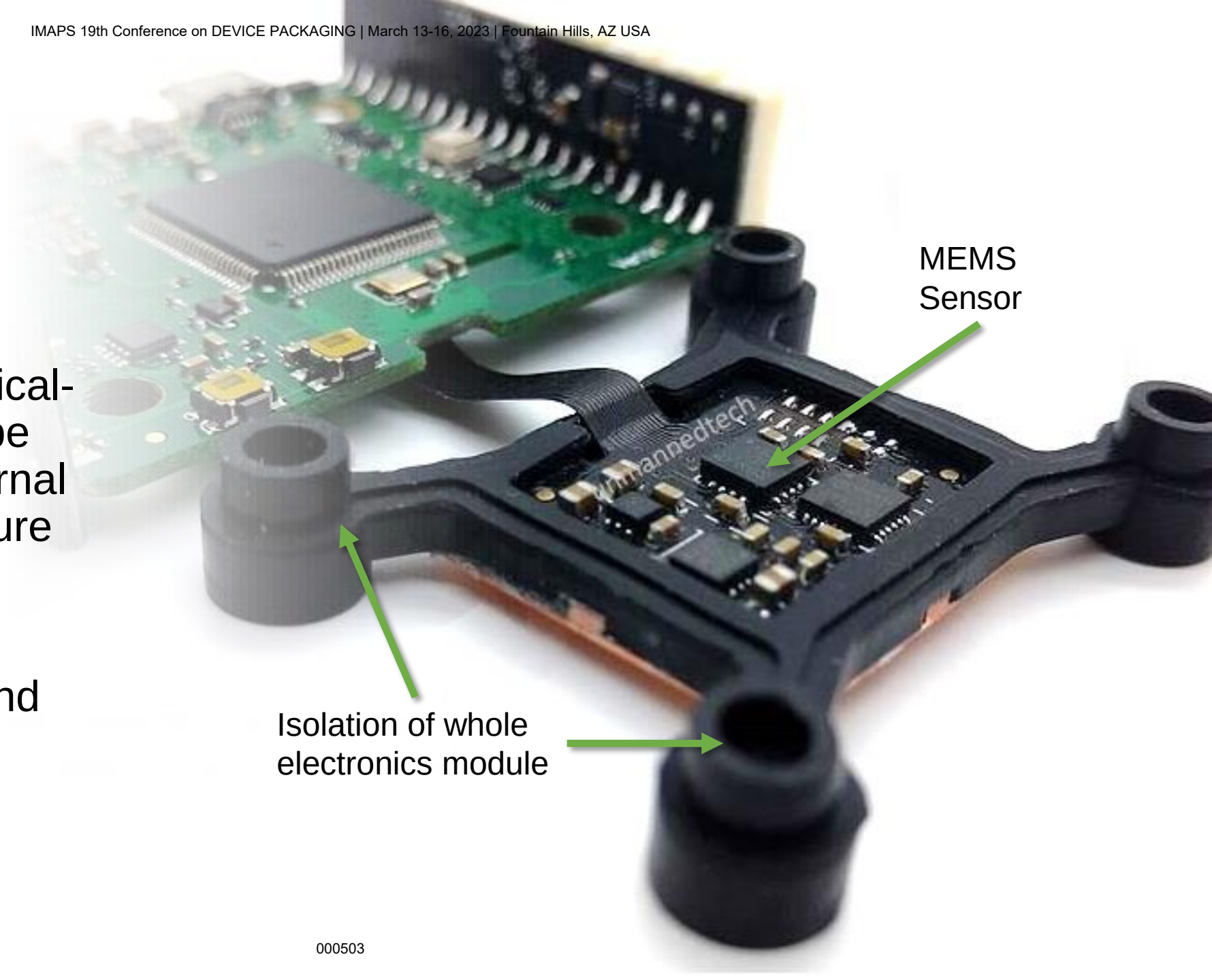
Problem

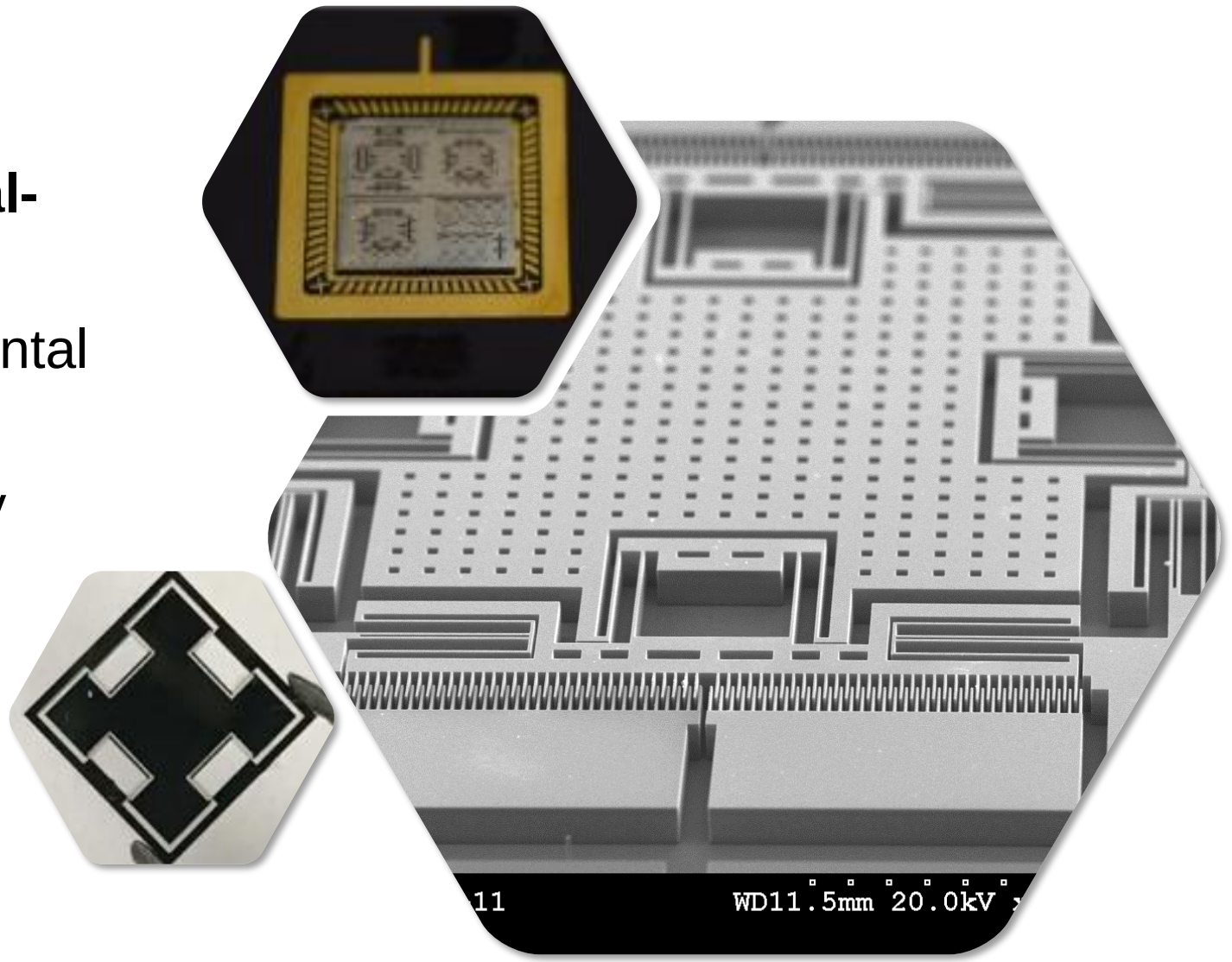
- Micro-electromechanical-systems (MEMS) can be highly sensitive to external vibration and temperature environments
- Common mitigations compromise the size and weight of the entire electronics system



