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Development of a MEMS based Heat Switch for Nano-Satellite Applications

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Thermal Plug-and-Play concept

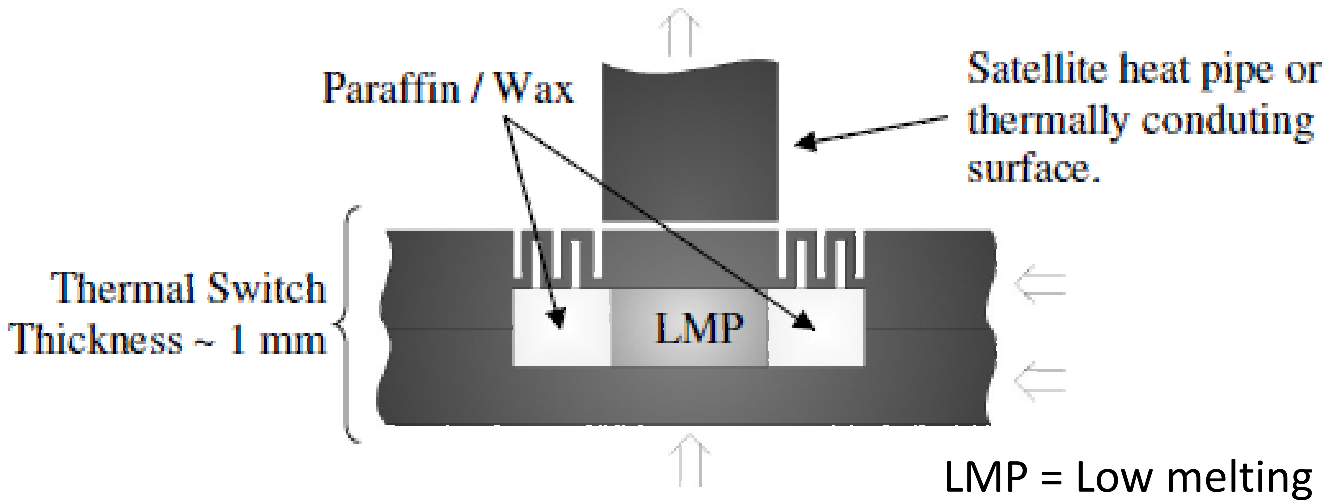
- Bring plug-and-play capabilities to the spacecraft/subsystem thermal subsystem
- Integrate thermal control as a “component” compatible with many different technologies

- The thermal switch is being developed with four different abilities in mind;

1. Autonomous (plug-and-play) heat switching
2. Autonomous heat switching with electrical status signal
3. Electrically controlled heat switching
4. Thermal (electrical) switching conducting high electric current at elevated temperature

