



Reconfigurable Microsystem Based on Wide Band Gap Materials, Miniaturized and Nanostructured RF-MEMS



April 2013

Newsletter #2

WORK PROGRESS DURING THE 2nd YEAR: KEY ISSUES

WP 2: Nanostructured Dielectric development and integration with MEMS and MiniMEMS

▶ PLD deposited PZT

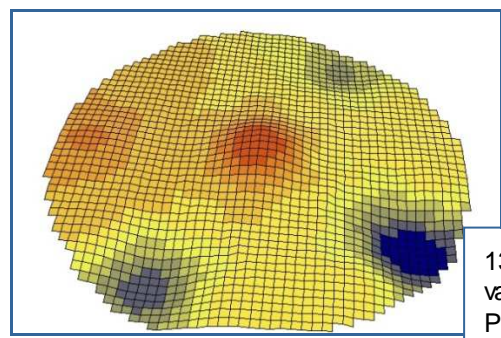
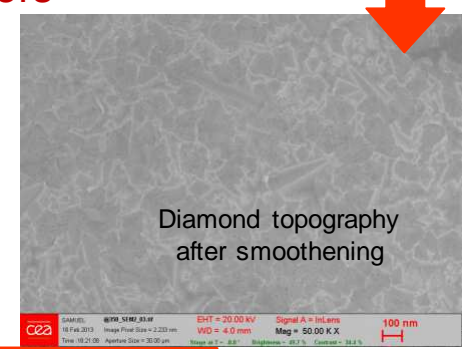
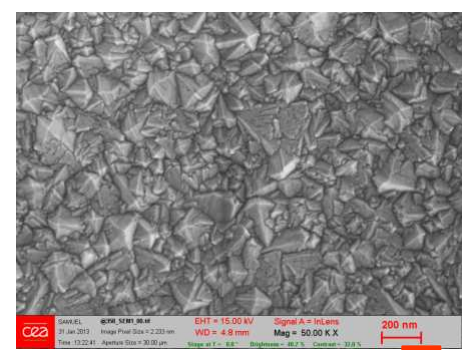
- ▶ Technology transfer
- ▶ Homogeneity optimization
- ▶ Roughness study

▶ Diamond

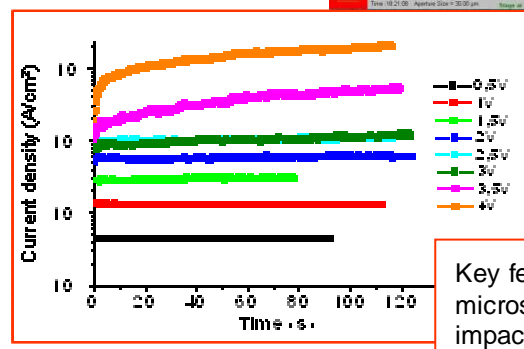
- ▶ Smoothing process development : RMS 1nm on gold electrodes
- ▶ Smoothing of doped and nanocrystalline layers
- ▶ Electrical characterization : promising results

