CBRAM RF pour application en RFID chipless

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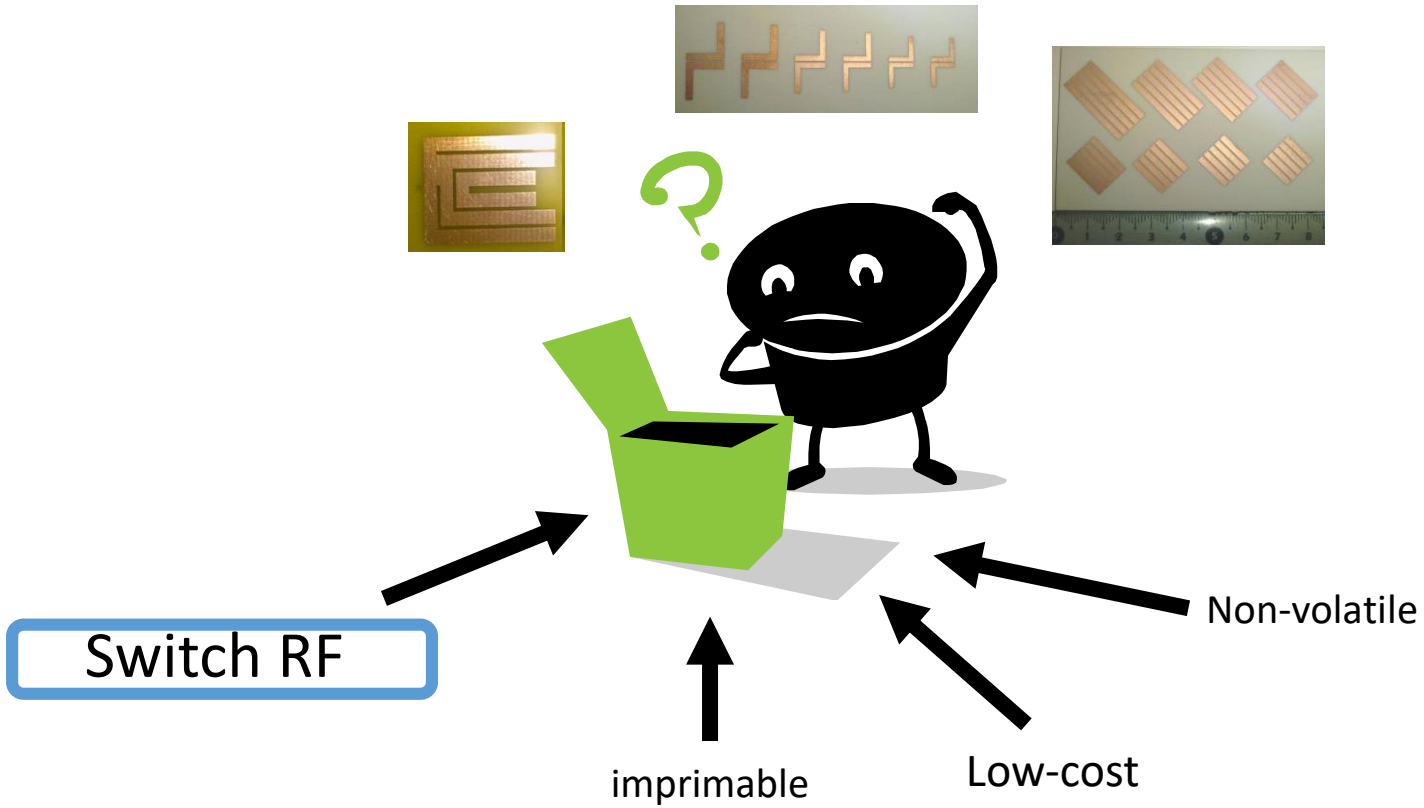
PLAN

- Technologie CBRAM
- Circuits passifs reconfigurables sur substrat rigide
- Circuits passifs reconfigurables flexibles
- Etude de structures planaires
- Conclusion et perspectives

TECHNOLOGIE CBRAM

Motivation de départ : Comment rendre un tag RFID chipless reprogrammable ?

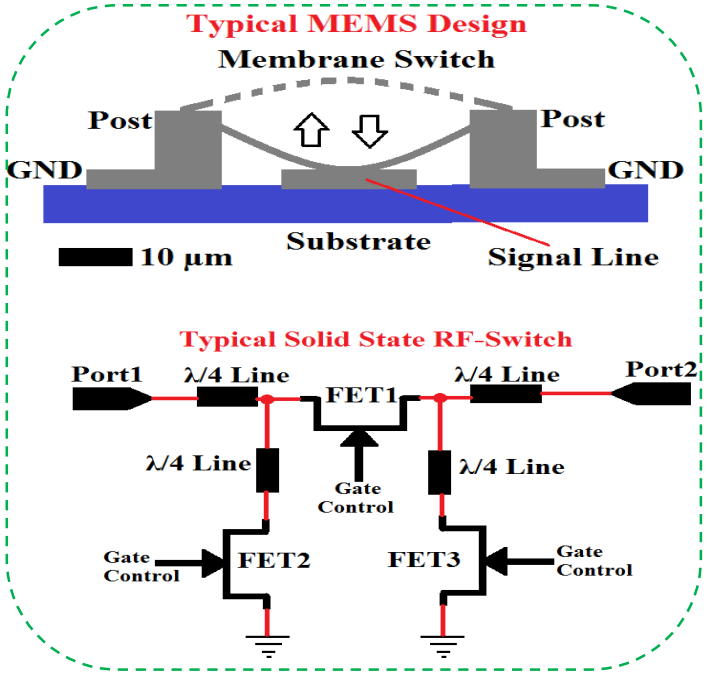


TECHNOLOGIE CBRAM

A Switch is an electrical component which makes or breaks an electrical circuit, interrupting, guiding or diverting the current from one conductor to another…!

RF Switch

Low-Loss, Broad Band performance, Fast Switching
Minimum addition of stray capacitance and inductances to the circuit
Electronic reconfigurability, Low Cost, Ease of fabrication



Volatile Switching Devices

- Solid State Semiconductors
- Micro Electro Mechanical Systems (MEMS)

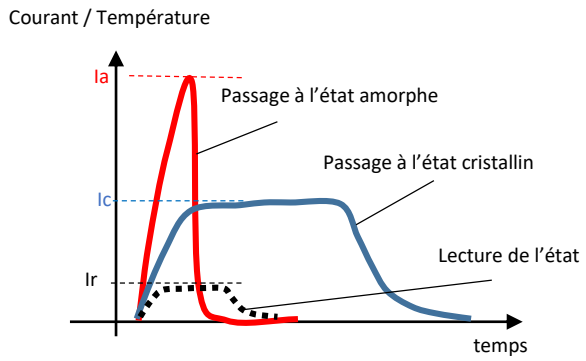
Non-Volatile Switching Devices

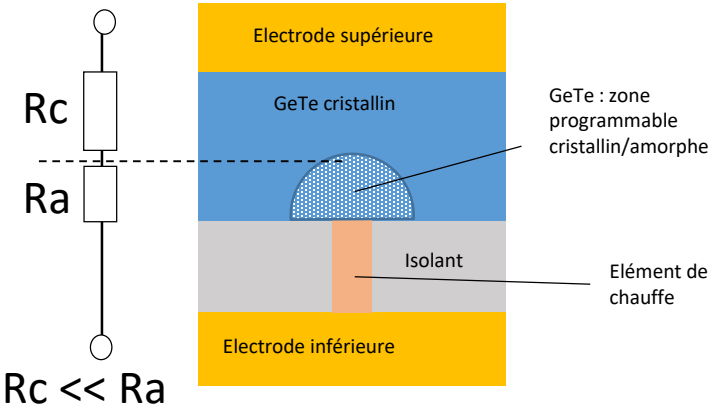
•Memristive Devices : PCM or Phase Change Memory switches, **CBRAM or Conductive Bridging Random Access Memory switches, also known as Metal-Insulator-Metal (MIM) Switches.**

TECHNOLOGIE CBRAM

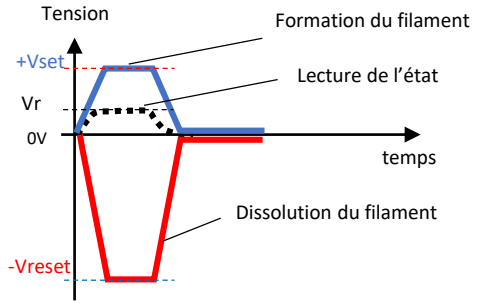
Principe de base : Mémoires résistives non volatiles

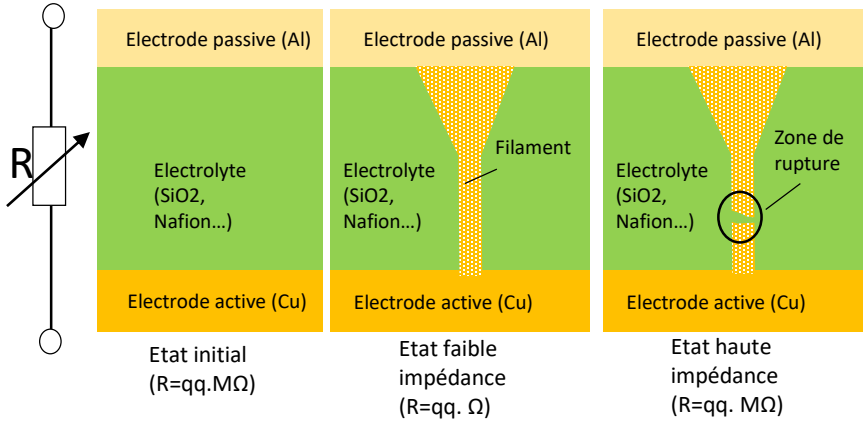
Phase change RAM (PCRAM)





Conductive bridging RAM (CBRAM)