Objective

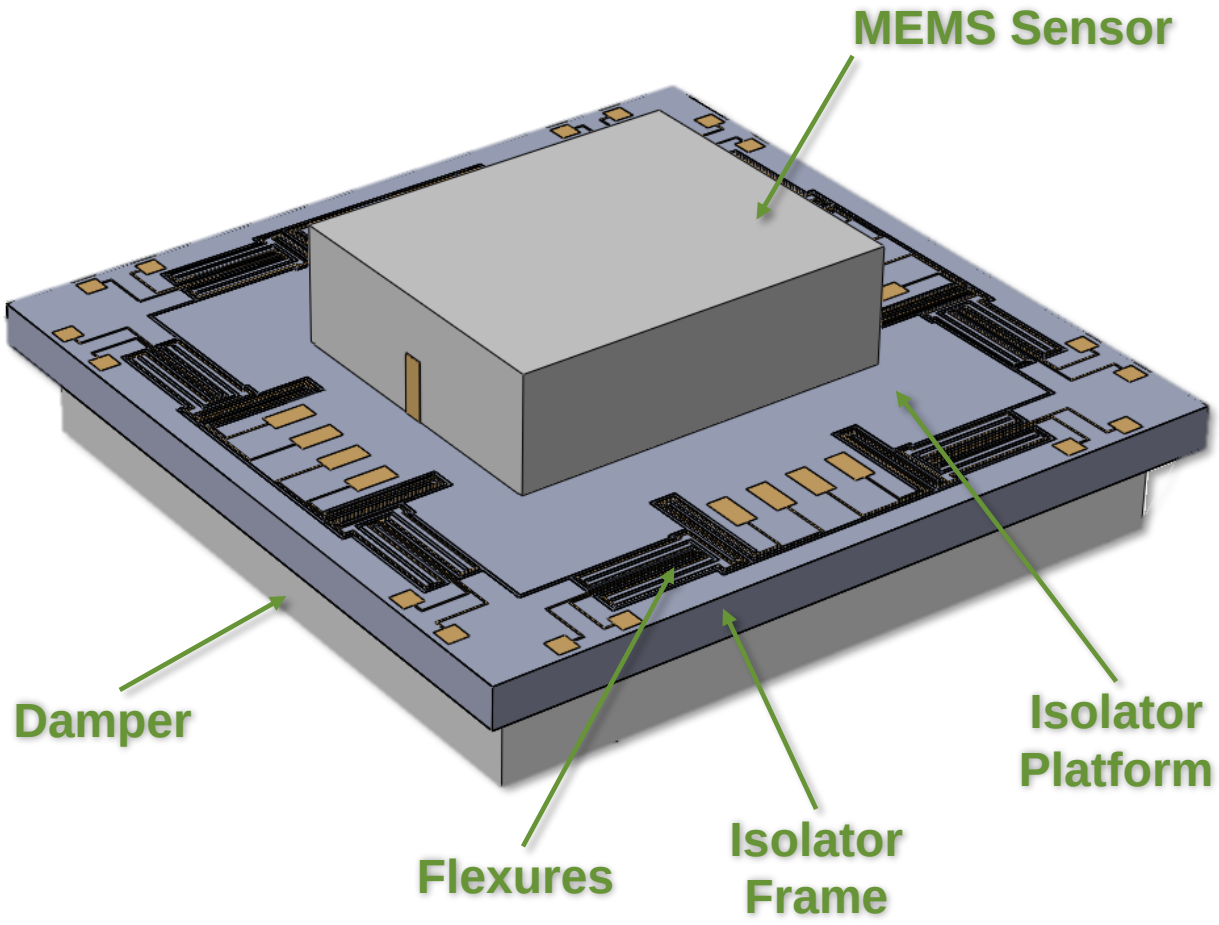
Protect micro-electromechanical-systems (MEMS) sensors

- Mitigate fracture from environmental shock and vibration.
- Mitigate sensor errors caused by external temp changes
- Maintain MEMS size and power advantages
- Maintain or improve sensor performance



Principal of Operation

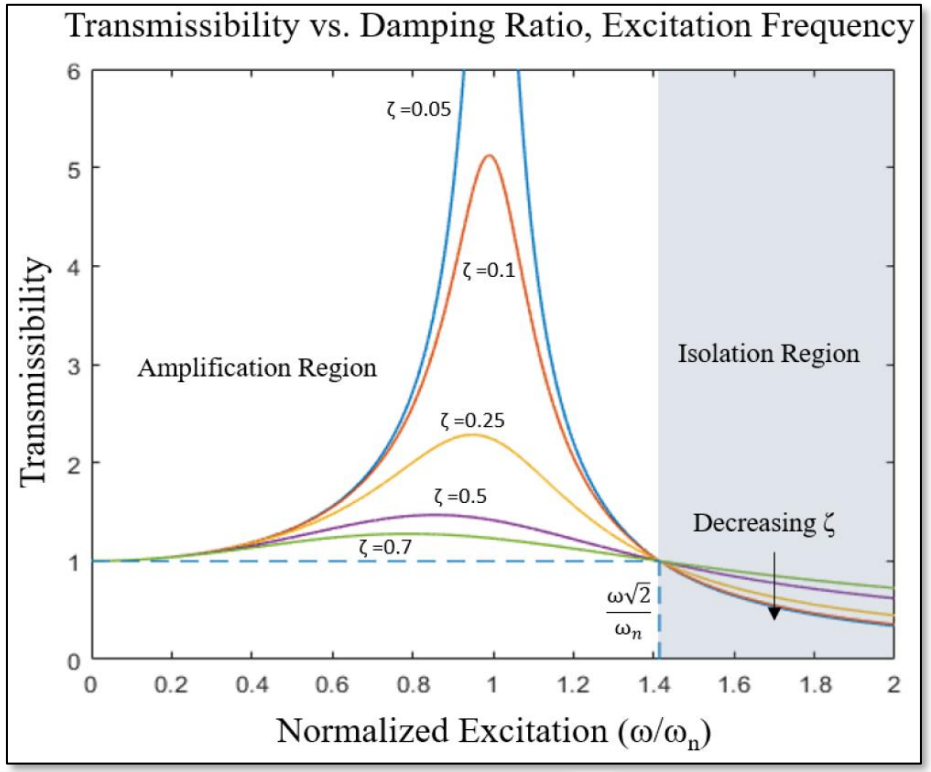
- MEMS Sensor packaged on microfabricated silicon isolation platform
- Platform has flexures compliant in X, Y, and Z directions
- Platform performs as a mechanical low pass filter
- Damper provides shock and vibration attenuation

