Electromagnetic Vibration Energy Harvesters: Linear and Non-linear Systems

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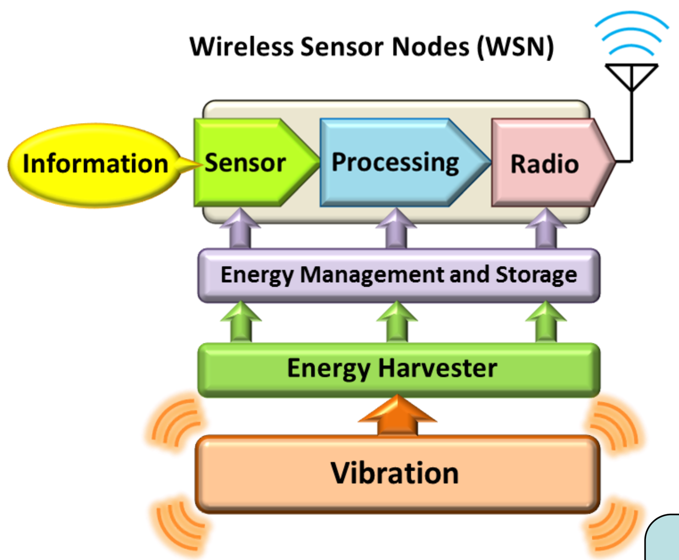
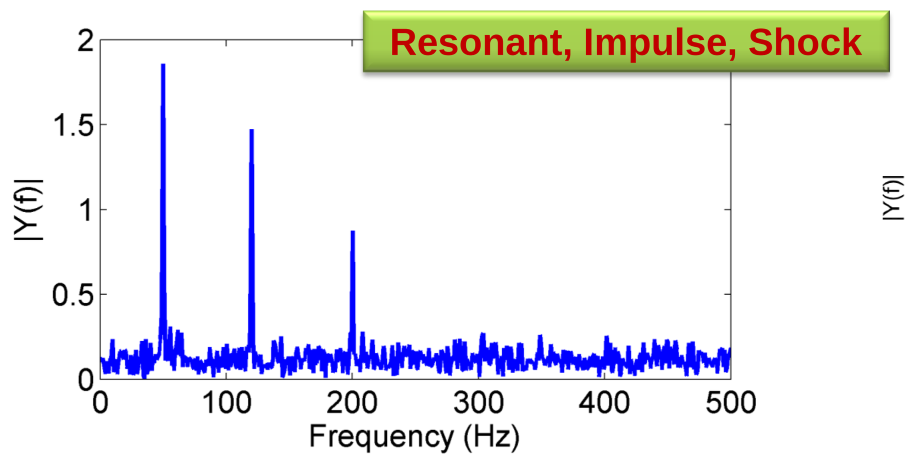
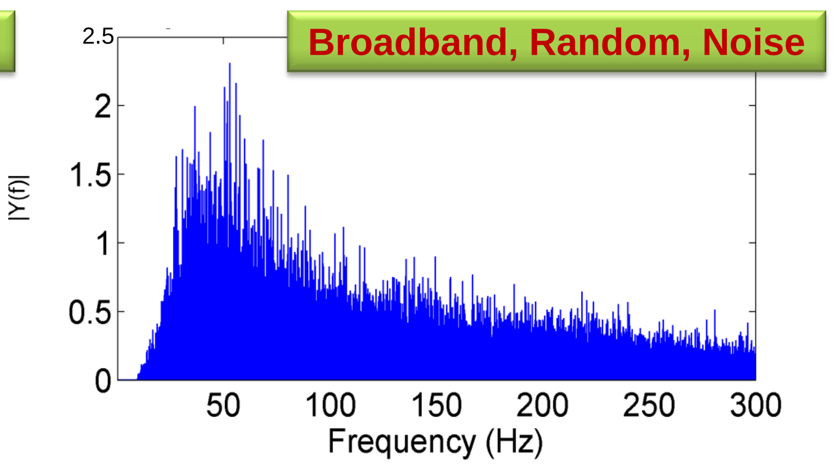
With the advent of the internet of things billions of embedded wireless sensor nodes will be exchanging data with each other. A long service life can be accomplished by utilizing energy harvesting technologies to supplement or replace batteries. Mechanical vibrations are an attractive source of harvestable energy due to their abundance in the urban and industrial environment. A major challenge in harnessing vibrations in a majority of environments is overcoming their random or frequency varying nature. The group is exploring novel methods of overcoming this through the utilization of nonlinear mechanisms as they yield a wider bandwidth to their linear counterparts.