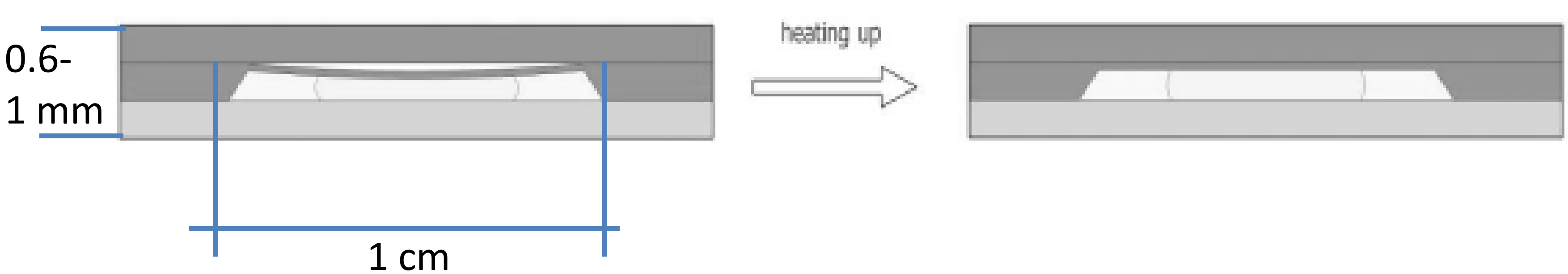
Thermal Switch Description

Concept

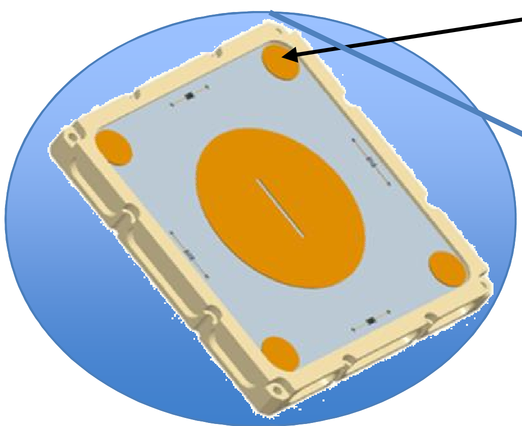


LMP = Low melting point alloy

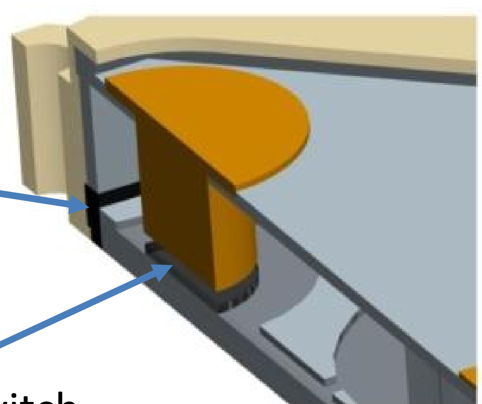
Implementation in MEMS



Example application of MEMS Thermal Switch



Images courtesy of Uppsala university.