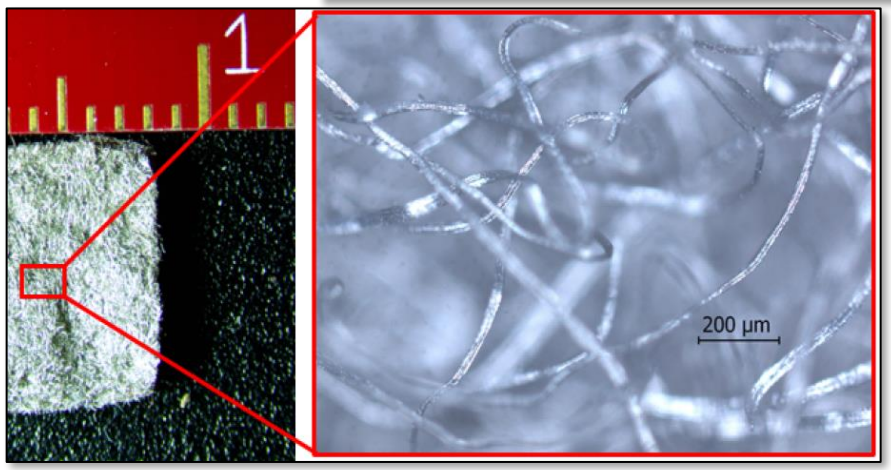


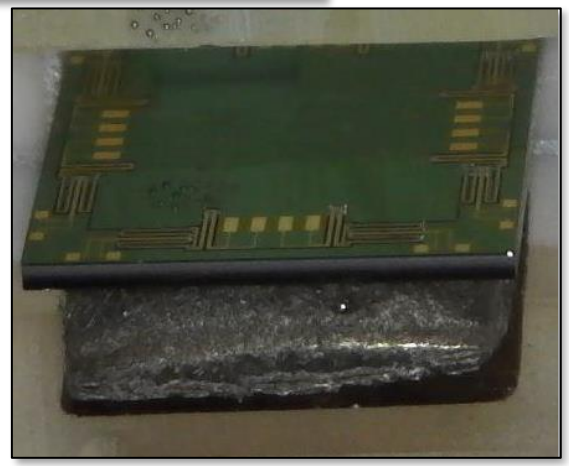
View of MEMS sensor and isolator components

Nickel Mesh Damper

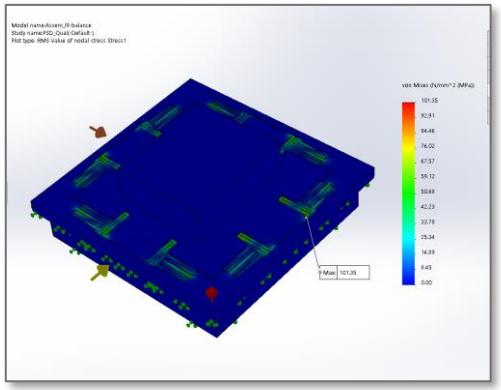
- Damper material should be compatible with hermetic packaging
- Experimentally determined damping ratios range from 0.1 to 0.21 with increasing fiber diameter
- Reflow soldered to isolator and bottom of package cavity. Have also glass frit bonded mesh to packaged

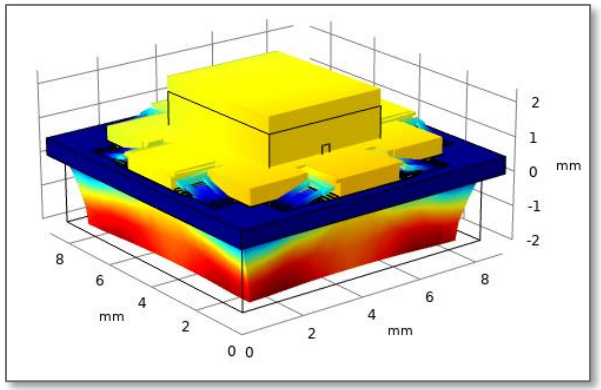


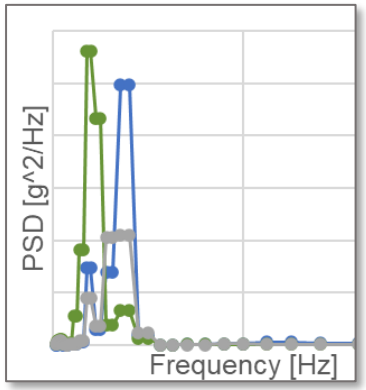


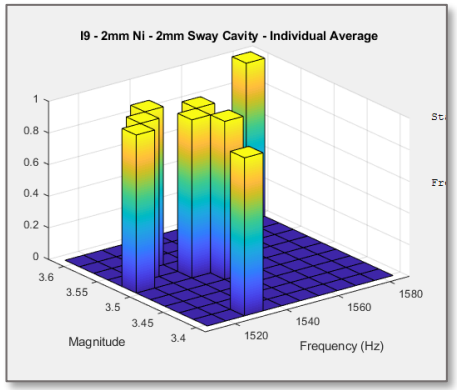


Isolator Design Process









Static Analysis

- Max VM Stress < 160MPa
- Max total strain <2%
- Max displacement/ no contact

Modal Analysis

- Promote translation modes 1-3
- Demote rotational modes
- Mass participation >80% in translation modes

Harmonic Analysis

- Determine transmissibility of input displacement to platform center
- Ensure max strain at resonance <2%
- Maintain yield stress safety factor of 1.5

Vibration Spectrum Analysis

- Test structure at maximum PSD for all phases of operation

Mfg Tolerance

- Effects of sensor misalignment
- Effects of assembly tolerance
- Design of Experiments and Analysis of Variance Methods used