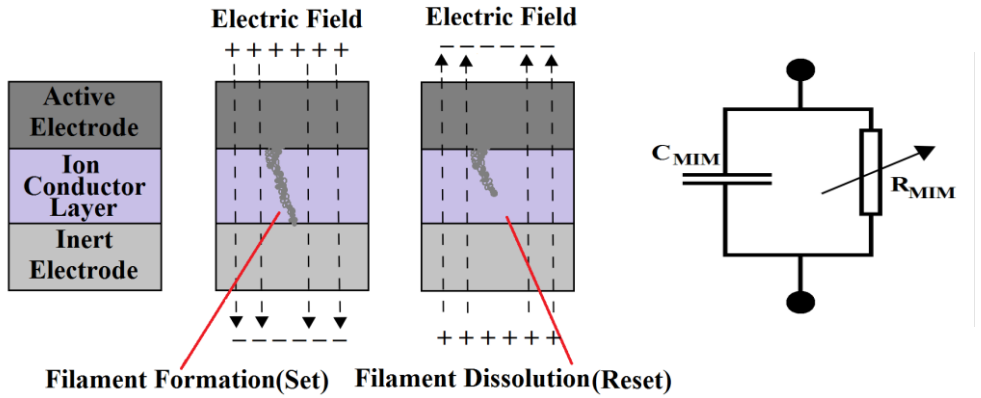


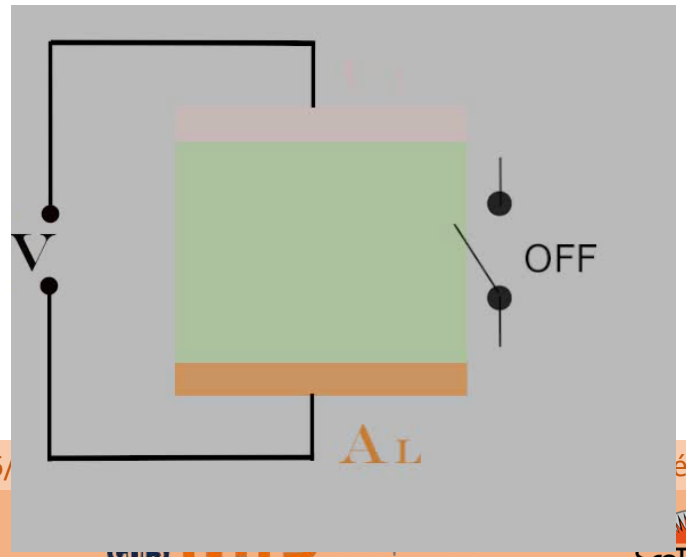
TECHNOLOGIE CBRAM

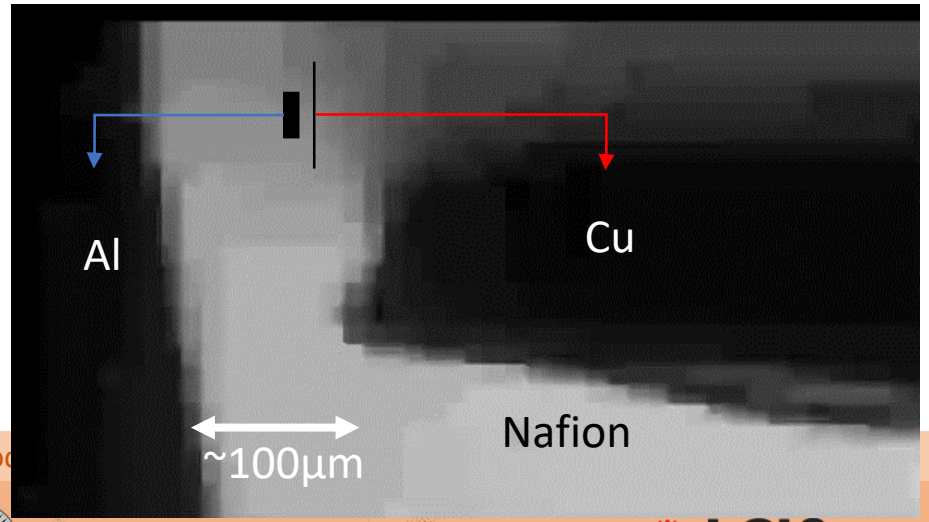
Principe de base : Mémoire CBRAM

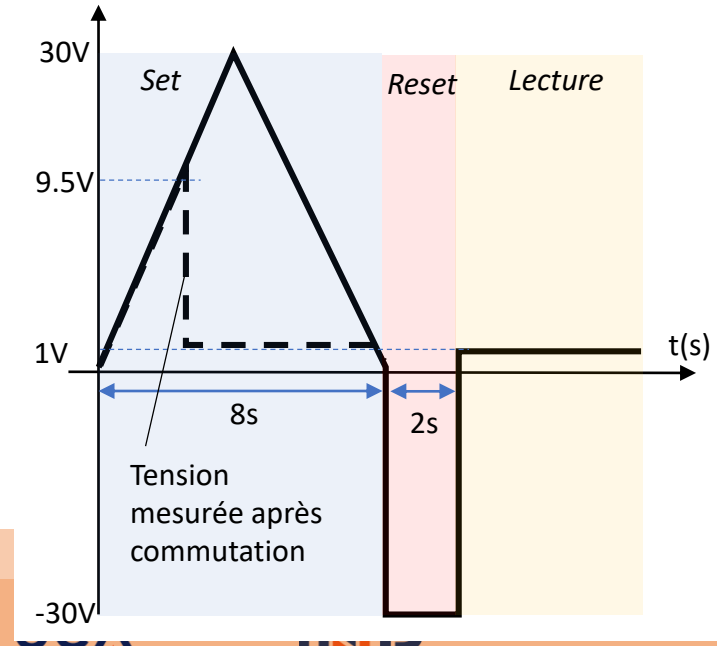
Phénomène physique

1) Oxydation d'une électrode active
2) Migration ionique vers l'électrode inerte
3) Réduction des ions sur l'électrode inerte
4) Croissance d'un filament conducteur de l'électrode inerte vers l'électrode active









TECHNOLOGIE CBRAM

We use Nafion as the ion conductor in our MIM Switches… Why?...

Nafion® is an Ionomer (Ion-Conducting Polymer) well known for its fast-ion conducting properties and use in proton-exchange-membrane fuel cells.

We have used Nafion, for the first time as an Ion-Conductor for CBRAM/MIM Applications

Advantages over the inorganic compounds like Chalcogenide glass, used classically :

- ✓ Ease of fabrication, Layer formed by spin coating the Nafion resin solution
- ✓ No need of any high temperature process, could be air dried
- ✓ Nafion layer is stable in ambient environment without any conformal coating

No Need for Clean Room

No Need for High Temperature Process

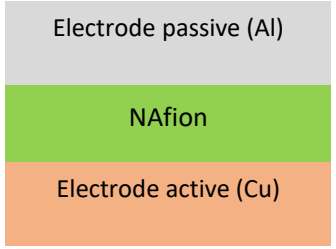
Stable in Ambient Environment

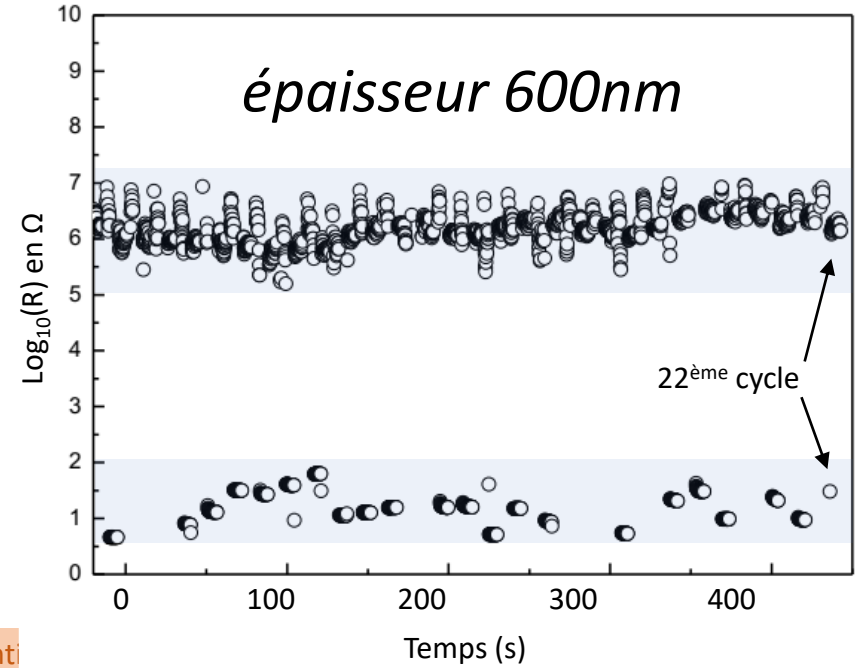
® Nafion is a registered trademark of the E. I. du Pont de Nemours & Co.

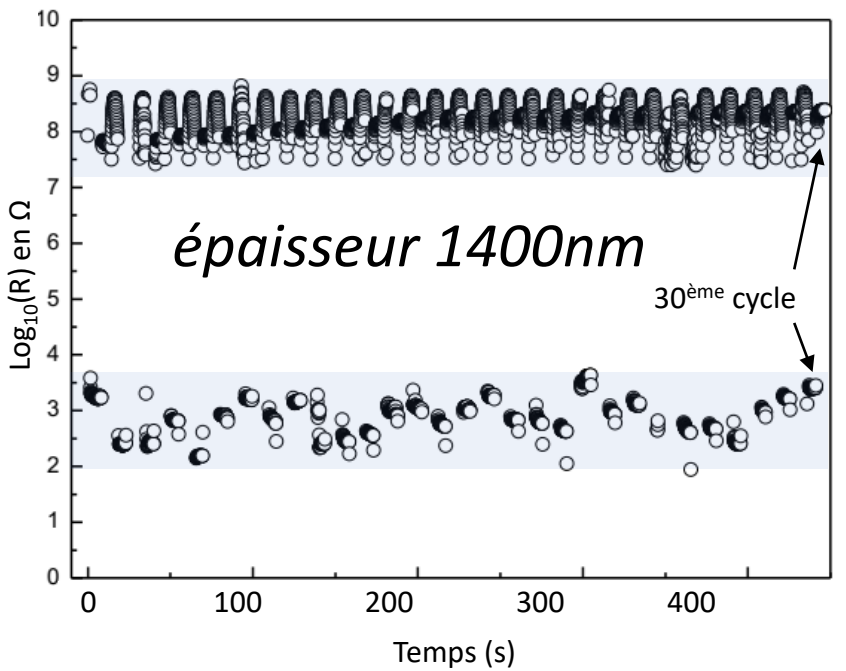
TECHNOLOGIE CBRAM

Etude de l'empilement Cu/Nafion®/Al

Propriétés du Nafion® →
- Bon conducteur ionique (ionomer)
- Grande résistance aux solvants
- Utilisé comme membrane d'échange de protons dans les PAC