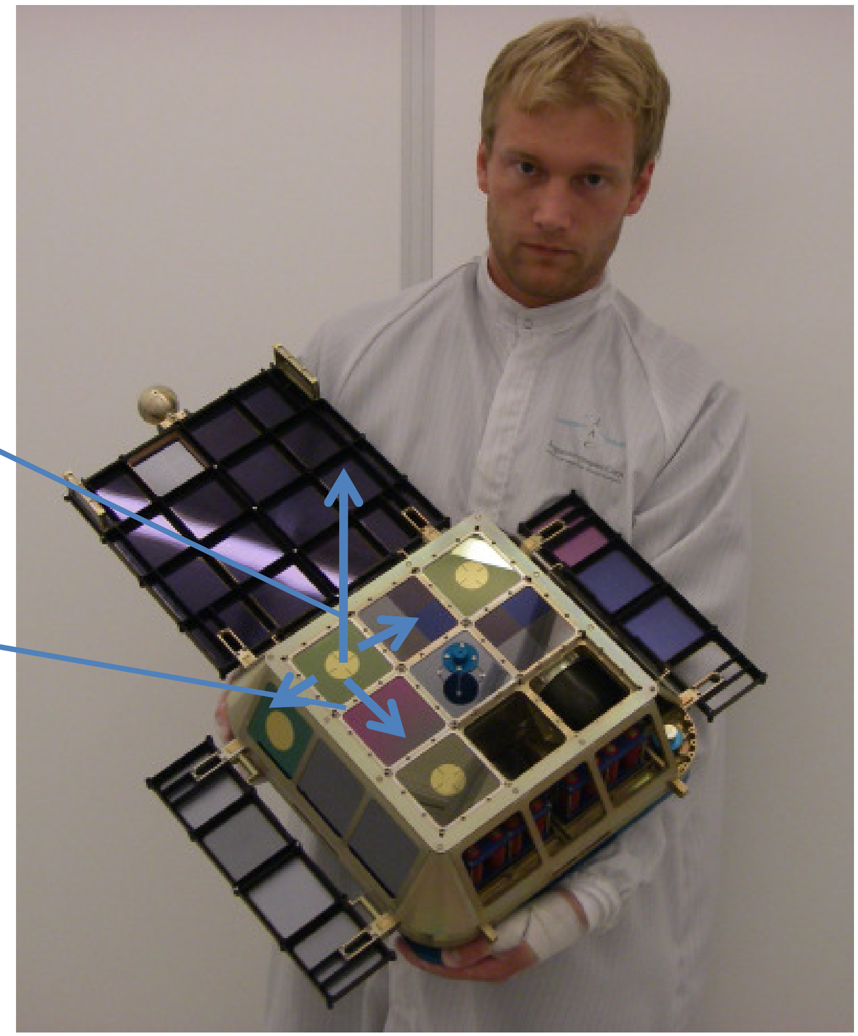
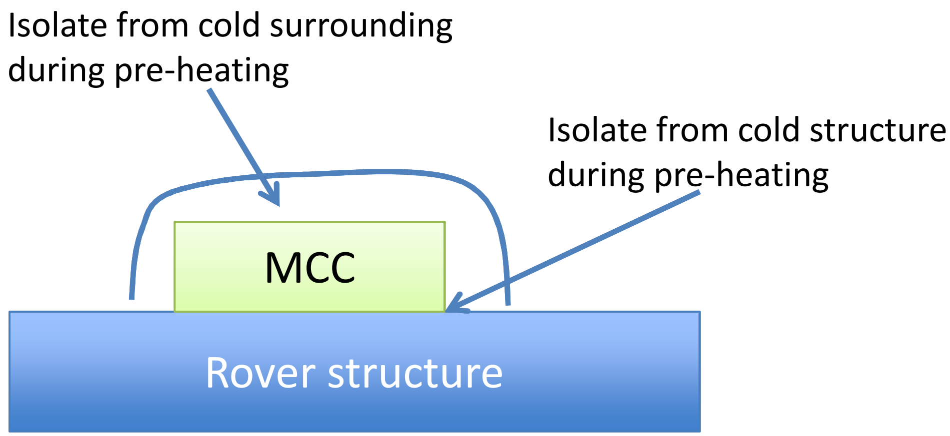


Photo: ÅAC. Satellite courtesy of Uppsala university.

Example application of MEMS Thermal Switch

- Motion control chip in cold environment
- Storage -120 °C to +70 °C
- Operation -55 °C to + 70 °C