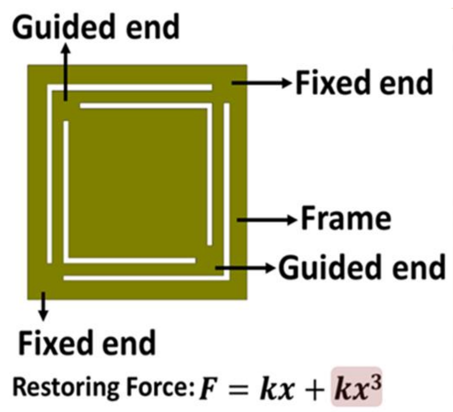


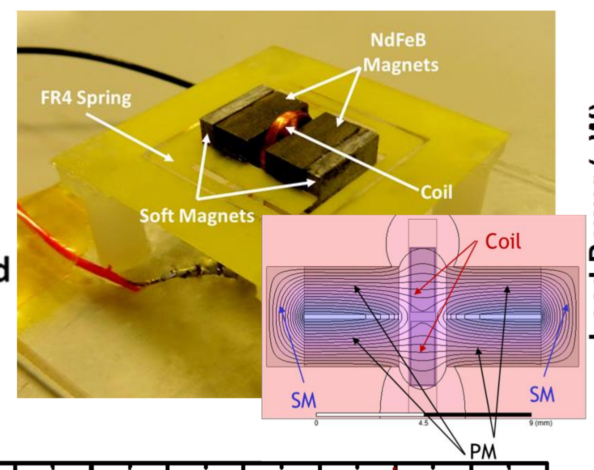
Application Areas: traffic (road safety/vehicle health); civil infrastructure monitoring; human and livestock monitoring; industrial systems monitoring

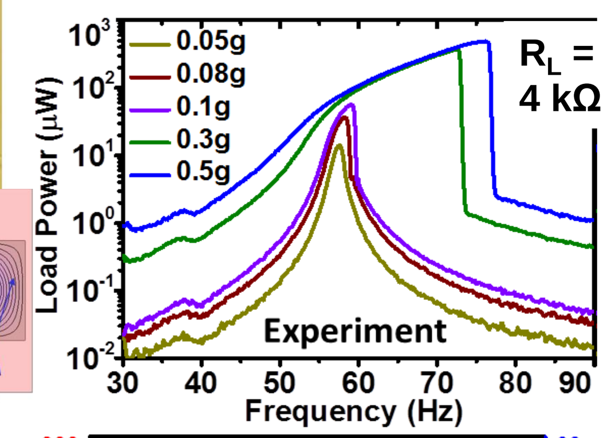
Non-Linear: Monostable Systems

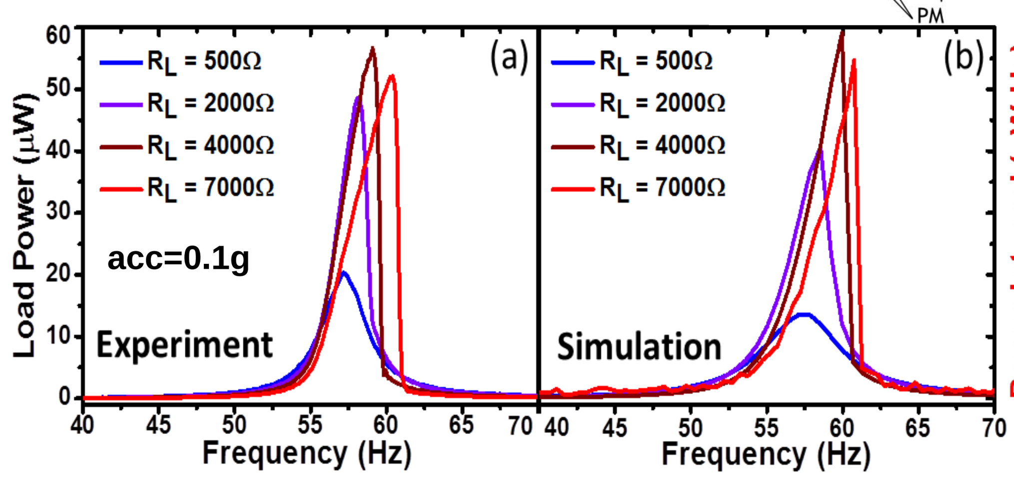
Key Properties:

- Nonlinearity due to *stretching*: two pairs of spring arms fixed at two opposite corners and guided at others.
- *Hardening* spring characteristic.
- Load resistance optimized for maximum achievable bandwidth under constant acceleration through a figure of merit.
- Resonant frequency: 58 Hz (out of plane).
- Footprint - 2.5 x 2.5 cm².
- 488.87 μW peak power at 0.5g.
- 9.55 Hz half power bandwidth.









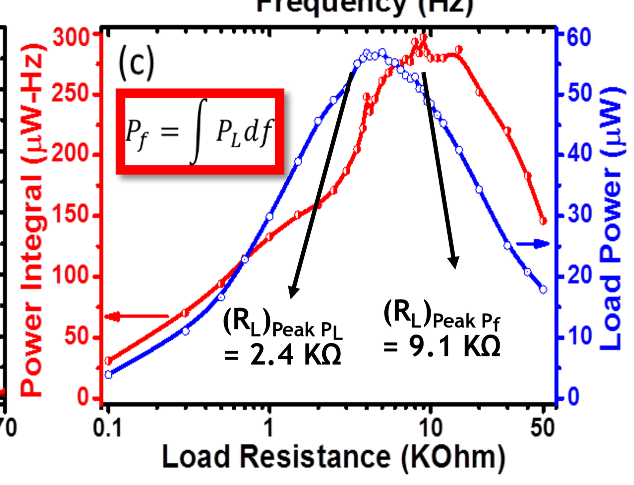
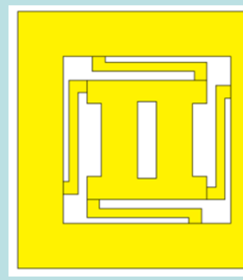


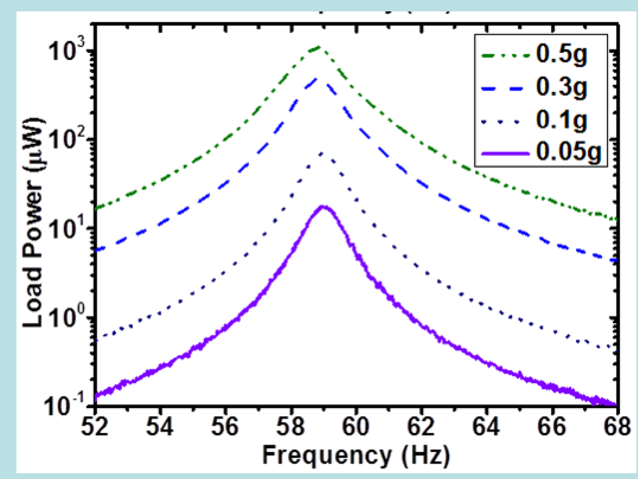
Figure of Merit, P_f, provides maximum bandwidth with minimum loss in power from peak power point.

D Mallick, A Amann, S Roy, Smart Materials and Structures 24 (1), 015013, 2015.

Linear Generator

468.13 μW generated under **0.3g** for a load of **2400Ω**.





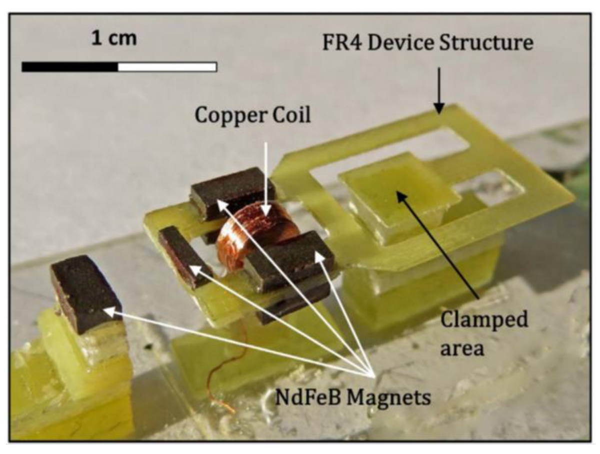
FR-4 is used as a suspension material due to its low cost; low Young's modulus – 22GPa; ease of use; and integration with electronic circuits.