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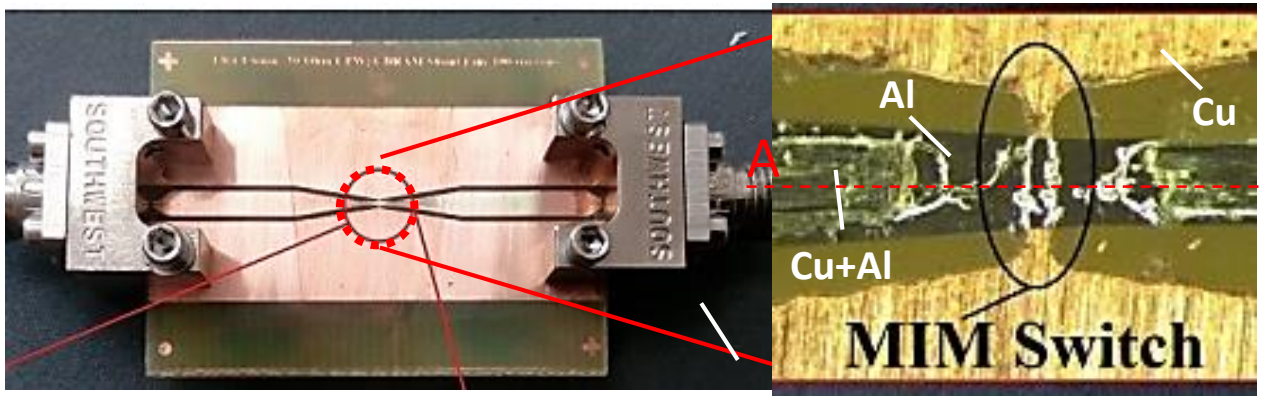
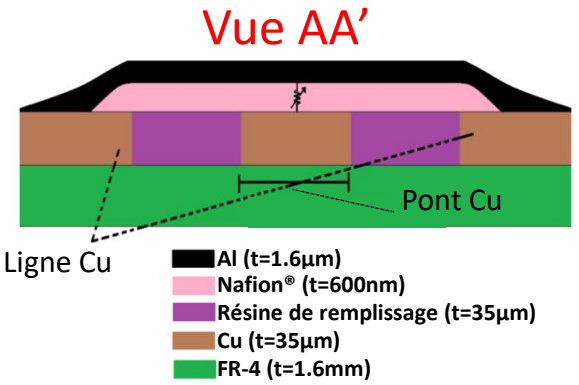
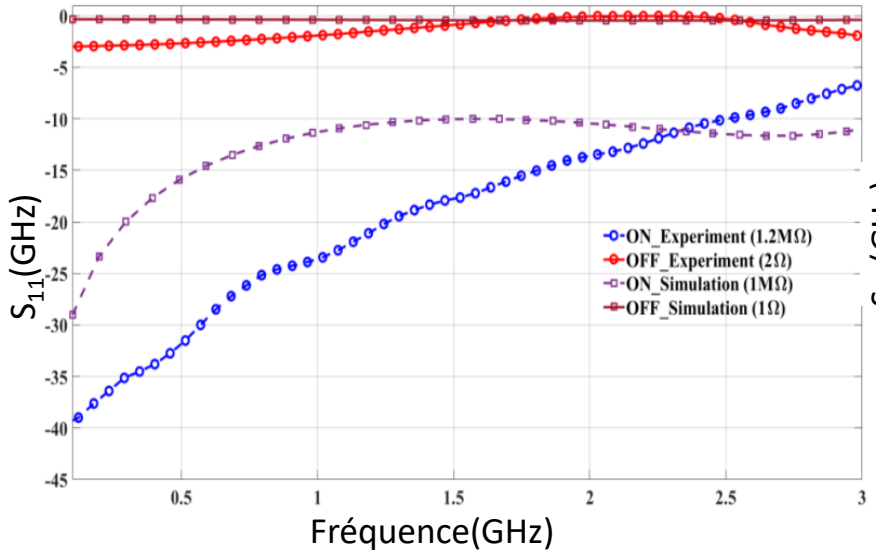
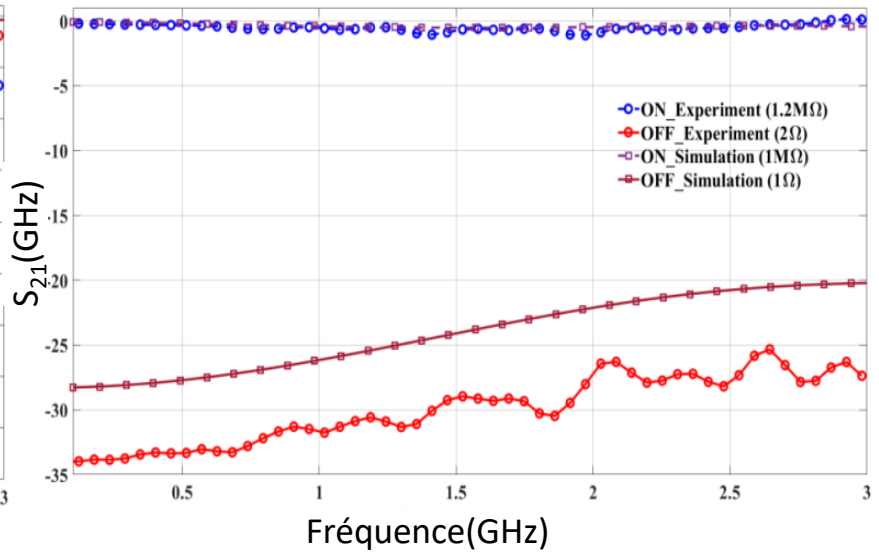
CIRCUITS PASSIFS RECONFIGURABLES SUR SUBSTRAT RIGIDE

Conception d'un switch RF en mode « shunt » réalisé sur PCB









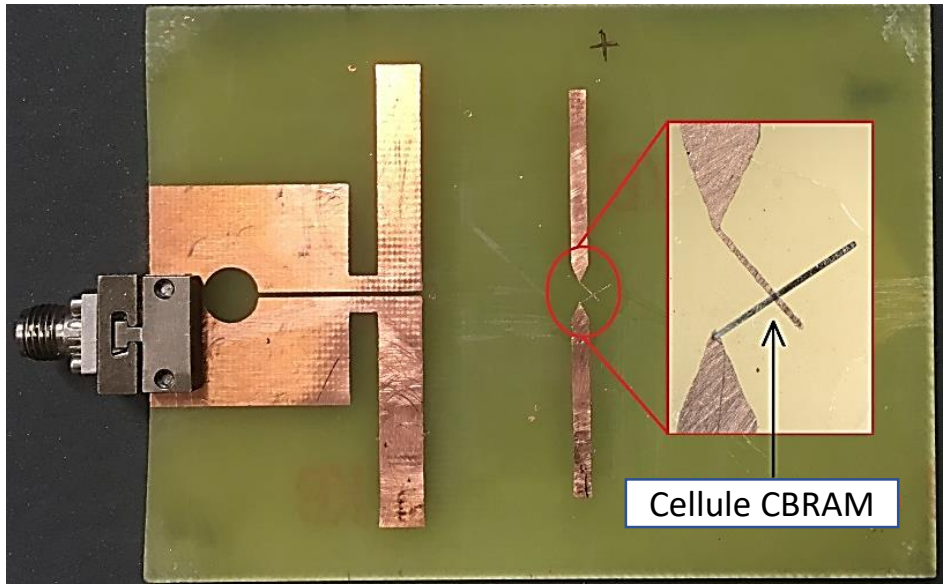
M. Jayakrishnan, A. Vena, A. Meghit, B. Sorli, et E. Perret, « Nafion-based fully passive solid-state conductive bridging RF switch », IEEE Microw. Wirel. Compon. Lett., vol. 27, no 12, p. 1104–1106, 2017.

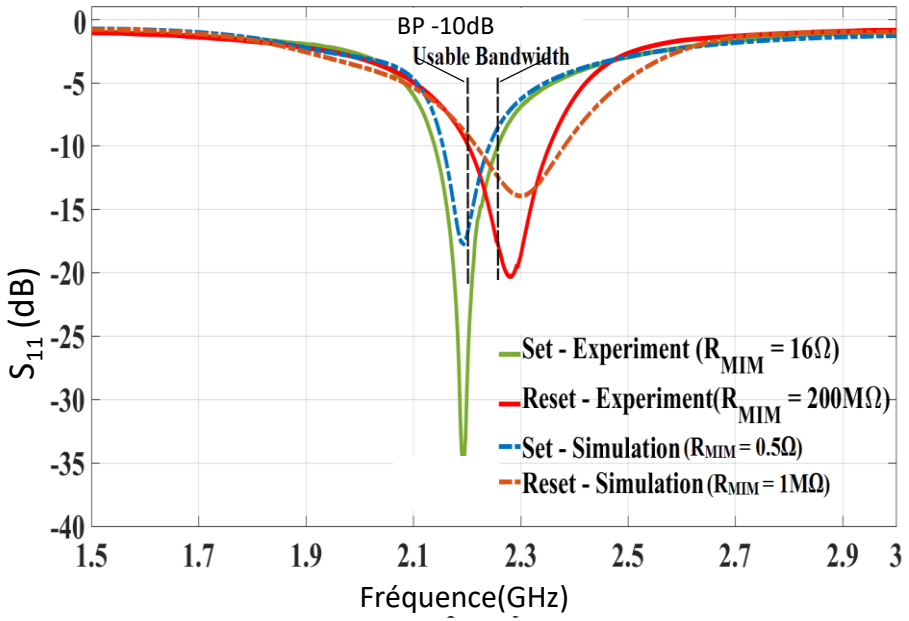
CIRCUITS PASSIFS RECONFIGURABLES SUR SUBSTRAT RIGIDE

Réalisation d'une antenne accordable en faisceau

Antenne dipôle avec élément parasite directeur chargé

- Fréquence centrale : 2,25GHz
- Niveau d'adaptation dans la bande passante : < -10dB
- Bande passante à -10dB : ~54MHz