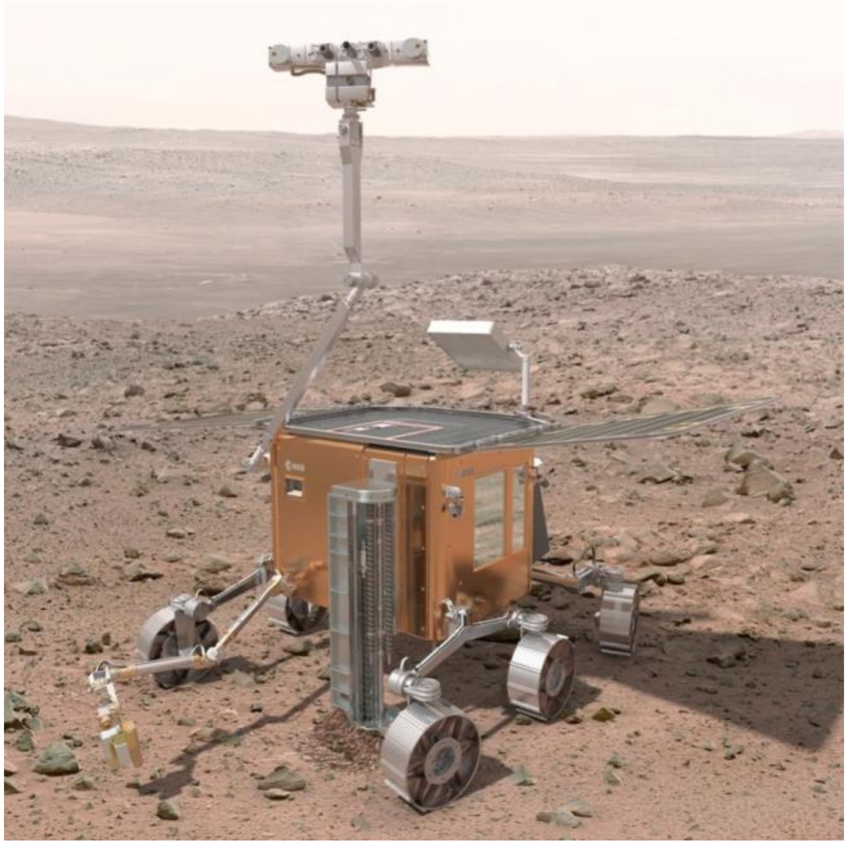
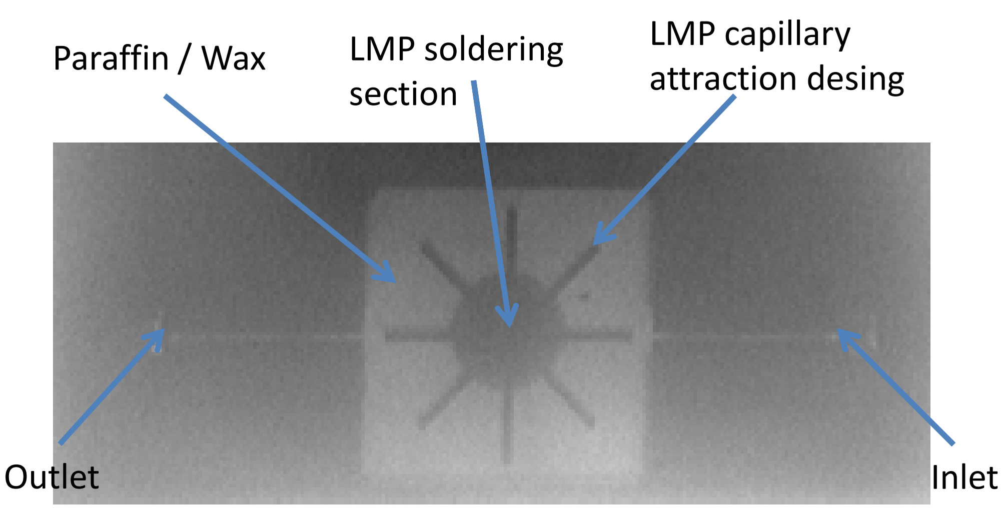
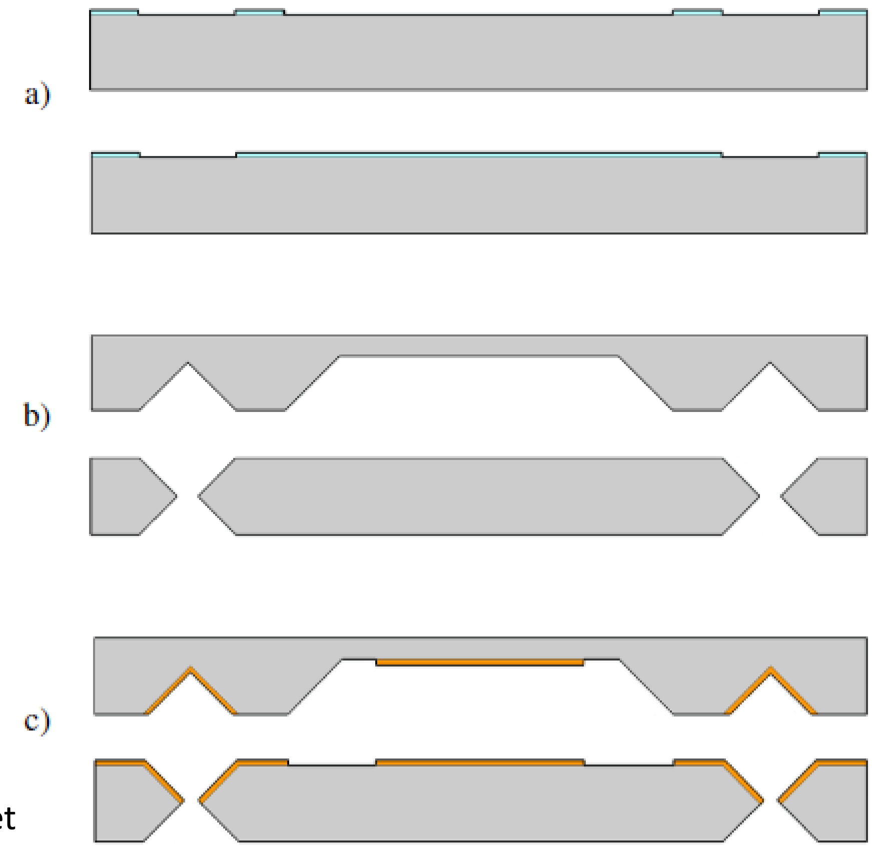