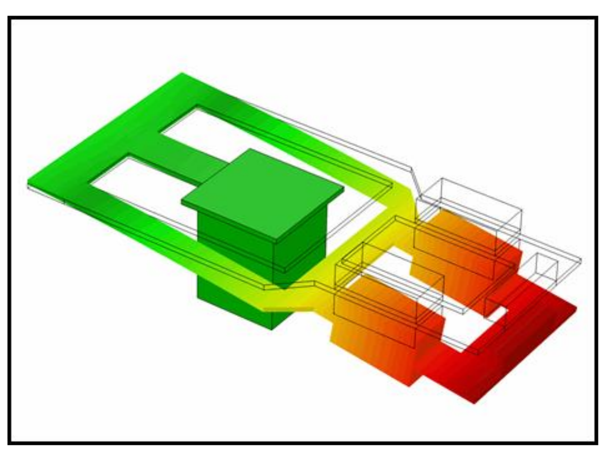
Prototypes exploit an electromagnetic transduction mechanism using discrete NdFeB magnets and coils.

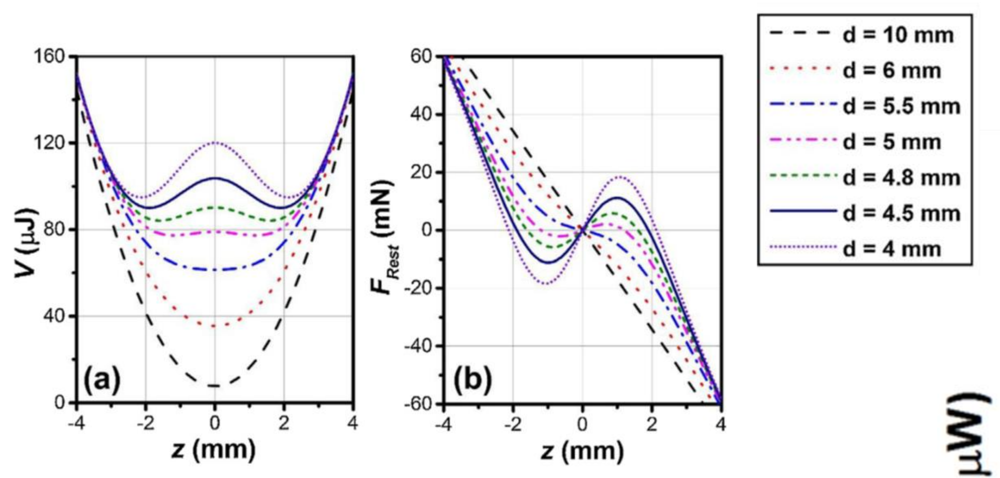
Non-linear: Bistable Systems

Key Properties:

- Repelling magnets at the end of the beam introduce a *bi-stability* with two potential wells: dependent on distance between repelling magnets (**d**)
- Resonant frequency: 35Hz.
- 22 μW peak power at 0.5g.
- 0.5 V_p open circuit voltage.
- 5Hz bandwidth (15% of peak power.