▶ CNT impregnated silicon nitride

- ▶ Technological process development
- ▶ CNT growth optimization



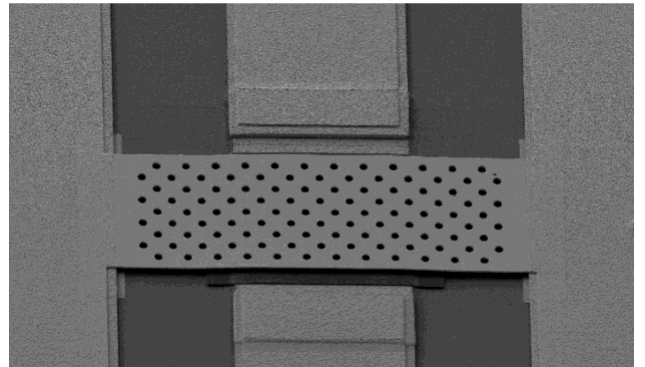
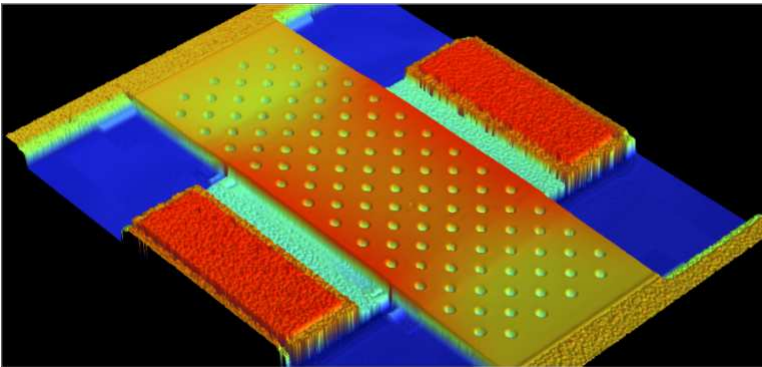
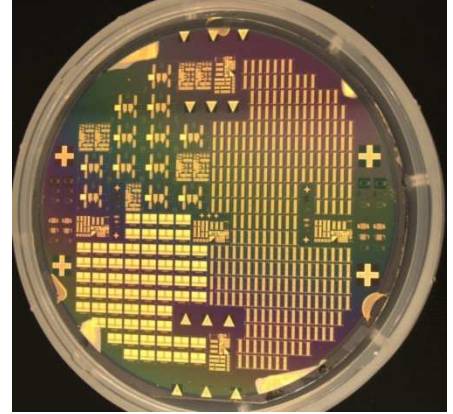
13% thickness variation PLD PZT layer on a 2 inch wafer



Key feature of PZT microstructure impact

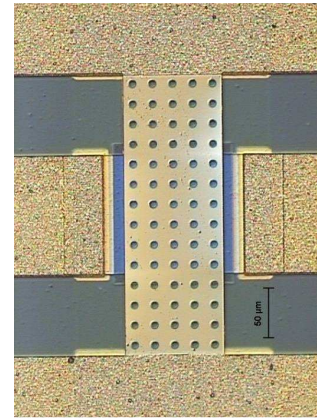
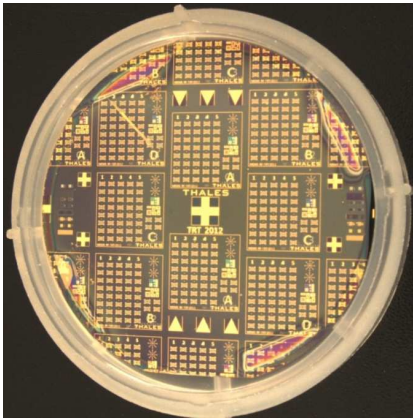
WP 3: Design, Fabrication and Test of GaN, Si and LCP based MEMS and Mini-MEMS switch Capacitors and Phase Shifters

- ✓ Realization of TiO_2 based RF MEMS on Si and GaN/Si
- ✓ Power handling up to 10W demonstrated
- ✓ Switching time $< 5\mu\text{s}$ achieved
- ✓ Switching cycles 10^6 demonstrated
- ✓ Actuation voltage : $< 35\text{V}$ & Insertion losses: 0.25dBmm^{-1}
- ✓ Isolation of 15dB demonstrated



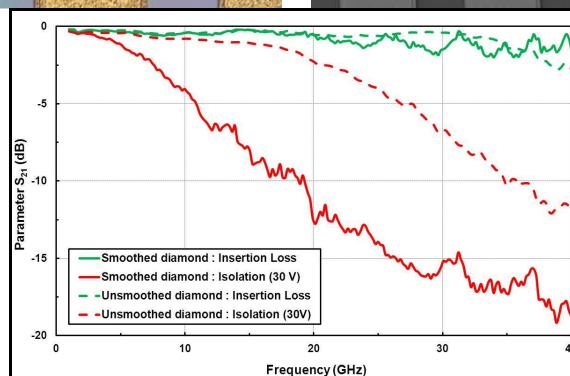
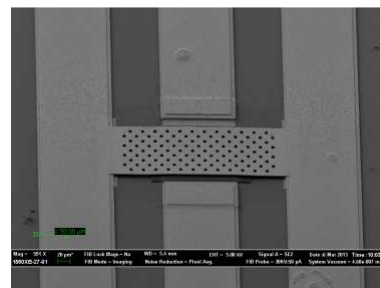
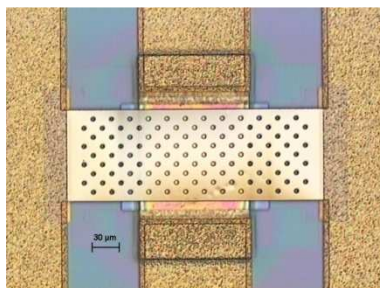
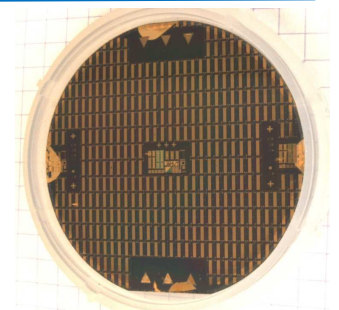
Fabrication run on Si substrate of 200 nm thick PZT/PLD based RF MEMS switches