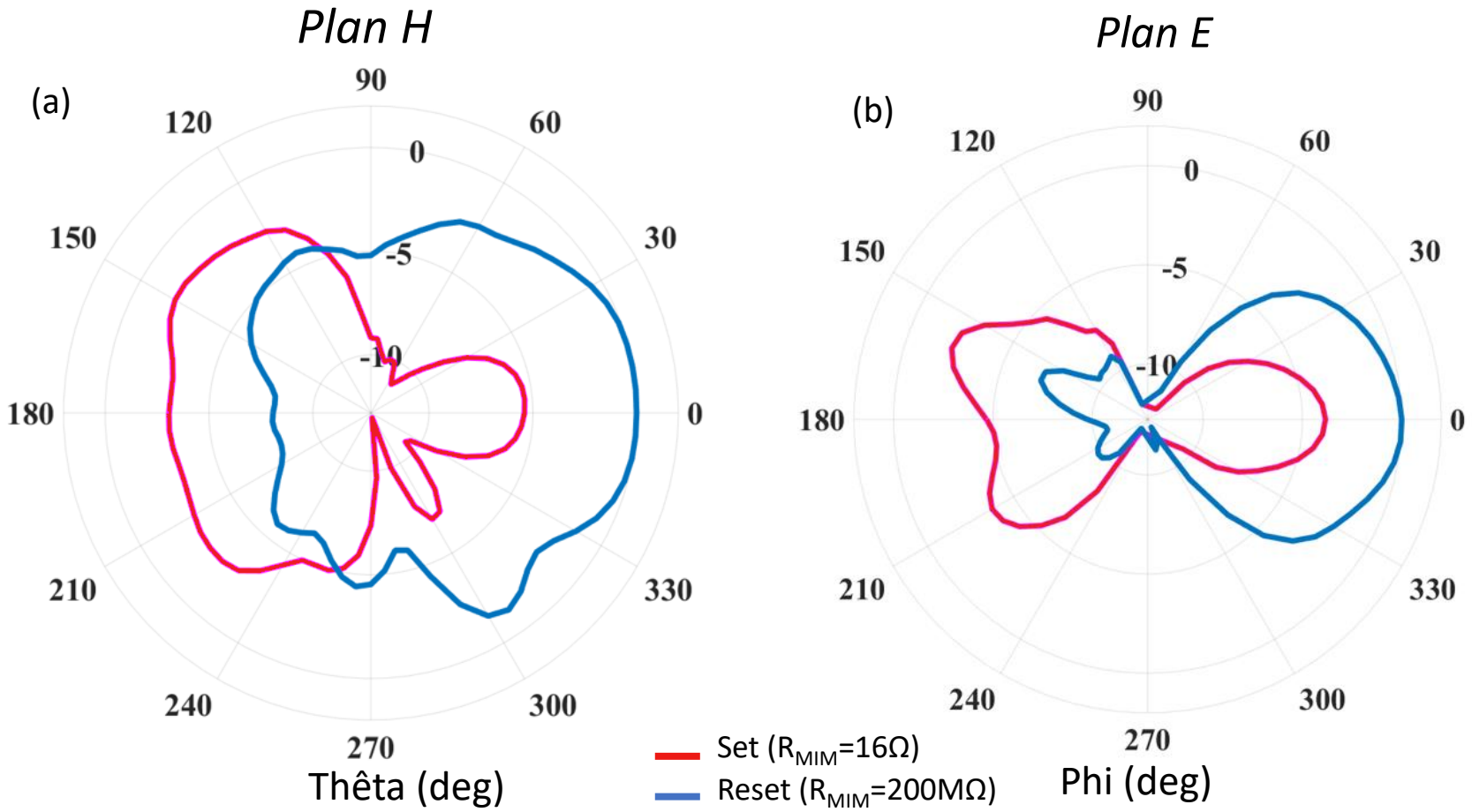




M. P. Jayakrishnan, E. Perret, A. Vena, et B. Sorli, « Electronically Reconfigurable Dipole Antenna Using Integrated Passive Non-Volatile Solid-State Metal-Insulator-Metal Switches », in 2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, 2019, p. 303–304.

CIRCUITS PASSIFS RECONFIGURABLES SUR SUBSTRAT RIGIDE

Réalisation d'une antenne agile en faisceau



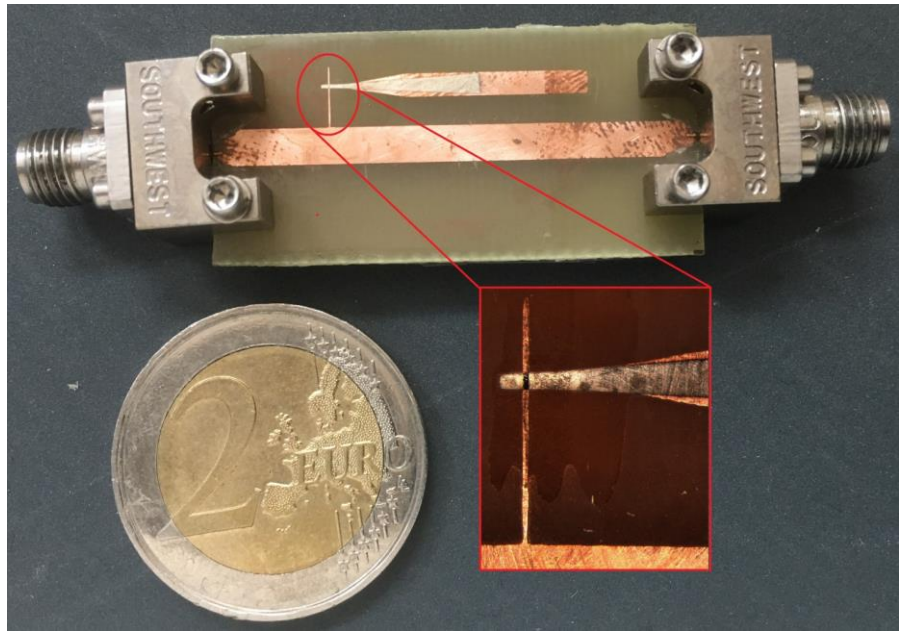
M. P. Jayakrishnan, E. Perret, A. Vena, et B. Sorli, « Electronically Reconfigurable Dipole Antenna Using Integrated Passive Non-Volatile Solid-State Metal-Insulator-Metal Switches », in 2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, 2019, p. 303–304.

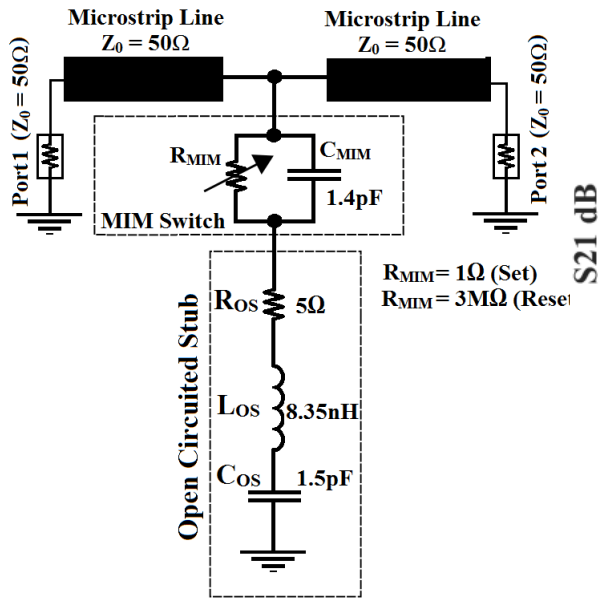
CIRCUITS PASSIFS RECONFIGURABLES SUR SUBSTRAT RIGIDE

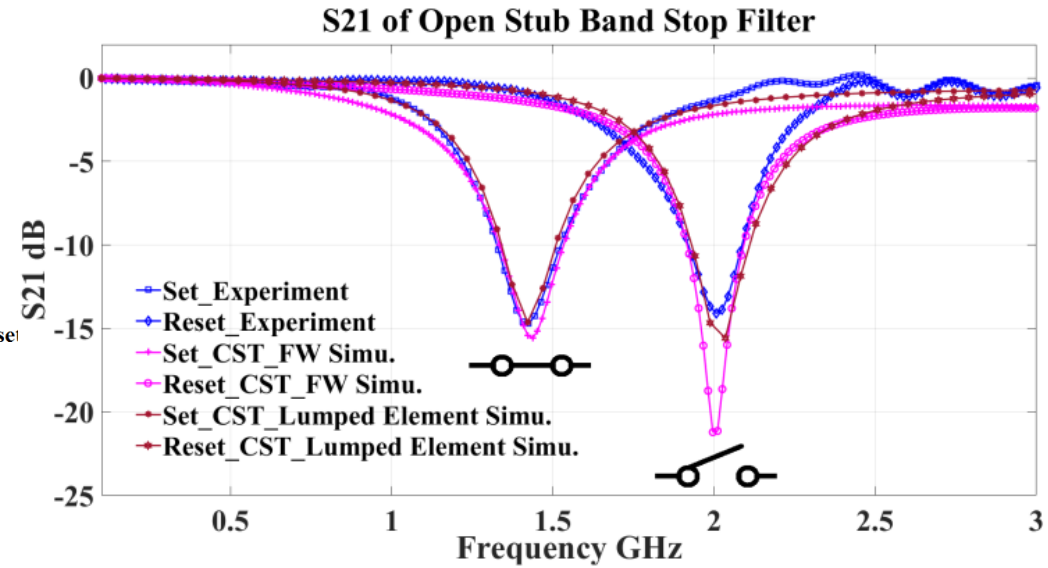
Réalisation d'une filtre réjecteur de bande accordable en fréquence

Ligne microstrip connecté à un stub en circuit ouvert

- Fréquence : 1,5GHz à 2GHz
- Largeur de bande à -10dB : 140 MHz
- Isolation : -14dB



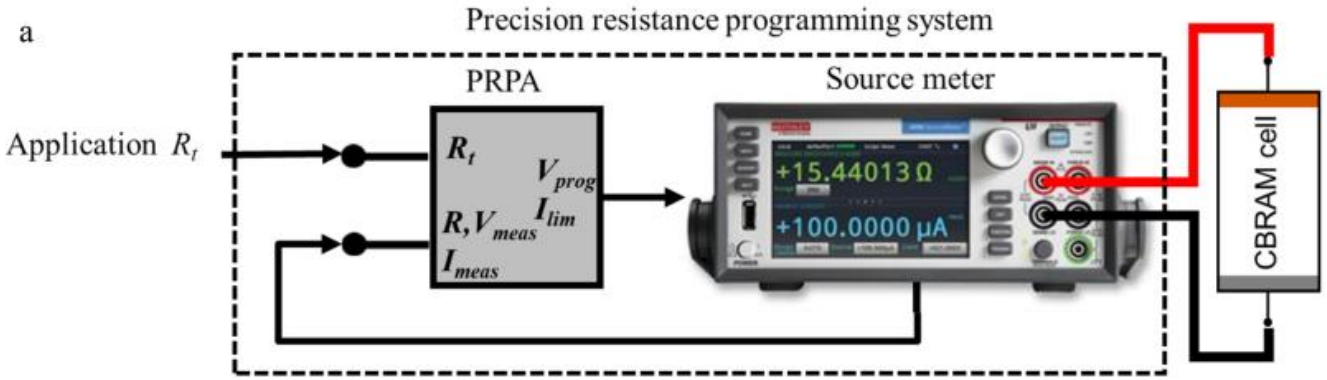


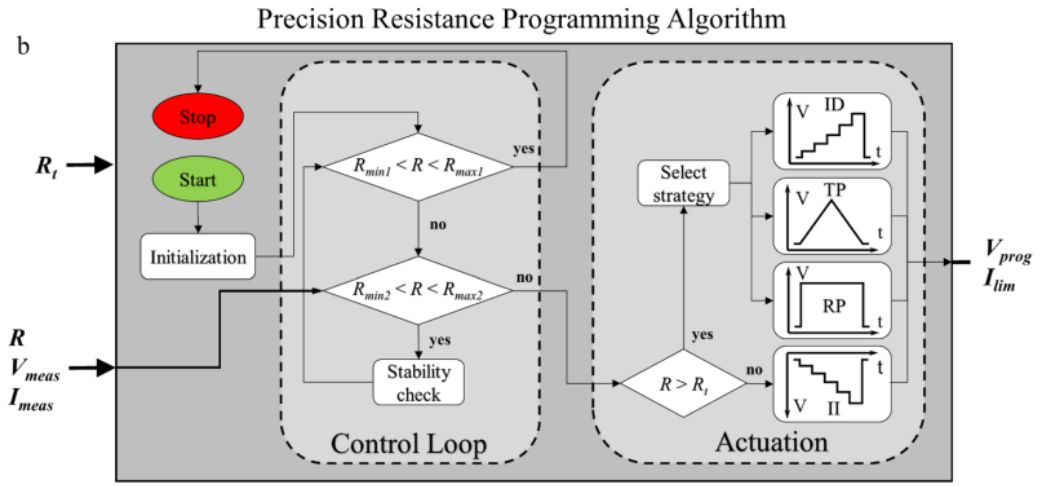


MP Jayakrishnan, A Vena, B Sorli, E Perret « Investigation of integrated solid state nano-ionic metal–insulator–metal switches for electronically reconfigurable band-stop filter applications, » IET Microwaves, Antennas & Propagation, 2019