Image courtesy of ESA.

Fabrication process and design

- Standard 100-Silicon
- Standard etching
- Standard metalization, TiW, Ni, Au





Fill process

- Fusion bond top and bottom silicon wafer
- Fill LMP and create the solder joint
- Fill Paraffin / Wax around LMP
- Seal the inlet/outlet

LMP solder joint

Device before fill process

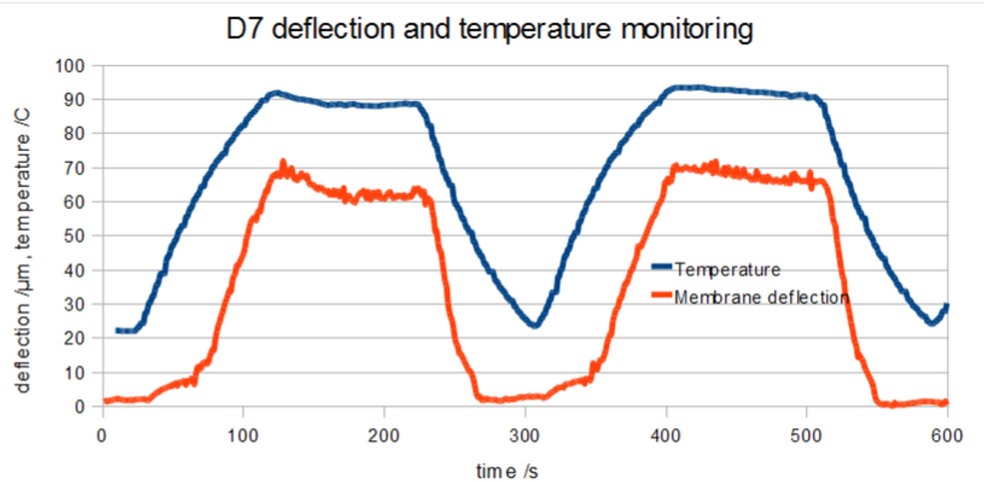
Filled device with pre-defined negative membrane deflection

(a) (b) (c)