Isolator Fabrication

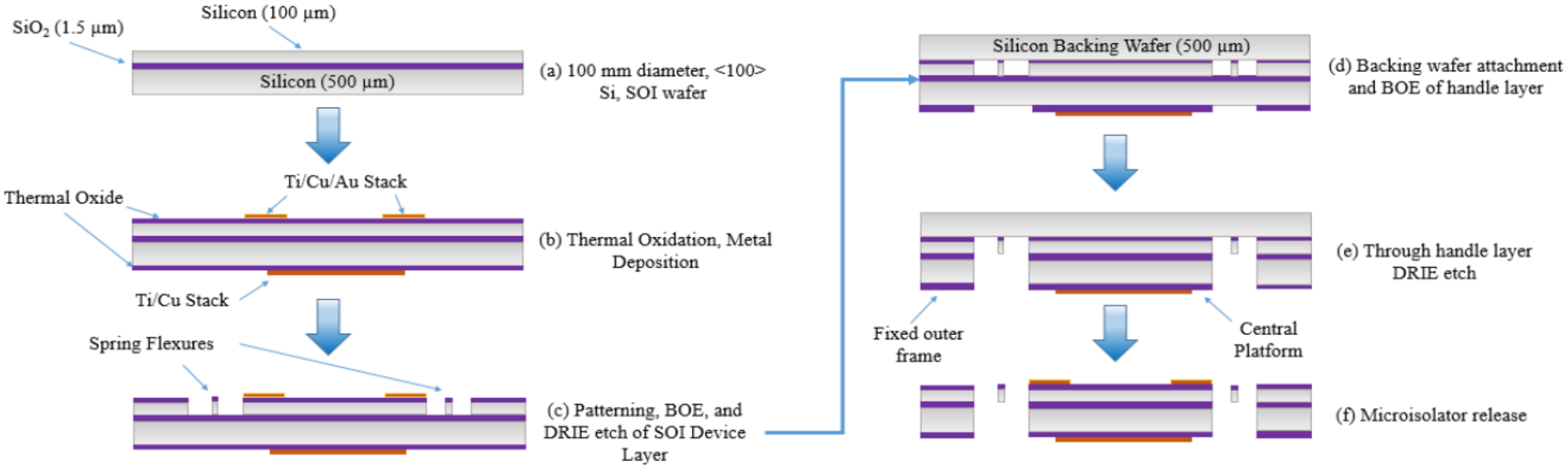
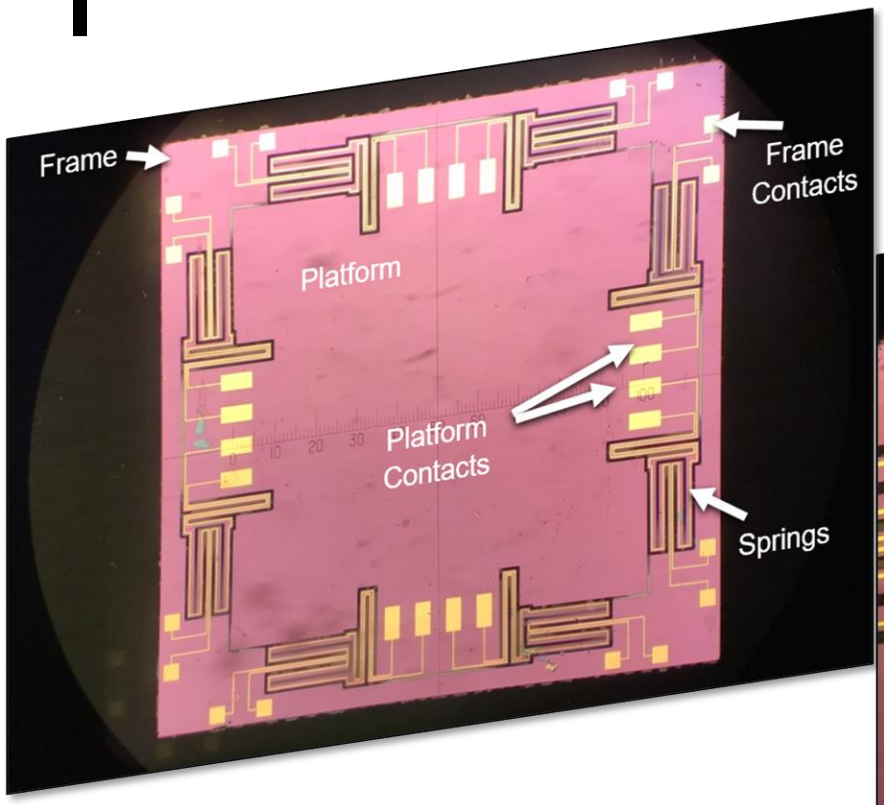
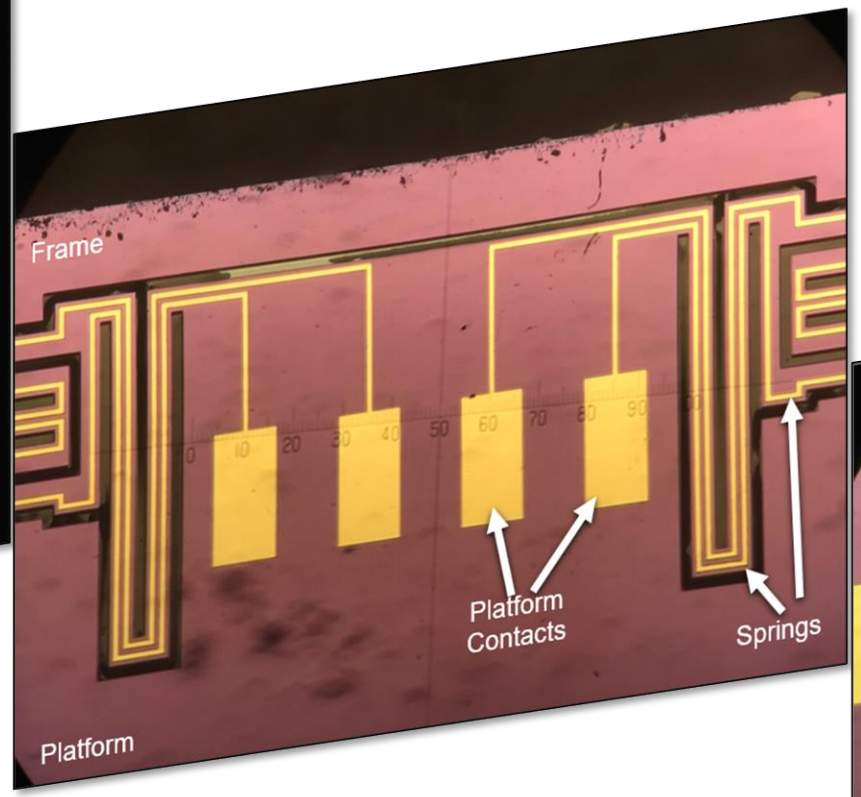
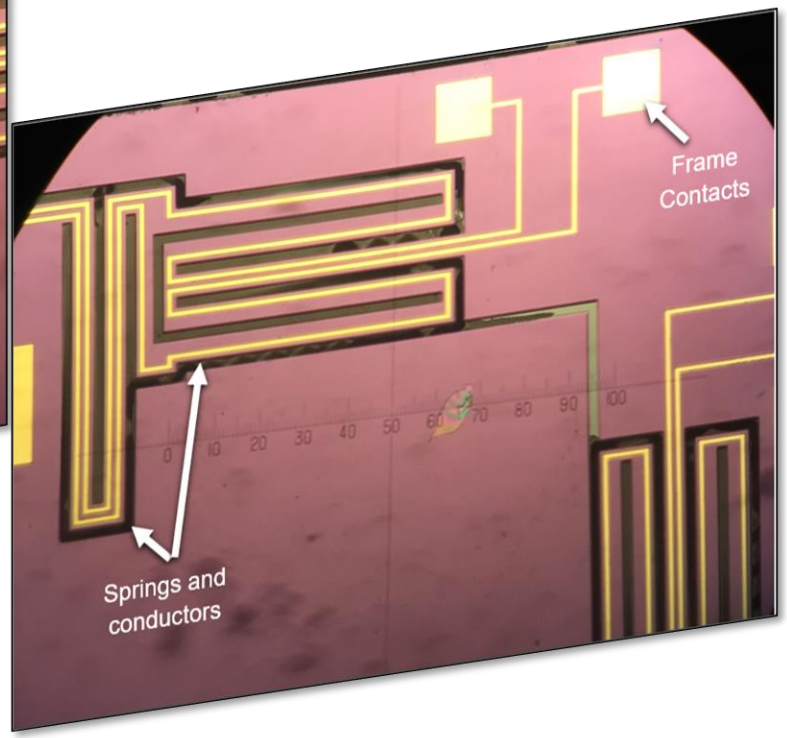