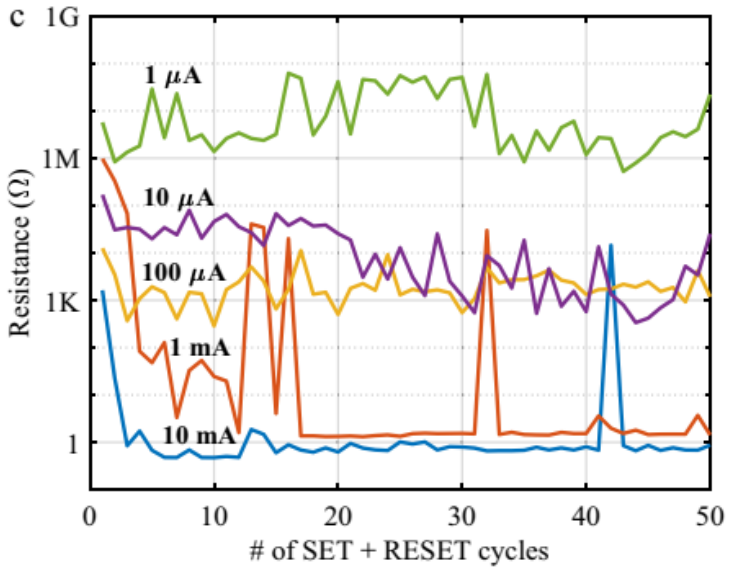
CIRCUITS PASSIFS RECONFIGURABLES SUR SUBSTRAT RIGIDE

Optimisation de la programmation des cellules CBRAM

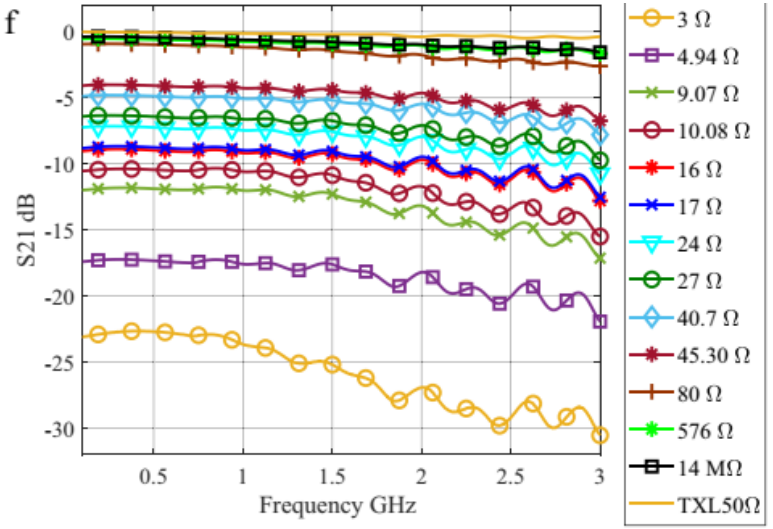




Resistance en fonction du courant de limitation



Atténuateur RF reconfigurable (S21)



López-Soriano, S., Methapettyparambu Purushothama, J., Vena, A. *et al.* CBRAM technology: transition from a memory cell to a programmable and non-volatile impedance for new radiofrequency applications. *Sci Rep* **12,** 4105 (2022)

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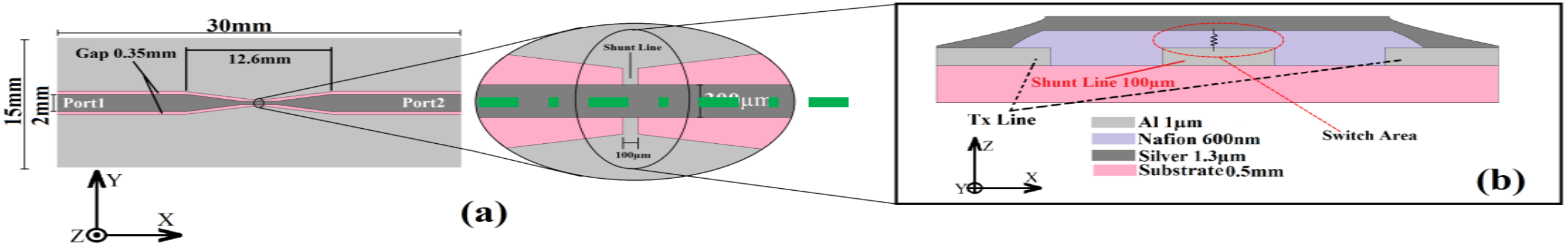
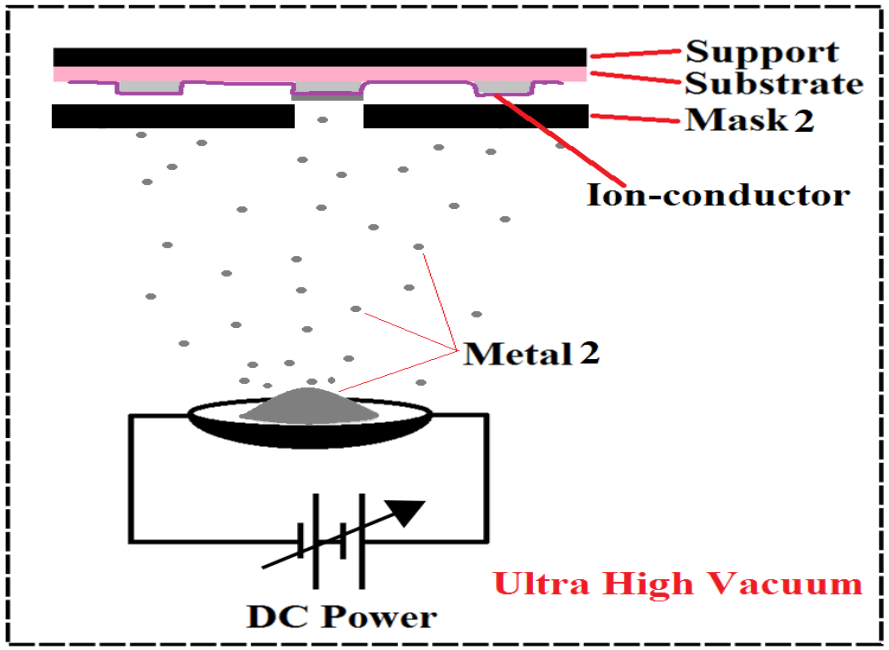
CIRCUITS PASSIFS RECONFIGURABLES FLEXIBLES



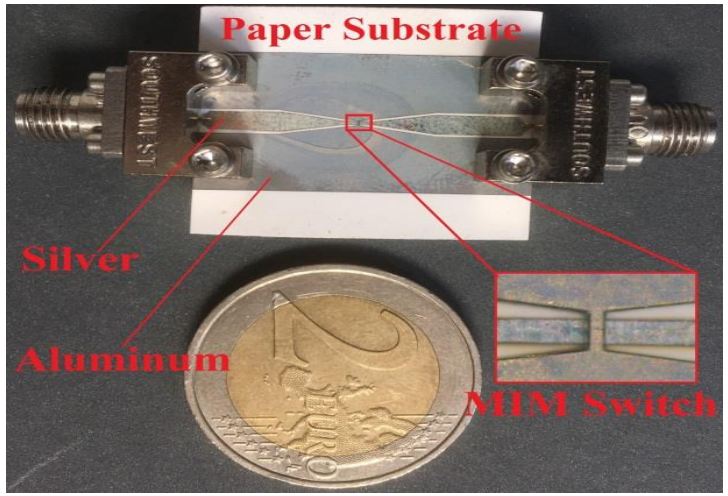
Active electrode : Silver
Inert electrode : Aluminum
Electrolyte/Ion Conductor : Nafion
Substrate : Paper (Univ. Montpellier)



Fabrication Process

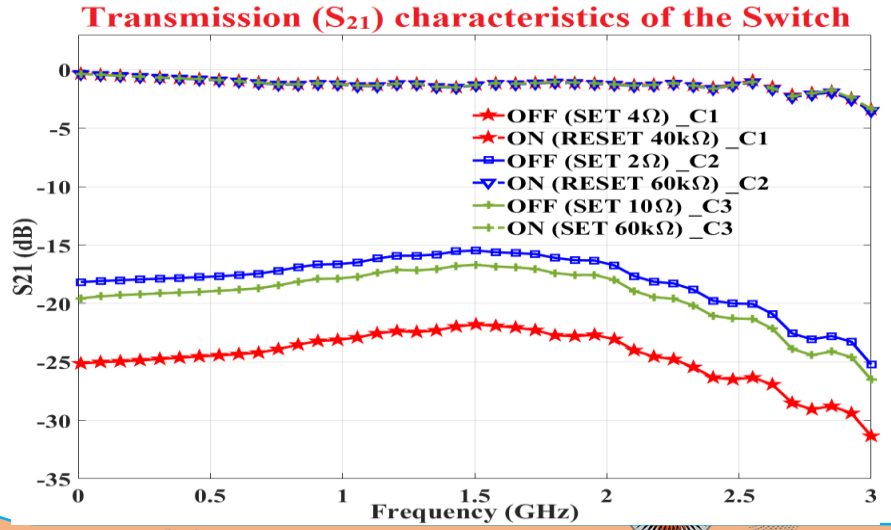
1. Place Mask 1 for Metal 1 and Thermal vapor deposition
2. Spin coating and drying of Nafion
3. Place Mask 2 for Metal 2 and Thermal vapor deposition