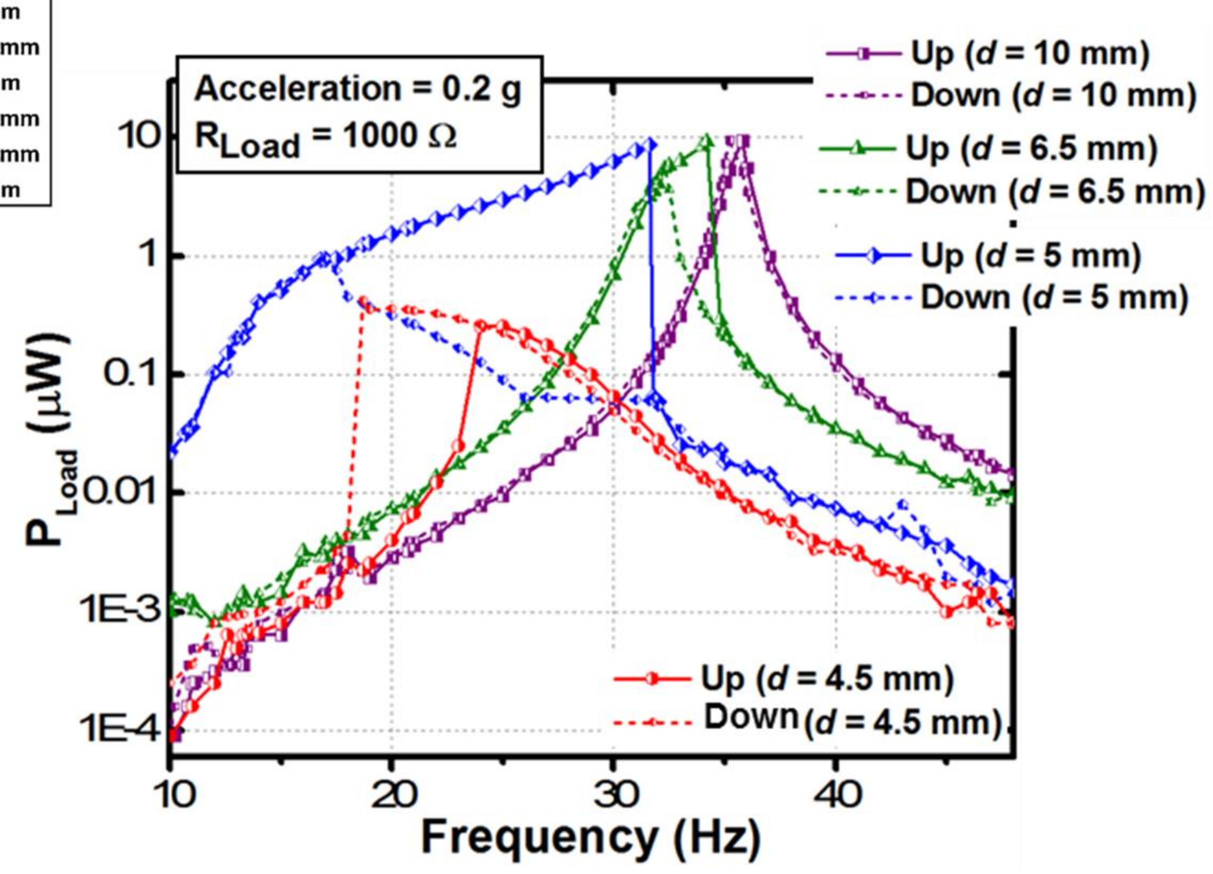






As '**d**' is reduced in steps:

- Peak power frequency shifts towards lower frequencies.
- Nonlinearity evolves from a *hardening to a softening* form.