Image from: Bottenfield, Brent & Bond, Arthur & English, Brian & Flowers, George & Dean, Robert & Adams, Mark. (2021). Microfibrous Mesh and Polymer Damping of Micromachined Vibration Isolators. IEEE Transactions on Components, Packaging and Manufacturing Technology. PP. 1-1. 10.1109/TCPMT.2021.3063854.

Fabrication Results

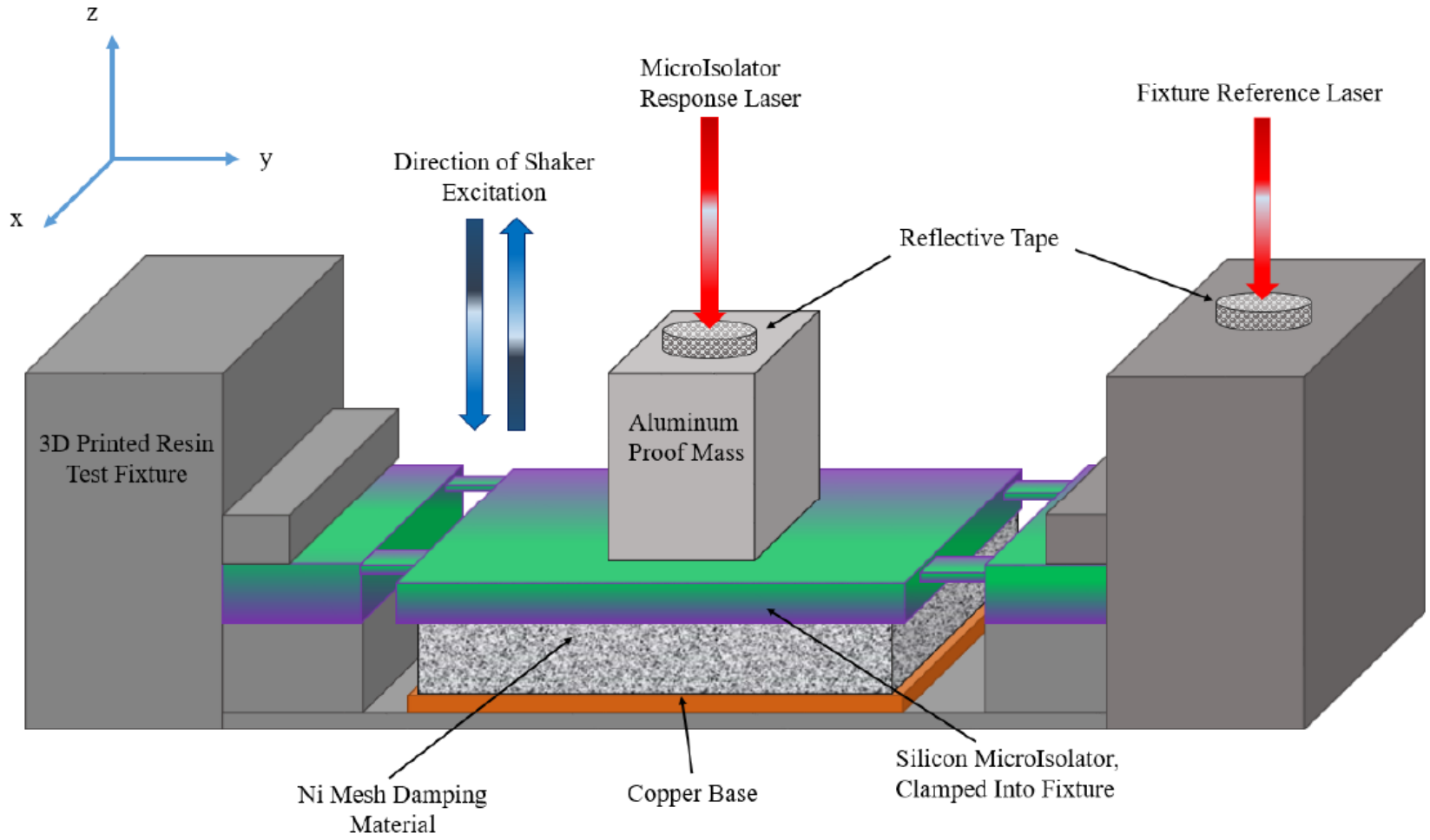






Testing