- Technological transfer between IEF & TRT
- 2-inch Si/SiO₂ substrate
- RF characterisation of MEMS in progress

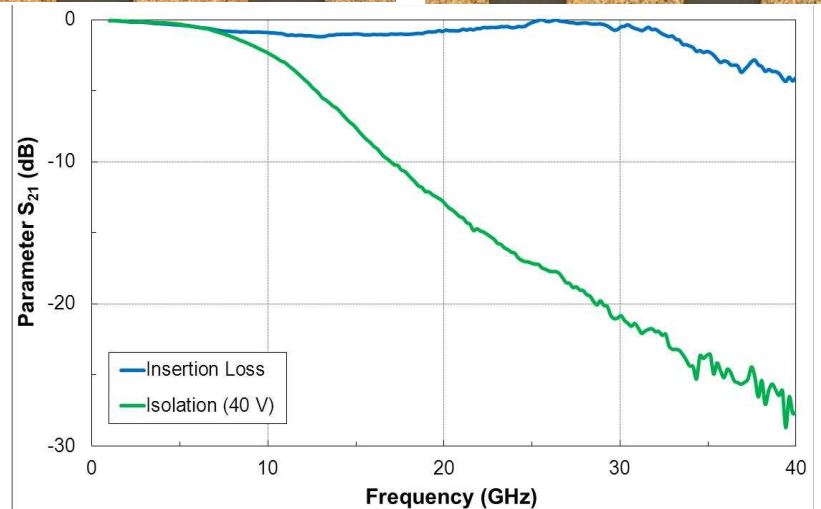
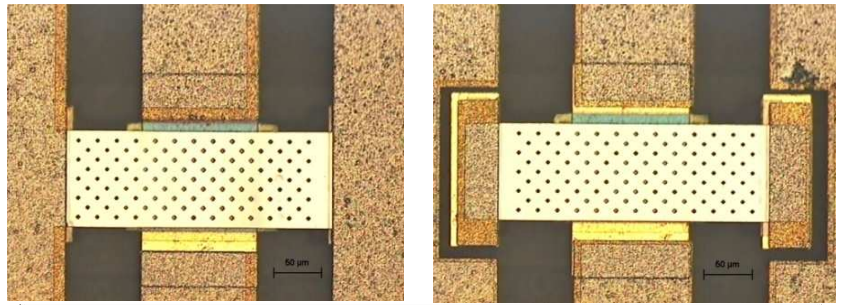
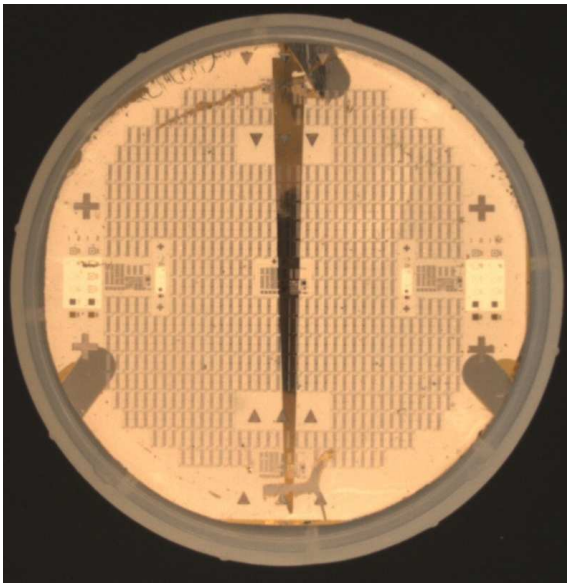


Fabrication run on Si substrate of 300 nm smooth diamond based RF MEMS switches

- 2-inch Si/SiO₂ substrate
- 300 nm thick smooth diamond (CEA)
- Improvement of isolation at 10 GHz (-4 dB)