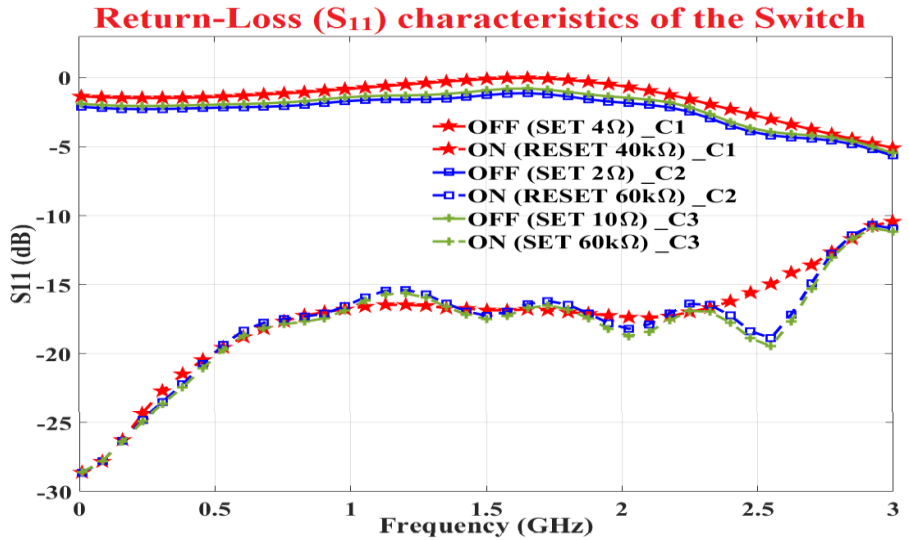
CIRCUITS PASSIFS RECONFIGURABLES FLEXIBLES



Photograph of the fabricated RF-Switch showing a microphotograph (Inset) of the MIM switch area

RF Performance (S-Parameters) of the switch

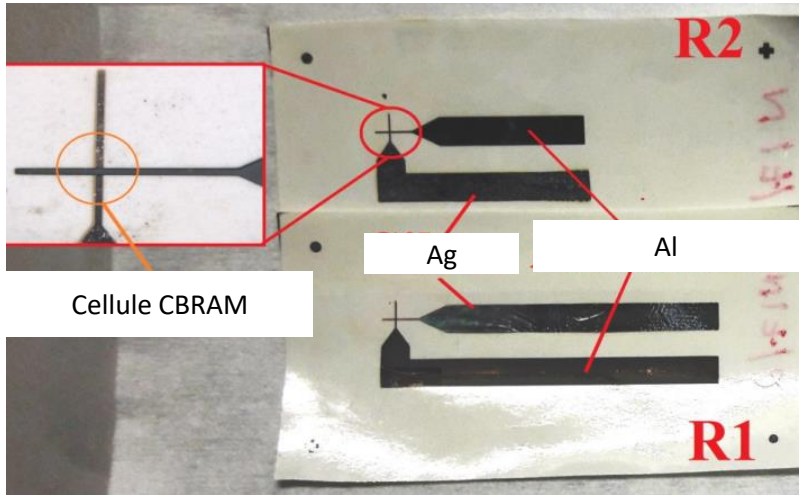


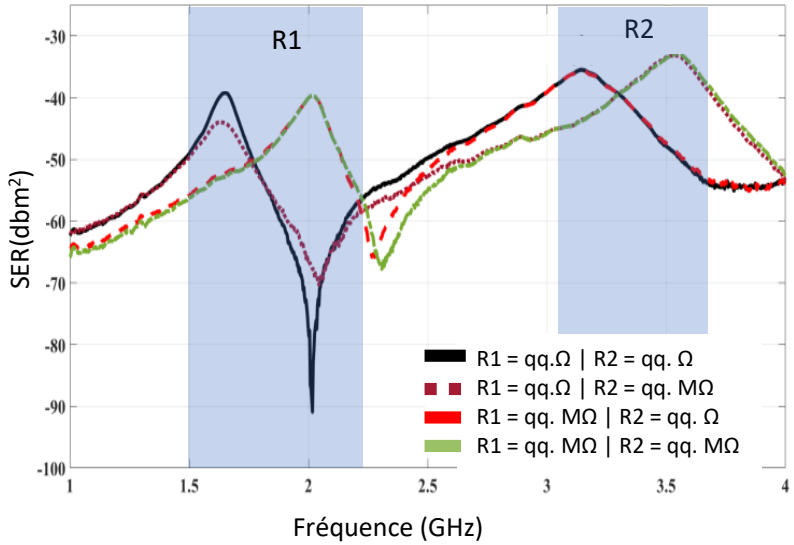


CIRCUITS PASSIFS RECONFIGURABLES FLEXIBLES

Tag chipless reconfigurable 4 bits sur papier

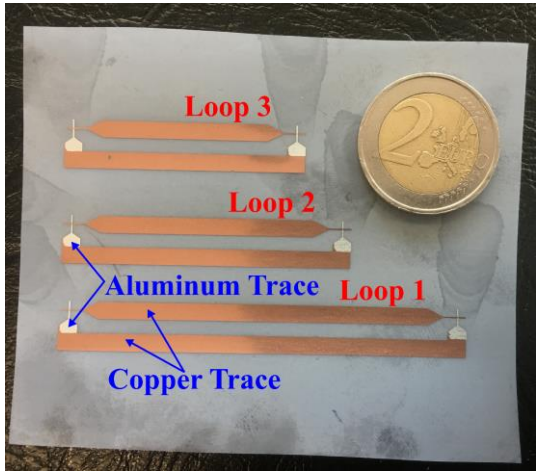
J. M. Purushothama, A. Vena, B. Sorli, et E. Perret, « Electronically Re-Writable Chipless RFID Tag Using Solid State Metal-Insulator-Metal Switches on Paper Substrate », in 2019 IEEE/MTT-S International Microwave Symposium-IMS 2019, 2019, p. 400–403.

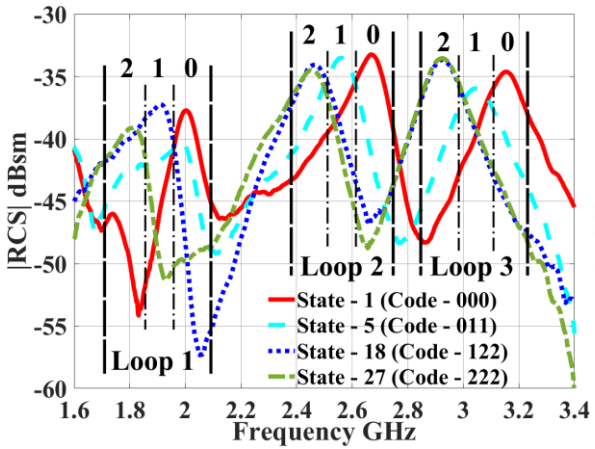


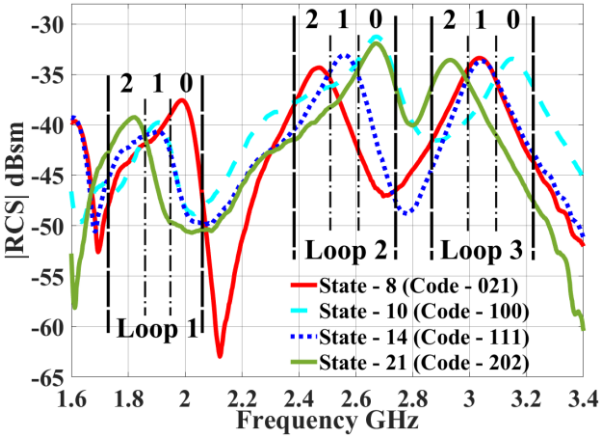


Tag chipless reconfigurable réalisé par impression thermique

J. M. Purushothama, S. Lopez-Soriano, A. Vena, B. Sorli, I. Susanti and E. Perret, "Electronically Rewritable Chipless RFID Tags Fabricated Through Thermal Transfer Printing on Flexible PET Substrates," in IEEE Transactions on Antennas and Propagation, vol. 69, no. 4, pp. 1908-1921, April 2021







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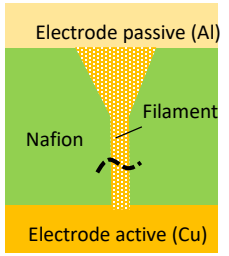
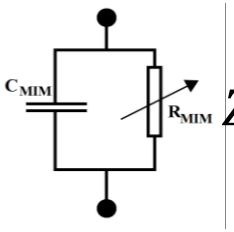
ETUDE DE STRUCTURES PLANAIRES

Impédance vs fréquence en fonction de la topologie

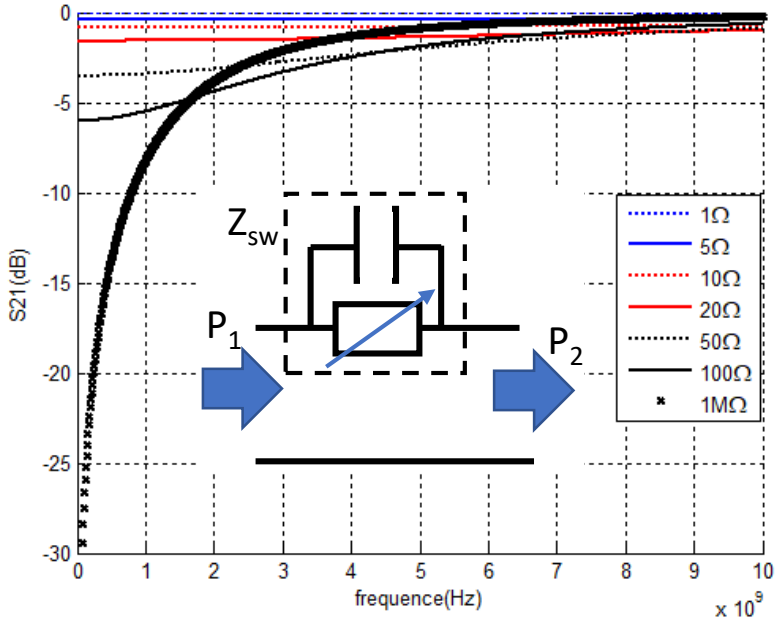
- épaisseur d'électrolyte : 500nm
- surface d'électrode : 100x100µm²