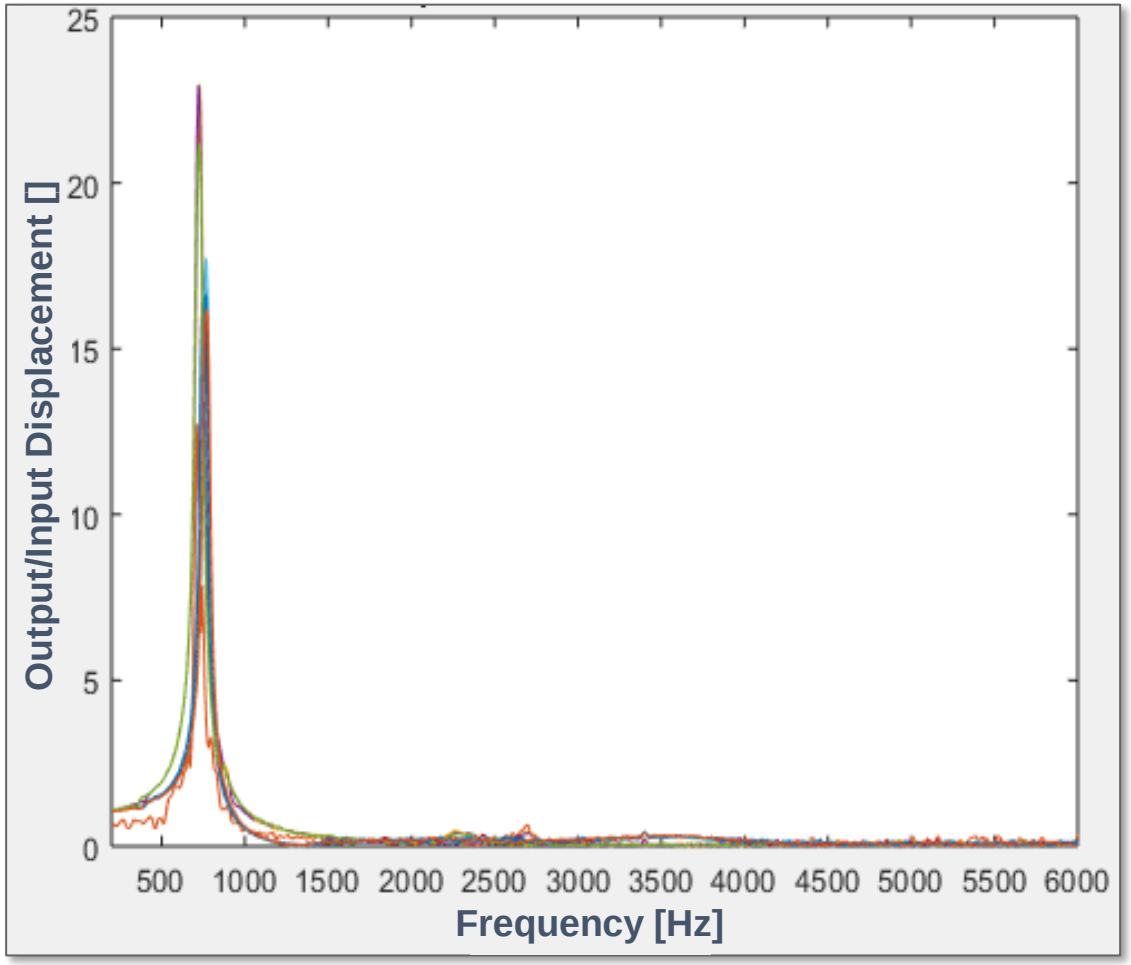
*Testing done at Auburn University



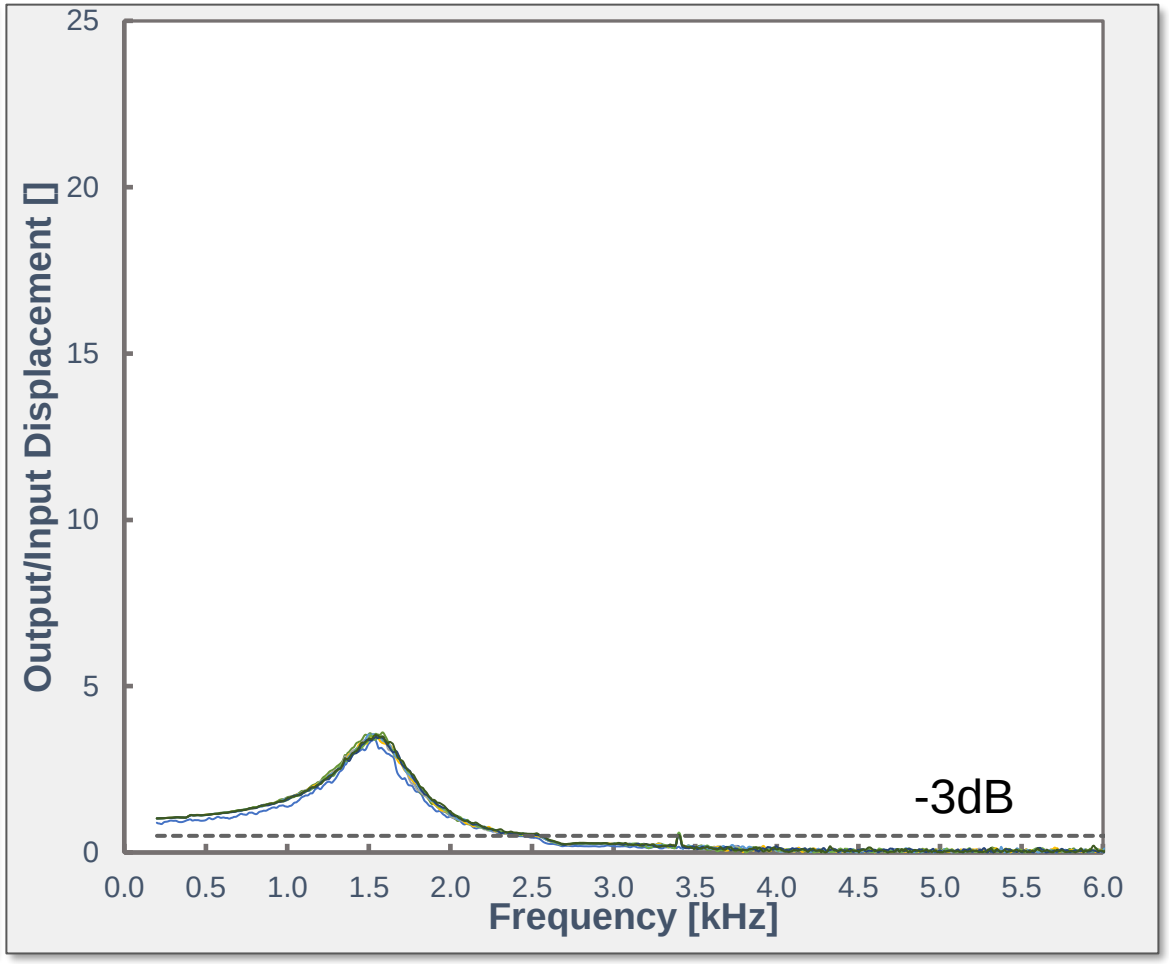
Ref. Bottenfield, Brent & Bond, Arthur & English, Brian & Flowers, George & Dean, Robert & Adams, Mark. (2021). Microfibrous Mesh and Polymer Damping of Micromachined Vibration Isolators. IEEE Transactions on Components, Packaging and Manufacturing Technology. PP. 1-1. 10.1109/TCPMT.2021.3063854.