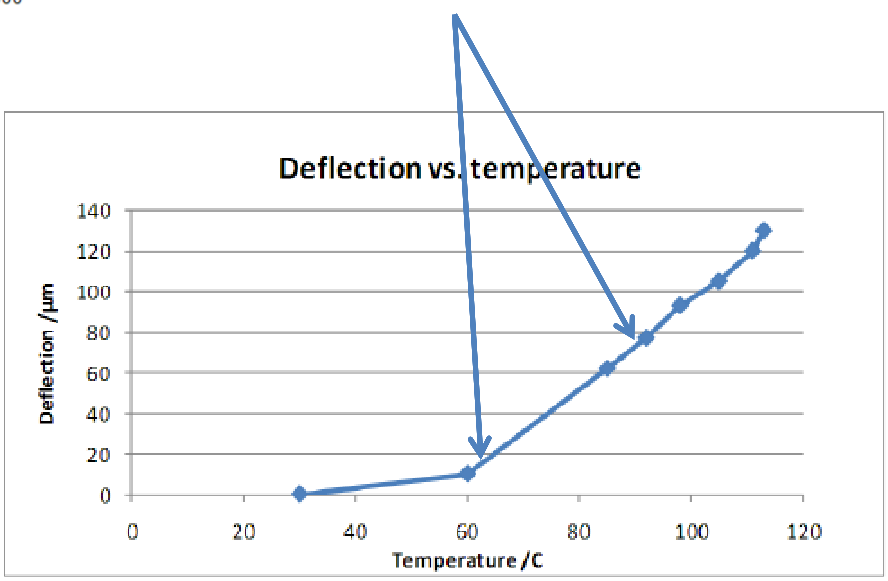
Testing sequence table

Test no	D1	D2	D3	D5	D7
0	calibration test	calibration test	calibration test	calibration test	calibration test
1	Storage test	Radiation test 10krad	Proof of concept of complete switch	Thermal conductivity test	Life-time testing 25-90ºC, 1645cc
2				Thermal shock on broken sample	Switch triggering temperature monitoring
3					Membrane deflection monitoring
4					Actuation in vacuum environment
5					Thermal shock testing
6					Vibration testing
7					Storage test
8					-20ºC to +125ºC

Results



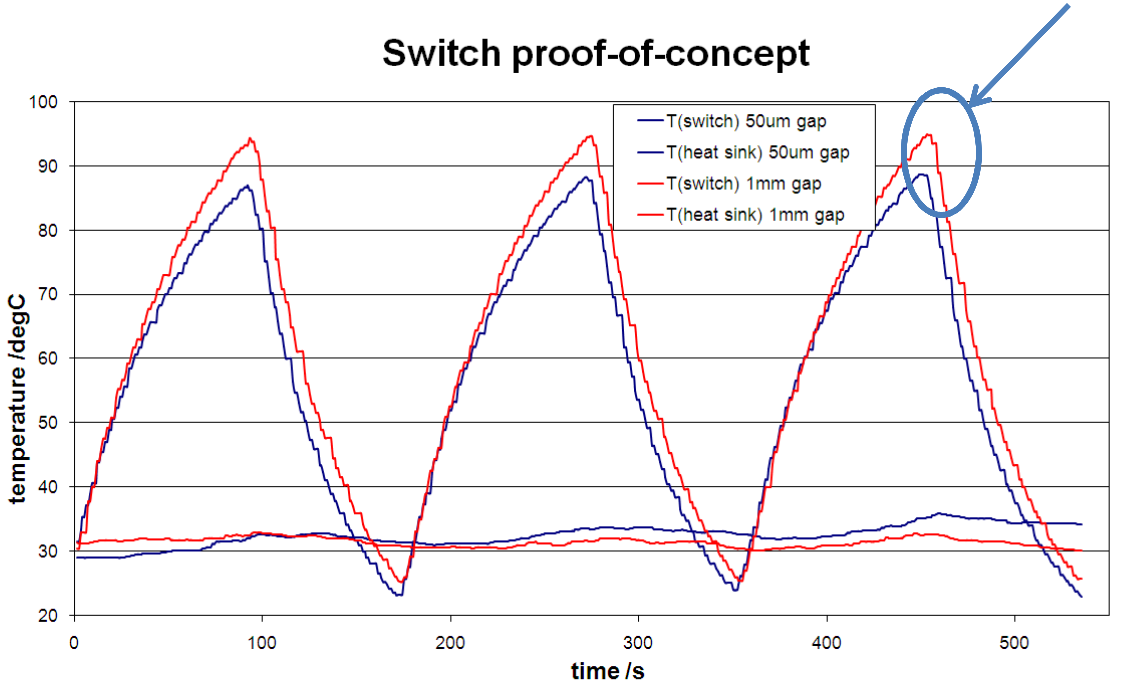
Activation point, 60 °C. Continous expansion to 120 °C.
Must be taken into design.