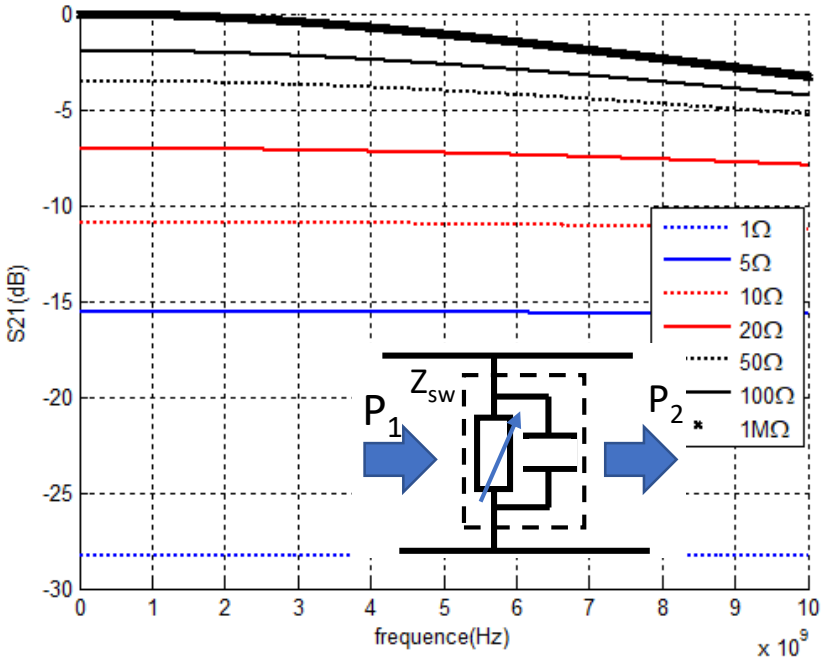




$$Z_{sw} = \frac{1}{\frac{1}{R} + j \cdot C\omega}$$

$$S_{21serie} = \frac{2Z_0}{2Z_0 + Z_{sw}}$$

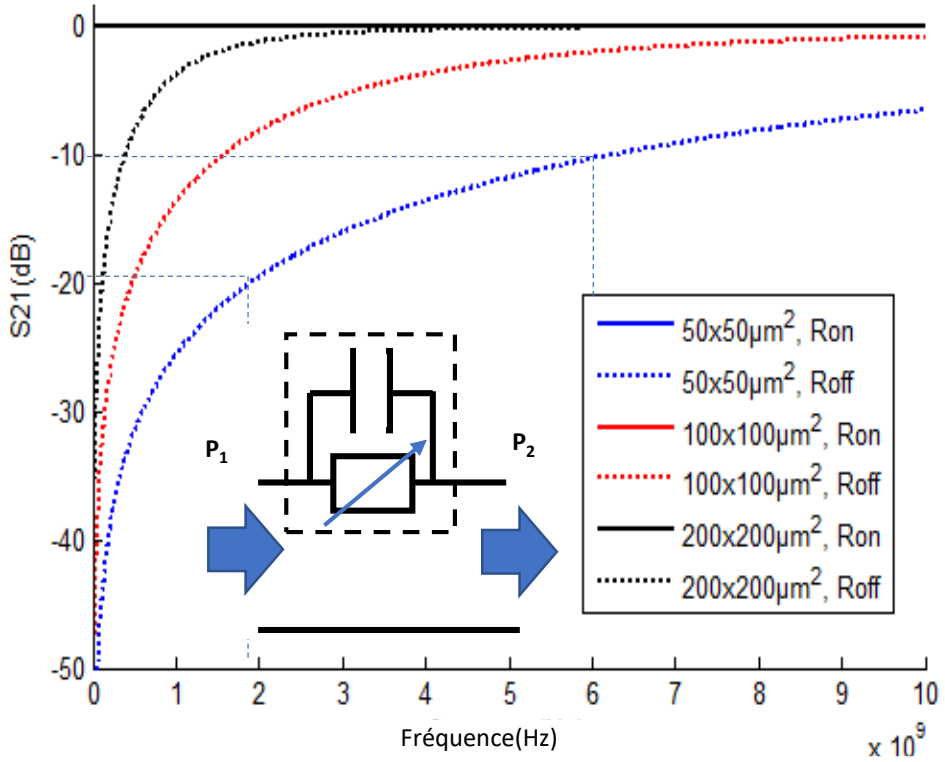




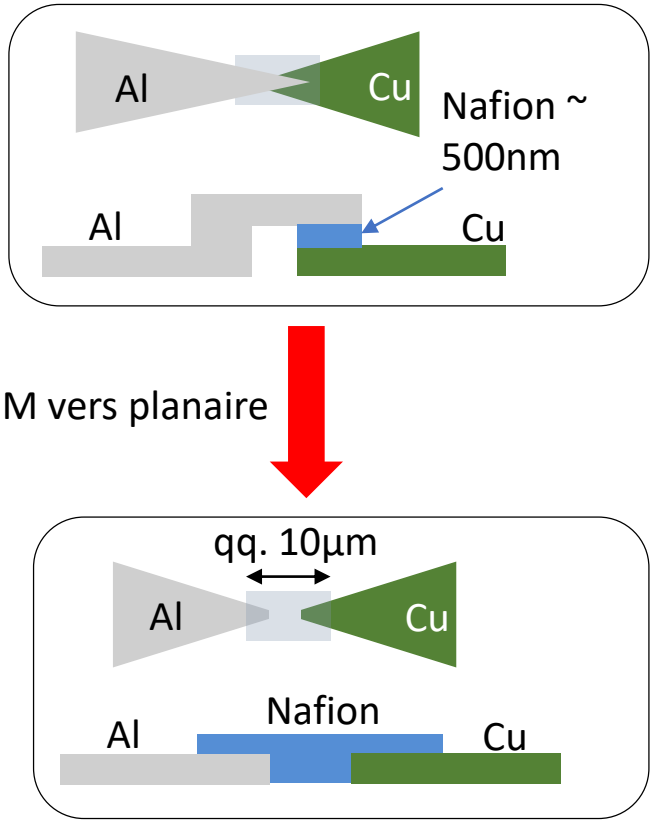
$$S_{21parallèle} = \frac{2Z_{sw}}{Z_0 + 2Z_{sw}}$$

ETUDE DE STRUCTURES PLANAIRES

Montée en fréquence



$$C_{MIM} \approx \varepsilon_0 \varepsilon_r \frac{S}{h}$$



Topologie planaire, augmentation du gap entre les deux électrodes

ETUDE DE STRUCTURES PLANAIRES

1. Using laser to form µgap

- 2W, 3R
- W-21 µm, D-15 µm

2. Sonication procedure

- Cleaning with DI water
- Sonication with Acetone for 20 mins, drying with compressed air

3. Chemical Etching procedure (After fabrication)

- Cleaning the sample with the sonication procedure
- Chemical Etching with $FeCl_3$ solution for 10-30 secs
- Cleaning with DI water
- Drying with compressed air

4. Electroplating of Cu

- For 40 mins and at 8 mA

5. Chemical Etching procedure (After Cu deposition)

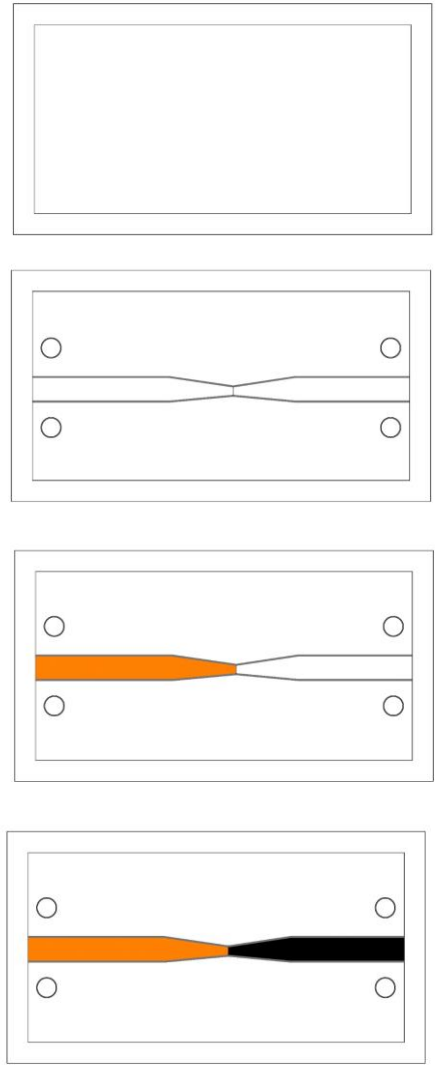
- Cleaning the sample with the sonication procedure
- Chemical Etching with $FeCl_3$ solution for 5-10 secs

6. Electroplating of Ni

- For 10 mins and at 8 mA

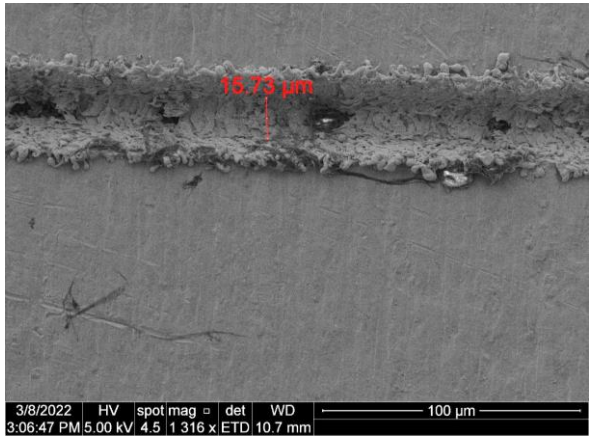
7. Nafion deposition

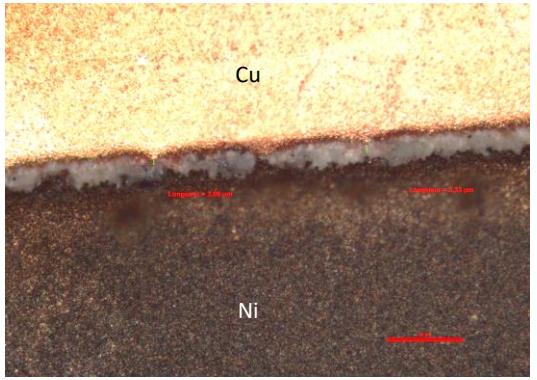
- Drop of Nafion

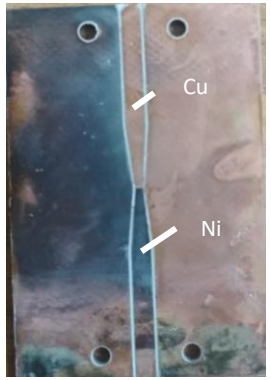


ETUDE DE STRUCTURES PLANAIRES

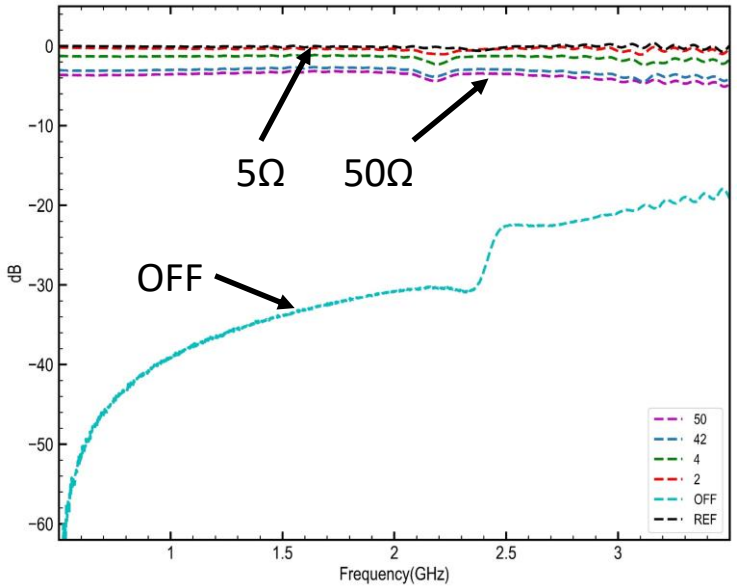
Switch planaire reconfigurable Cu-Ni réalisé sur substrat rigide