Test Results

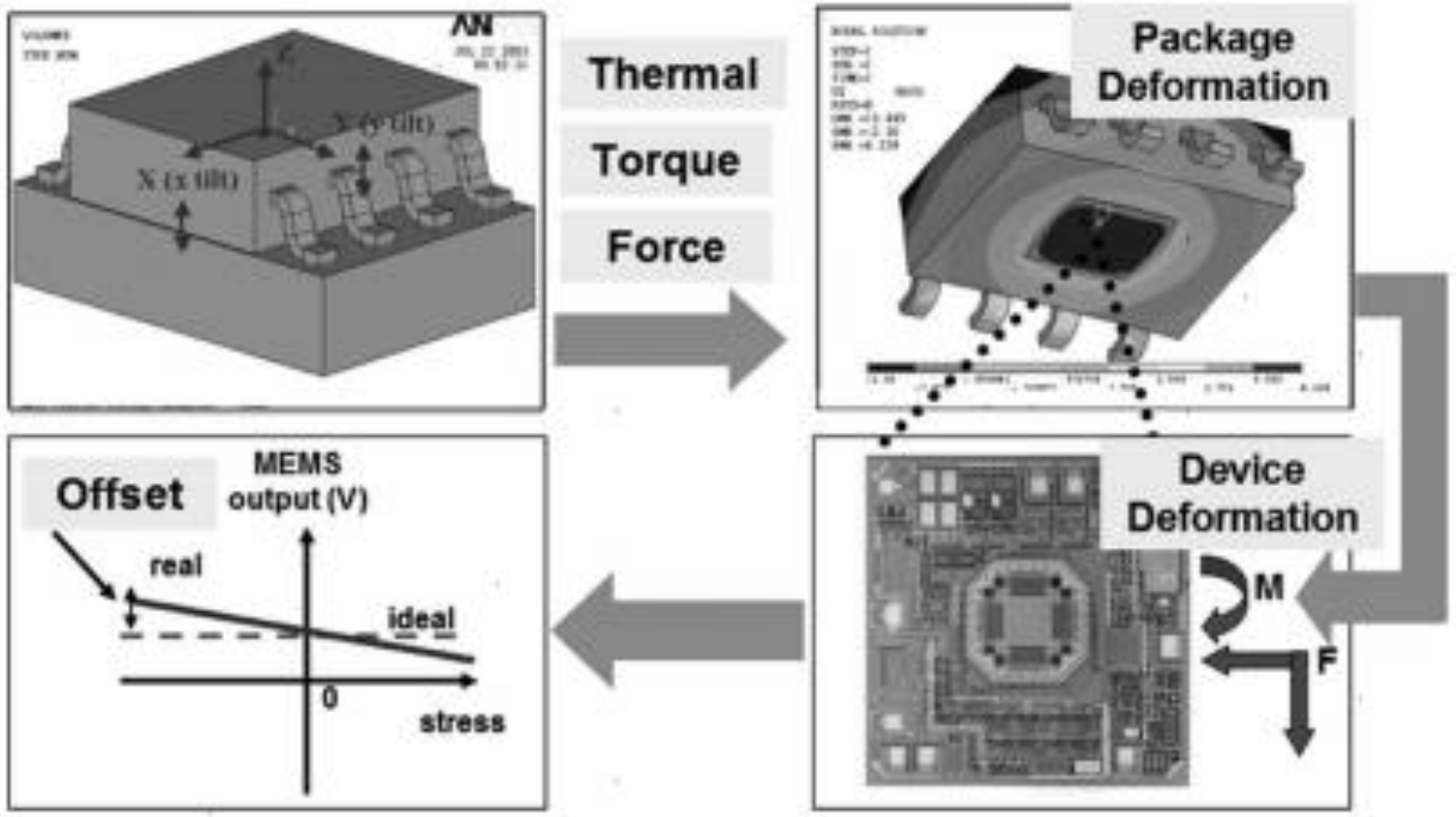
Undamped Response



Damped Response



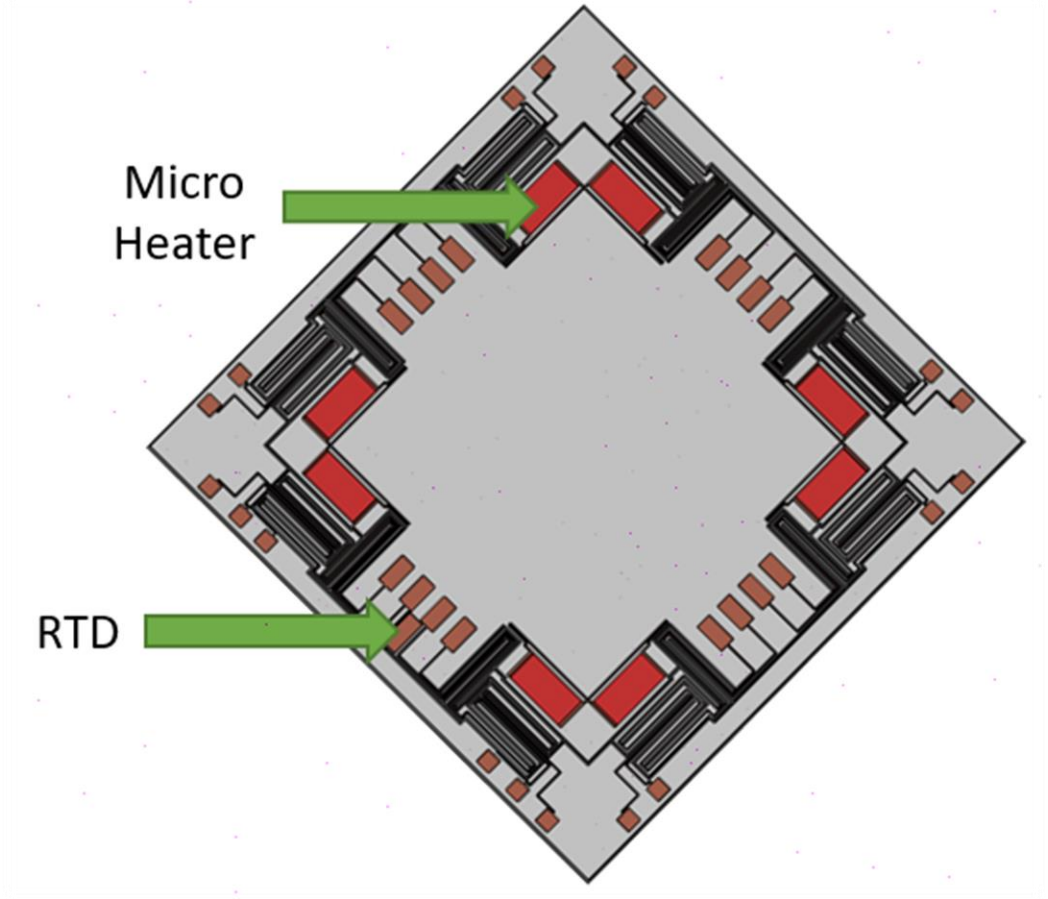
Errors from Temperature Instability

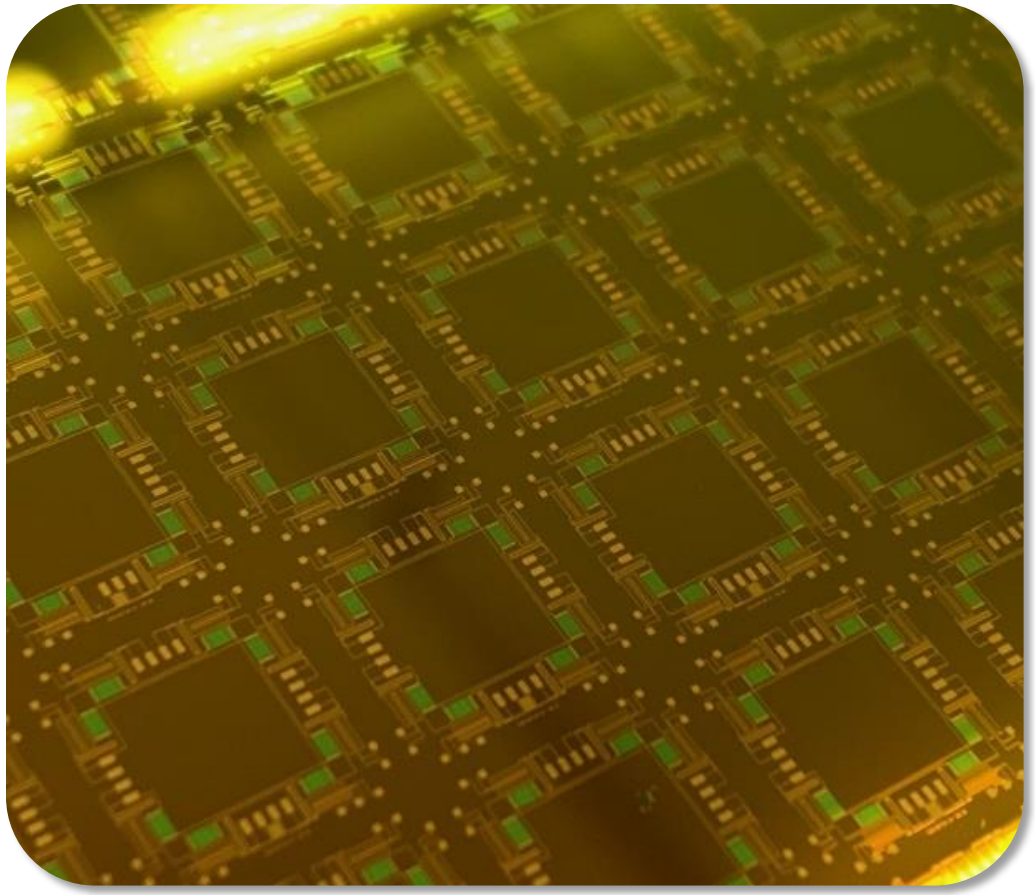


Figures from: X. Zhang, S. Park and M. W. Judy, "Accurate Assessment of Packaging Stress Effects on MEMS Sensors by Measurement and Sensor–Package Interaction Simulations," in *Journal of Microelectromechanical Systems*, vol. 16, no. 3, pp. 639-649, June 2007, doi: 10.1109/JMEMS.2007.897088.

Ovenization: How would you like your MEMS cooked?

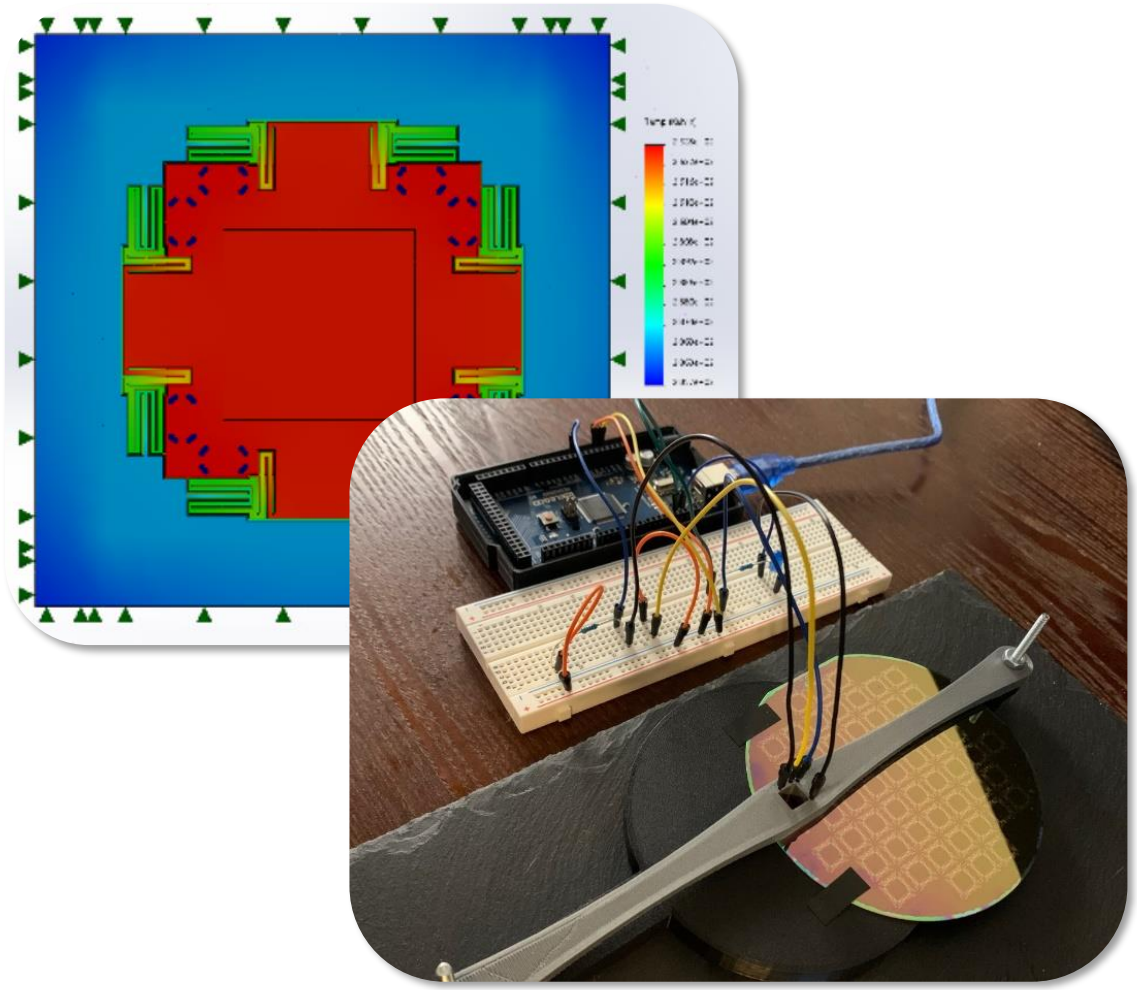
Phosphorus doped polysilicon microheaters added to further improve sensor long term stability by maintaining constant sensor temperature.





Preliminary Development & Testing

- Heaters designed for total max power of 100mW.
- Simulations shown that heaters can maintain platform temperature of 20C with ambient of -20C and a 10 W/m^2K convective coefficient.
- Developed PID feedback controls for maintaining a set temperature. Characterization of the RTDs and microheaters was required to do so.



Summary

- Mitigated vibrational noise errors via application of a chip scale micromachined isolators in combination with a microfibrous metal mesh damper
- Mitigated thermal strain errors via ovenization of isolator platform

Thank you!

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