Results (2) in Air atmosphere environment

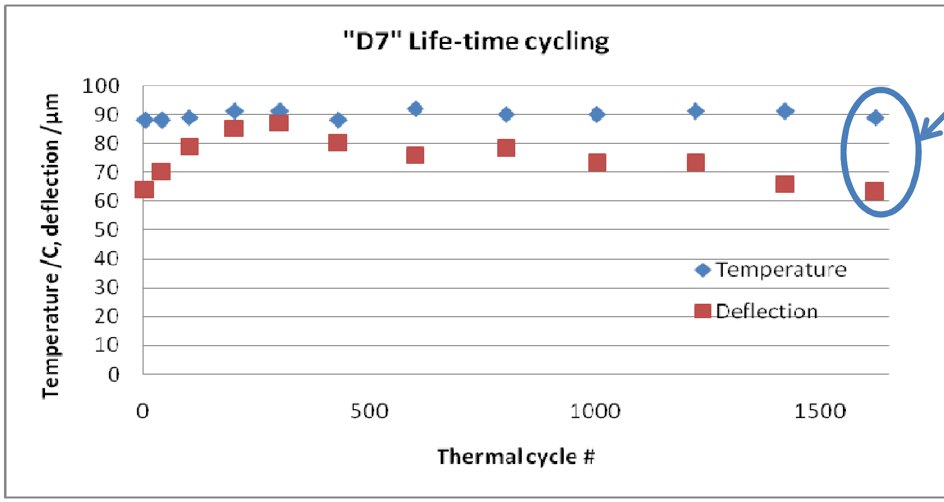
- Higer modulation possible in vaccum and with optimized switch design
- A modulation factor of 2 is measured in Air atmosphere with first generation device.
- A modulation factor of at least 5 is possible.

1.3 W dissipation in ”off” state
3 W disspiation in ”on” state



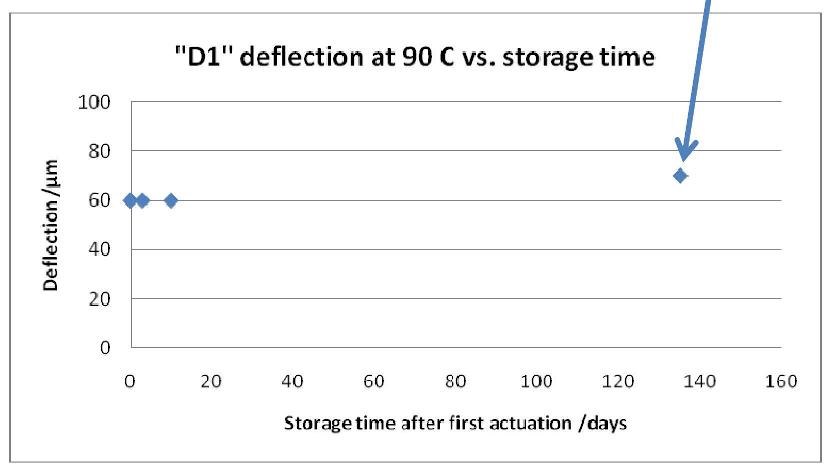
Results (3) Life time aspects and ECSS standard compliance

- ECSS-E-10-03A compliance with exception for 1 year storage (still waiting for the year to go to find out the answer).