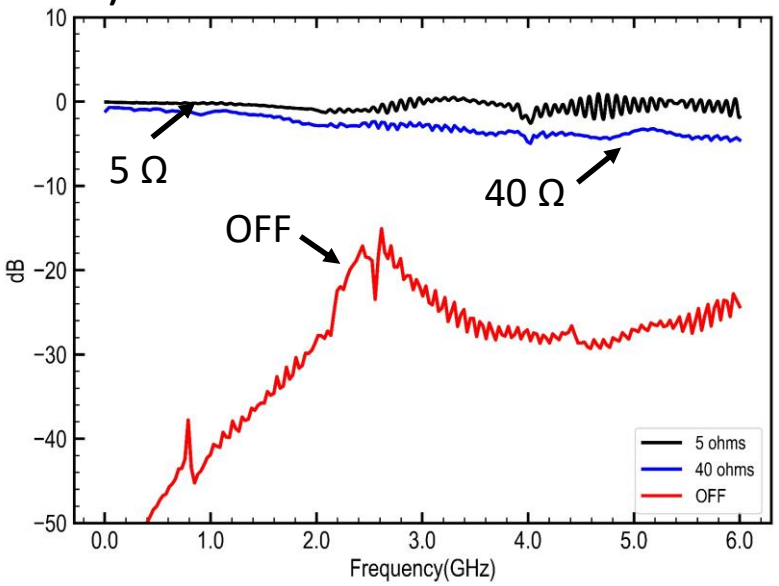




Echantillon 1 : coefficient de transmission S21 (100kHz-3GHz)



Echantillon 2 : coefficient de transmission S21 (300kHz-6GHz)

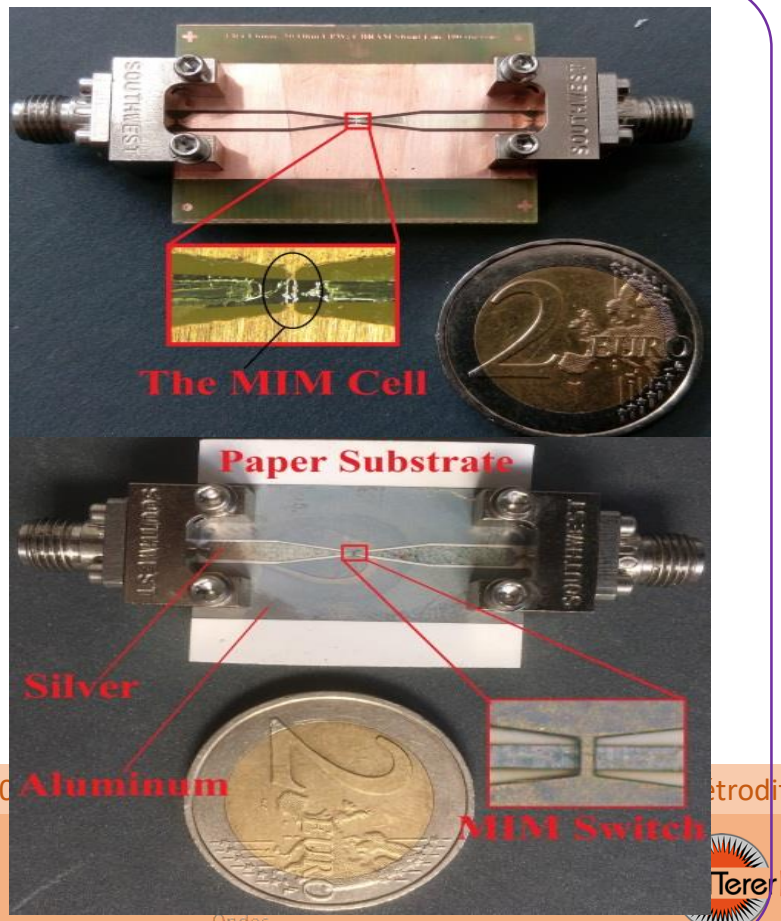


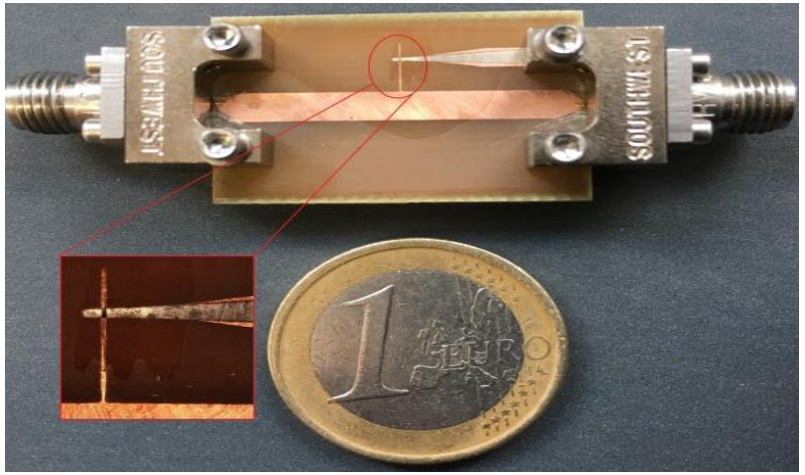
PLAN

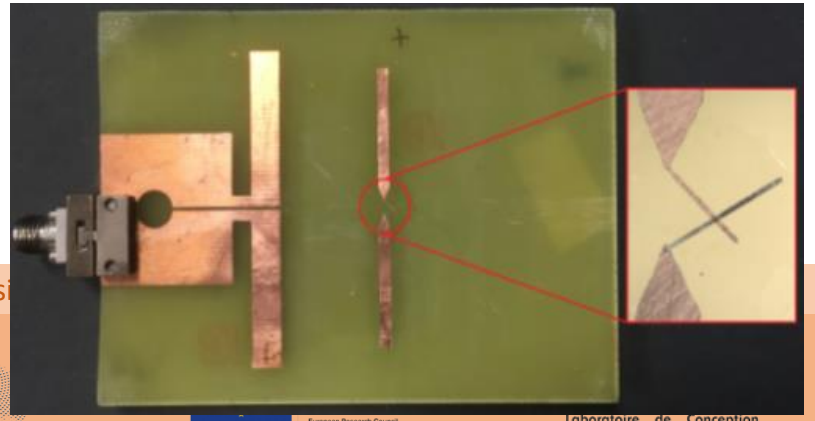
- Technologie CBRAM
- Circuits passifs reconfigurables sur substrat rigide
- Circuits passifs reconfigurables flexibles
- Etude de structures planaires
- Conclusion et perspectives

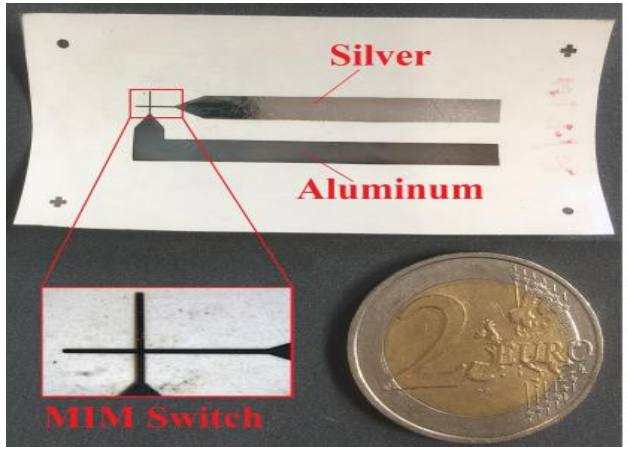
CONCLUSION

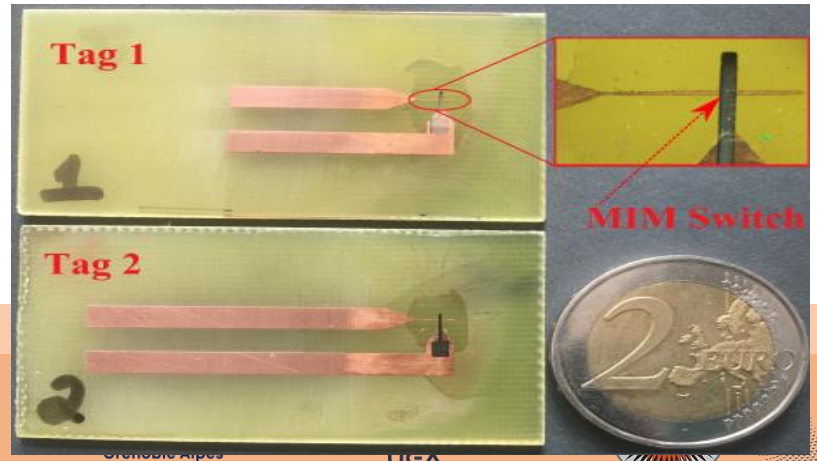
Development of Fully Passive Solid-State RF-Switching Technology using **simple fabrication steps**, without any 'Clean Room' technologies, on common everyday objects (like **paper substrate**), and to apply this in the development of **electronically reconfigurable RF-Electronic devices**.









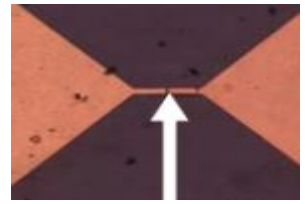


CONCLUSION

Features	Our Design on Paper substrate	Our Design on FR4 [7]	State of the Art [3]
Min. Fabrication size Requirement	100µm	100µm	10µm
Frequency Range	DC - 3GHz	DC - 3GHz	DC - 6GHz
Isolation (avg.) (Off state)	**-16dB to -25dB**	**-16dB to -34dB**	-35dB
Insertion Loss(avg.) (On state)	**1.2dB**	**0.5dB**	0.5dB
Actuation Voltage	~10V/-20V*	~10V/-20V*	~1V
Power Consumption	µW/mW*	µW/mW*	µW
Energy Consumption to Maintain State	0	0	0
'Set' - Resistance (avg.)	**2–5Ω**	**2–5Ω**	**10Ω**
Switching Speed	#	#	1 - 10µs
Alignment Accuracy required for fabrication	Low	Low	Very High
Fabrication Environment	Ambient room	Ambient room	Clean room
Fabrication Cost (Laboratory Perspective)	**Low**	**Low**	**High**
Fabrication Cost (Industrial Perspective)	**Low**	**Low**	**Moderate**

* For Set/Reset respectively

At present, we do not have enough information for calculating the switching time of the presented device.



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