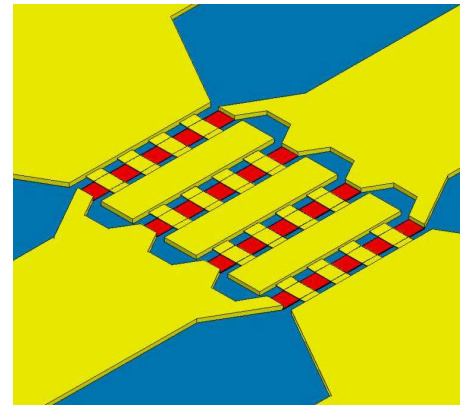
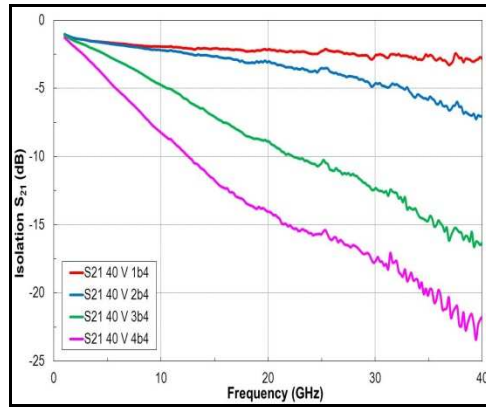
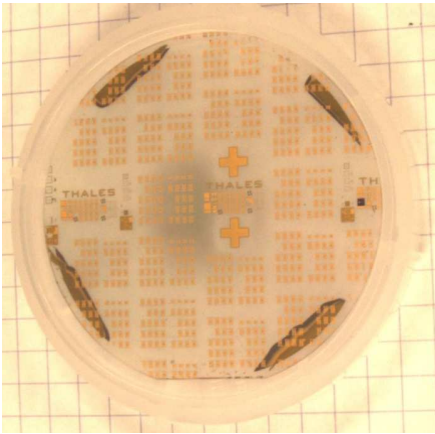


1st run fabrication on 3-inch LCP substrate of TiO₂ based RF MEMS switches

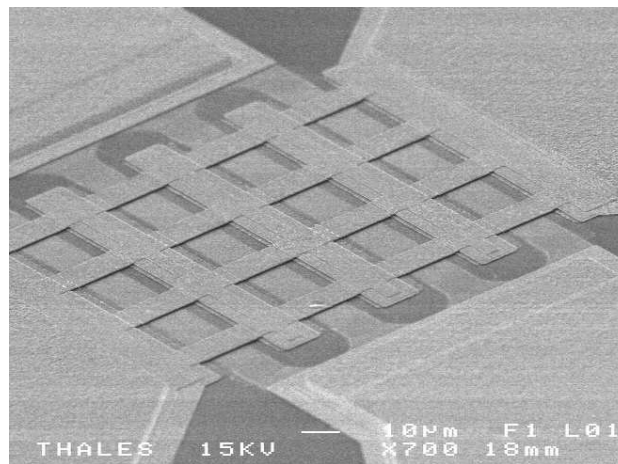


- Assessment of technological feasibility
- Improvements identified for a compatibility with RF MEMS technology
- Validation of RF MEMS switching function on LCP

RF MiniMEMS



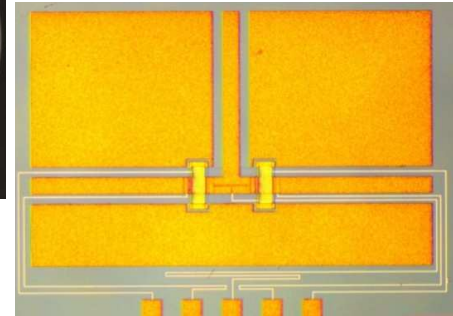
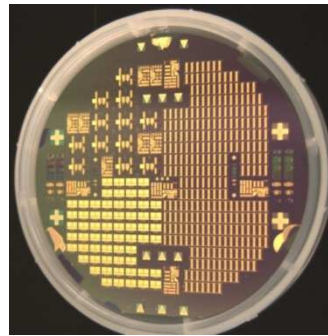
✓ **First demonstration of RF MiniMEMS with <math><1\mu\text{s}</math> switching time**



WP 4: Design, fabrication and test of GaN, LCP and Si based RF-MEMS circuits and LCP boards