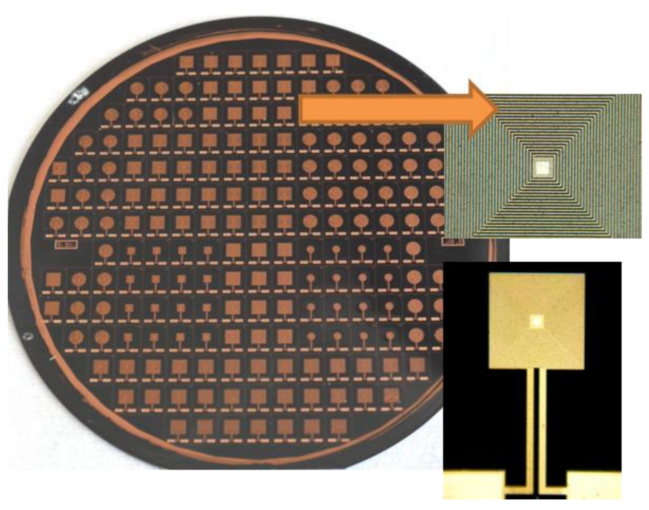


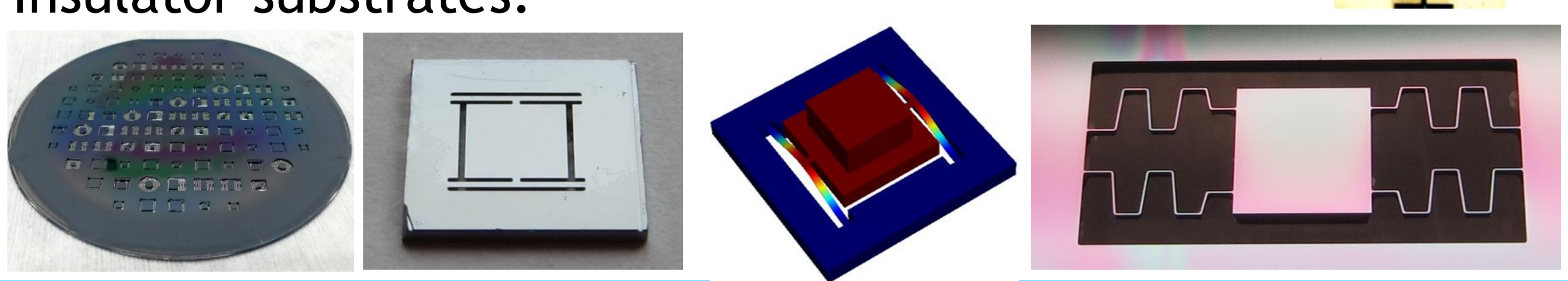
P Podder, A Amann, S Roy, Sensors and Actuators A: Physical (Vol. 227, 39-47 pp), 2015.

MEMS Devices

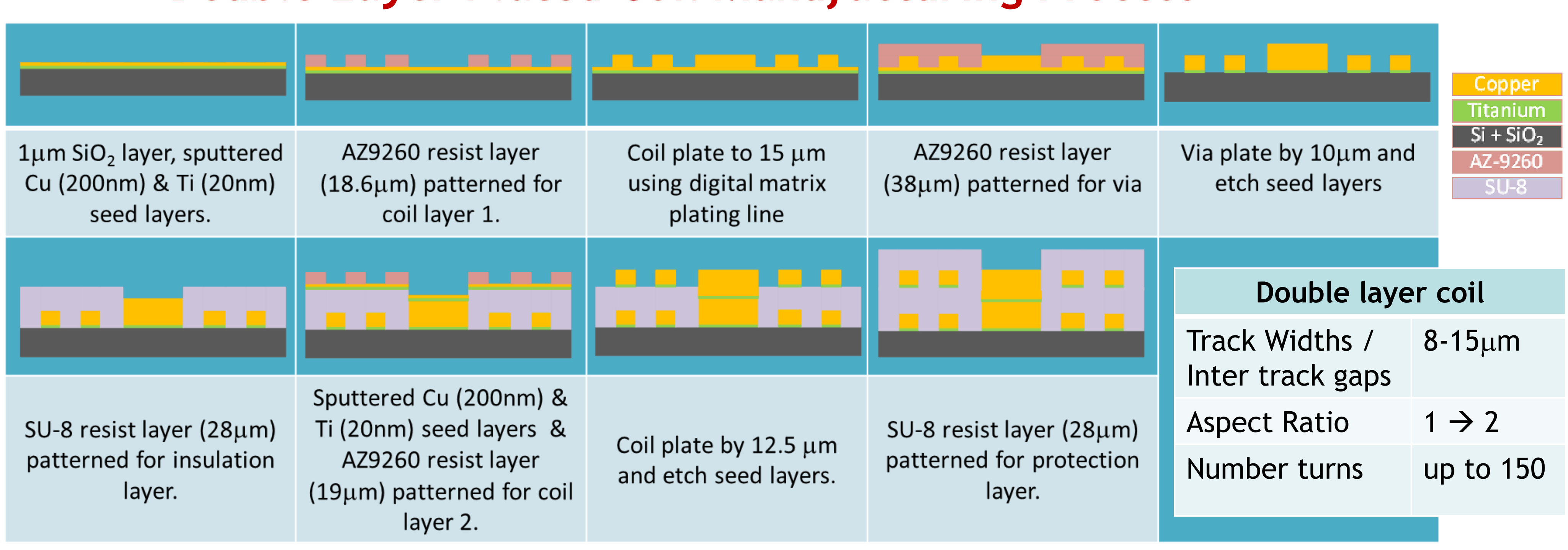
The group is investigating topologies manufactured using Silicon compatible processes.

Springs: fabricated on Silicon On Insulator substrates.





Double Layer Plated Coil Manufacturing Process



Double layer coil	
Track Widths / Inter track gaps	8-15μm
Aspect Ratio	1 → 2
Number turns	up to 150

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