Change of Deflection in order of 30 µm after 1500 thermal cycles

Change of Deflection in order of 12 µm after 4.5 months in storage



Conclusions

- Affordable MEMS switches are realiable options for both active and passive thermal control
- Thermal modulation factors of 5 times can be reached
- Production costs can be lowered with combination of micromachining and MEMS technology
- Silicon, aluminum or other substrate material is possible
- Filling of LMP requries a carfefully tailored (diluted) HCL solution to enable self-alignment of the LMP and to remove oxidation of the solderable surfaces.
- LMP with melting point at 58 °C works well with paraffin with a melting point at 70 °C.

- Study report un-classified and in public domain. Contact ÅAC for a copy.

Acknowledgments and Questions

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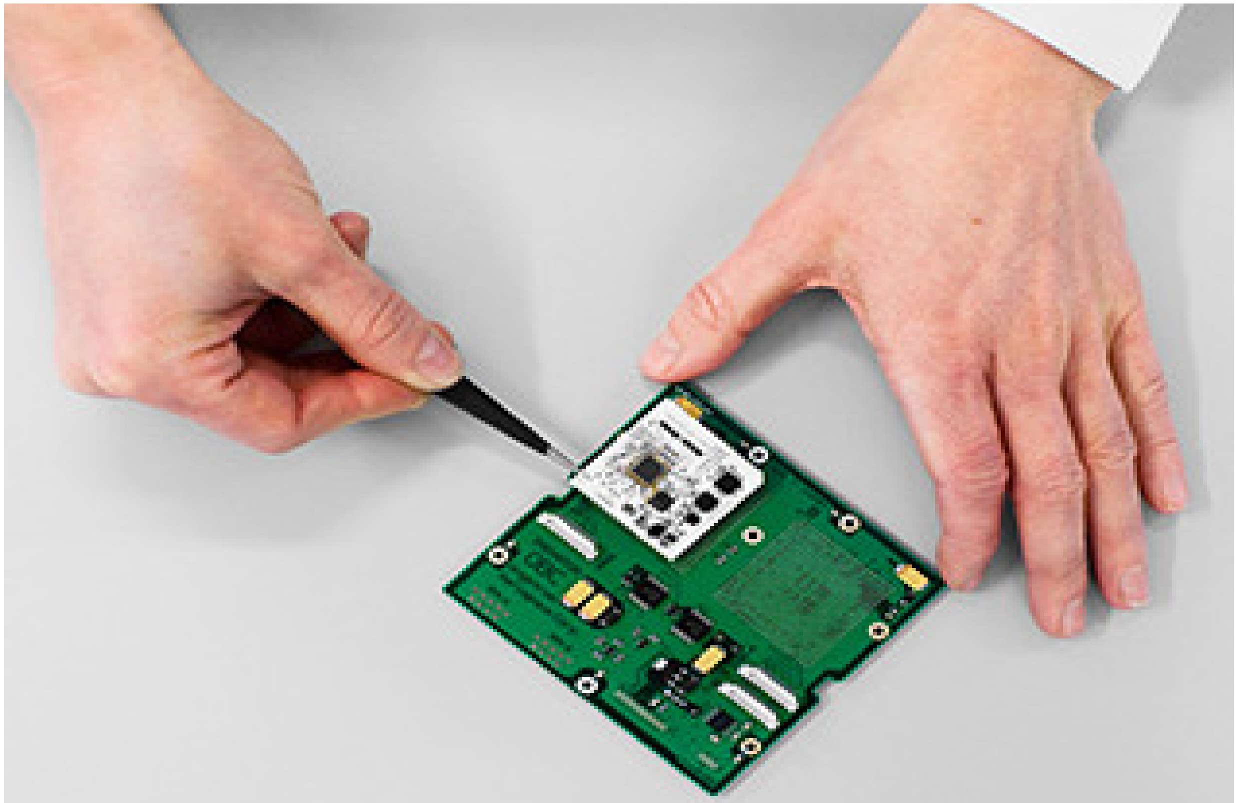
- END - Questions



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