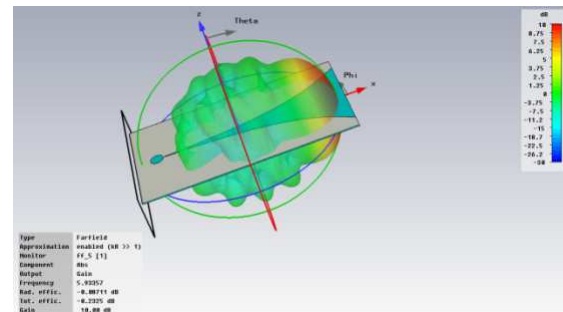
▶ SPDT

- ▶ Design finalized for GaN/Si
- ▶ First fabrication run finished
- ▶ First characterisation started



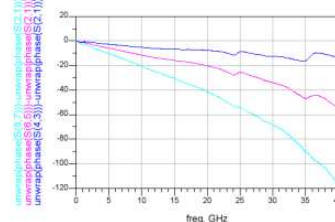
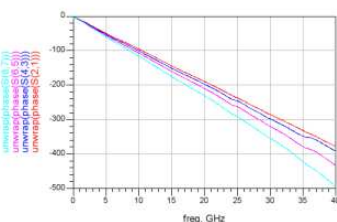
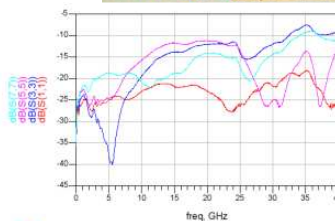
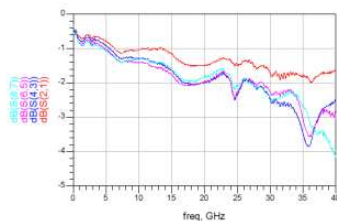
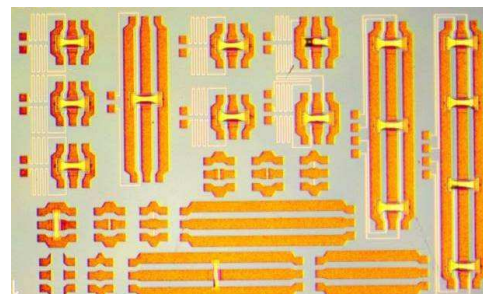
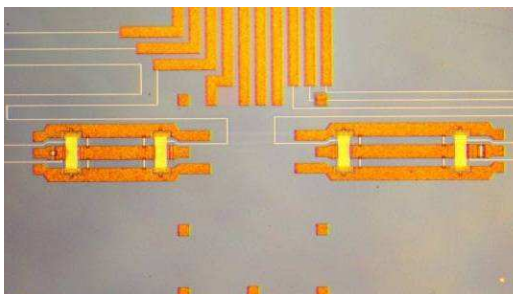
▶ UWB Antenna and RA Antenna

- ▶ Antenna cells simulated for Si-HR and LCP substrate
- ▶ UWB antenna simulated for 3.4-8 GHz and 8-20 GHz




▶ Matching network

- ▶ Calibration standards on chip cal-kit
- ▶ Test circuits (RF MEMS switching circuits and fixed capacitors)



- ▶ Newsletter
- ▶ Publications (22)
- ▶ Forum poster (2)



**Reconfigurable Microsystem
Based on Wide Band Gap Materials,
Miniaturized and Nanostructured RF-MEMS**

European Nanoelectronics Forum 2012
20th-21st November, 2012
Munich, Germany
Grant Agreement #270701

Objectives

MEMS/CMOS objectives:

- ▶ Develop innovative solutions for the RF MEMS based on manufacturing light RF transducer and microfluidic elements with hybrid switches, sensors and actuators.
- ▶ Develop 2: Achieve the integration of MEMS sensors and RF-MEMS switches in CMOS.
- ▶ Develop 3: Achieve the long-term reliability of MEMS devices in order to bring this technology to industrial systems.
- ▶ Develop 4: Develop and optimize MEMS based sensors and actuators and extend the electronic technology for their monolithic integration with WBG MEMS and RF MEMS.
- ▶ Develop 5: Develop the integration of all of these technologies through four demonstrators.
- ▶ Develop 6: Transfer of the demonstrators process flow to foundry and system development.
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NANO-CMOS objectives:

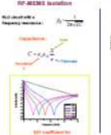
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RT Developments during first year

