Reliability of MEMS by X-ray and Infrared Analyses

Ecole Nationale Supérieure des Mines SAINT-ETIENNE

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INSPIRING INNOVATION | INNOVANTE PAR TRADITION

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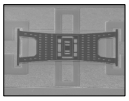
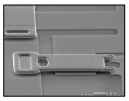
Context & objectives

Increase the reliability of MEMS

- ✓ **Micro-Contacts study**
- ✓ **Material selection**
- ✓ **Stress and thermal analyses**
- ✓ **Thermo-Mechanical Modeling**
- ✓ **Understand the failure mechanism**



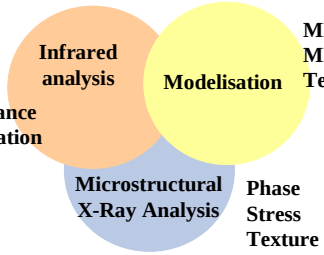
Bridge (LAAS)



Cantilever (LETI)

Method

Thermal dissipation
Thermal contact resistance
Reliability during actuation



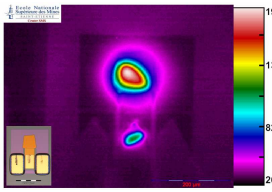
MEMS design and material
MEMS actuation
Temperature distribution

Phase
Stress
Texture & Cristal orientation

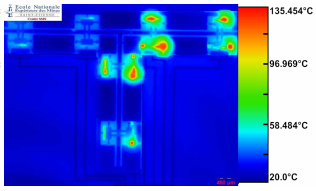
Major Achievements

Infrared Thermal Measurement

The Armines infrared bench could be fitted on the LAAS prober stations.



Thermography of a Baw from LETI at 2GHz 2W actuation.

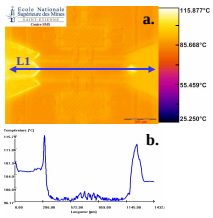


Thermal distribution reconstitution of a Tuner from LAAS at 10GHz, 2W actuation

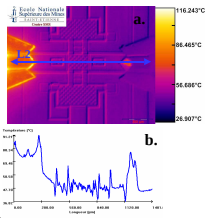
Planck law : $\frac{dR(\lambda,T)}{d\lambda} = \frac{2\pi hc^2\lambda^{-5}}{\exp\frac{hc}{\lambda kT}-1}$

$$R_{\text{det}} = \int_{\Delta\lambda} \Re_a(\lambda)\cdot\frac{dR(\lambda,T_a)}{d\lambda}\cdot d\lambda + \int_{\Delta\lambda} \Im_f(\lambda)\cdot\frac{dR(\lambda,T_f)}{d\lambda}\cdot d\lambda + \int_{\Delta\lambda} \varepsilon_a(\lambda)\cdot\frac{dR(\lambda,T_a)}{d\lambda}\cdot d\lambda$$

Via cooling efficiency analysis RF-MEMS // switches

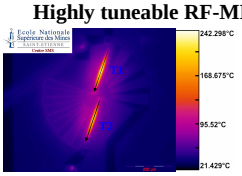


a. Thermal mapping of a switch for an activation at 10GHz, 1W
b. Temperature versus length along L1.

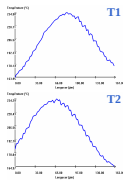


a. Thermal mapping of a switch for an activation at 10GHz, 1W.
b. Temperature versus length along L2.

Local temperature mapping Highly tuneable RF-MEMS capacitor



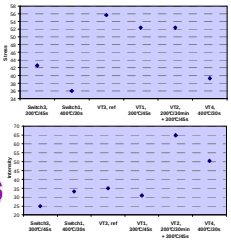
High resolution thermal infrared mapping for an activation at 0.9V. Top electrode is rotationally driven by 2 electro-thermal actuators (size 200×4×8µm).



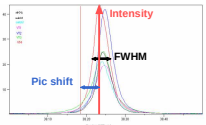
Temperature versus length along T1 and T2.

Local texture X-ray analysis

A 20 µm microfocus X-ray analysis



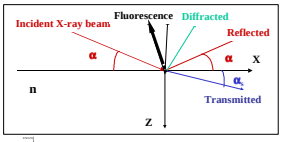
Effect of temperature treatment on gold microswitches structures.



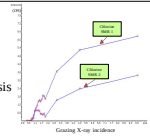
X-ray texture and stress analysis

$$\varepsilon_{\psi\eta}^{\{hkl\}} = S_1^{\{hkl\}}[\sigma_{11}+\sigma_{22}] + \frac{1}{2}S_2^{\{hkl\}}[\sigma_{11}\cos^2\phi + \sigma_{22}\sin^2\phi + \tau_{12}\sin 2\phi]\sin^2\psi + \frac{1}{2}S_2^{\{hkl\}}[\tau_{13}\cos\phi + \tau_{23}\sin\phi]\sin 2\psi$$

X-ray Chemical Analysis

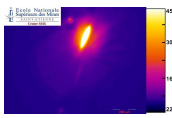


Depth resolved chloride analysis after humid storage aging

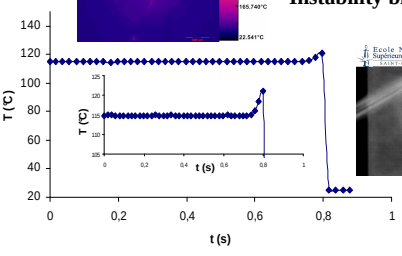


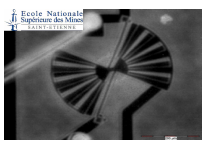
Conclusions & Perspectives

High Resolution Infrared Imaging

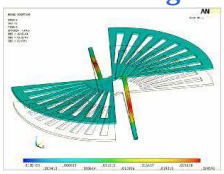


Instability bifurcation of heat transfer

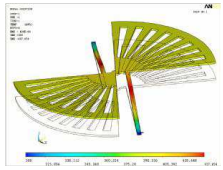




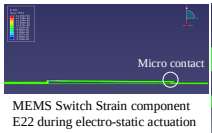
Modeling Thermal activation



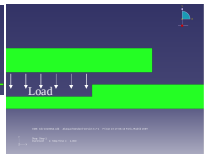
RF-MEMS capacitor strain due to the thermal expansion for an input voltage of 1V



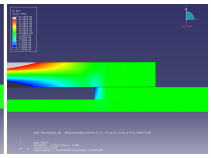
Simulated temperature distribution of a RF-MEMS capacitor for an actuation at 1V



MEMS Switch Strain component E22 during electro-static actuation



Micro switch off



Micro switch on

In-Situ, Microstructural, Thermal and Stress Analysis of MEMS :

- ✓ **Validation of MEMS design & process parameters**
- ✓ **Reliability analysis and improvement**