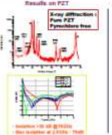
MEMS/CMOS technology integration:

- ▶ Integration of miniaturized PZT
- ▶ Development and integration of oriented carbon nanotubes in silicon nitride dielectric
- ▶ Development and first integration of diamond thin layers
- ▶ Electrical and thermal characterization of diamond
- ▶ Development and fabrication of micro-HEMT

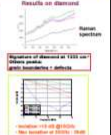
RF MEMS technology:



Results on PZT:



Results on diamond:



Application Demonstrators

DEMA 1:

- ▶ Reconfigurable smart active antenna with RF-MEMS switches
- ▶ 4x4 dBi, 20W CW

DEMA 2:

- ▶ RF MEMS based agile radio for air traffic management systems
- ▶ Wideband, 5W CW, high linearity

DEMA 3:

- ▶ RF-MEMS based reconfigurable Reflect Array antenna
- ▶ 4x4 dBi, 20W CW

DEMA 4:


- ▶ Miniaturized piezo sensor and actuator based on 100nm MEMS
- ▶ Low noise sensor module


Transducer / Resonator (TR) Modules:

- ▶ Resonance Circuits by RF-MEMS based SPECT
- ▶ RF MEMS Monolithic integration on GaN substrate
- ▶ Active Antenna
- ▶ Reflected Array Antennas
- ▶ Low cost, reconfigurable cells
- ▶ Heater and Variable inductor Resonance
- ▶ Electronic device protection (operation during...)

Project Fact Sheet


- ▶ ENIAC Joint Undertaking
- ▶ SP 2 - Wireless Communications
- ▶ SP 3 - Energy Efficiency
- ▶ Total cost: 5,57 ME
- ▶ ENIAC Contribution: 3,33 ME
- ▶ Total effort: 5,25 person-years
- ▶ 13 European Partners
- ▶ 5 countries
- ▶ 2 large industries
- ▶ 2 academic institutes
- ▶ Coordinator: THALES Research & Technology PT
- ▶ Duration: 3 years





THALES Research & Technology
Paris/Le Mans / France
www.thalesgroup.com

Contacts:
Afonso_cora@thalesgroup.com

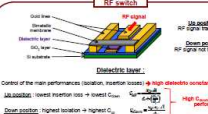


PZT thin films for capacitive RF-MEMS

Objective : assessment of integration of PZT thin film in RF MEMS
Key words : MEMS, pulsed laser deposition, functional oxide thin films, RF measurements, electrical measurements

G. Jégo, L. Michalas, T. Maroutian, S. Agnia, M. Koudsourel, G. Papanicolaou, L. Largeau, A. Leclercq, P. Aubert, Ph. Lecœur

RF switch



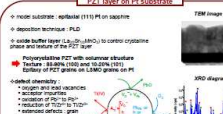
Control of the high performance isolation, insertion losses, & high dielectric constant

Advantage: lower insertion loss → higher Q_{ext} → higher Q_{int} for good performance of the device

Disadvantage: higher isolation → higher C_{off} → lower Q_{ext} → lower Q_{int} for good performance of the device

Reliability of the device → charges evaluation → ferroelectric degradation and breakdown

PZT layer on Pt substrate



RF MEMS resonator (100 MHz) on substrate

Deposition technique: PLD

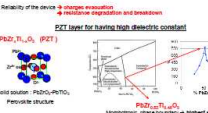
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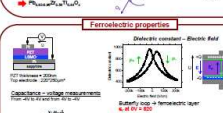
PZT layer for thinning high dielectric constant



Monolithic phase structure → highest Q_{ext} → higher reliability

Phase structure: $Pb_{1-x}Zr_xTi_{1-x}O_3$

Ferroelectric properties



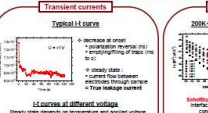
Dielectric constant → Electric field

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Transient currents



Typical I-t curve

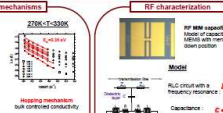
Decrease of current → ferroelectric degradation

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Conduction mechanisms



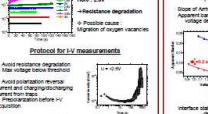
200K-C200K

200K-C500K

200K-C500K

200K-C500K

RF characterization





RF MEM resonator


RF MEM resonator


RF MEM resonator

RF MEM resonator









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