2020 Research Day

Reconfigurable Radiofrequency Circuits based on Phase-Change Materials

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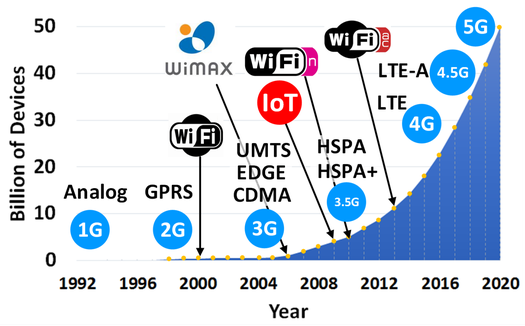
Introduction

Exponential Growth of Mobile Communications



- Exponential increase in number of wireless standards
- Large heterogeneity in mobile handsets
- Different chips for each standard

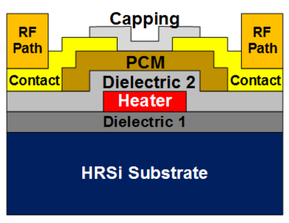
The Need for Reconfigurable RF Systems

- Reduce the need for an RF chain for each band
- Add **flexibility**
- Reduce **area** and **complexity**
- Enable **block reutilization**
- Reduce **time-to-market** of radio transceivers
- Reduce **development costs**

Our Goal

- **Develop fabrication process** of indirectly-heated 4-terminal phase-change material **(PCM)-based RF switch**
- Design and fabricate **reconfigurable RF circuits** based on the PCM high performance RF switch

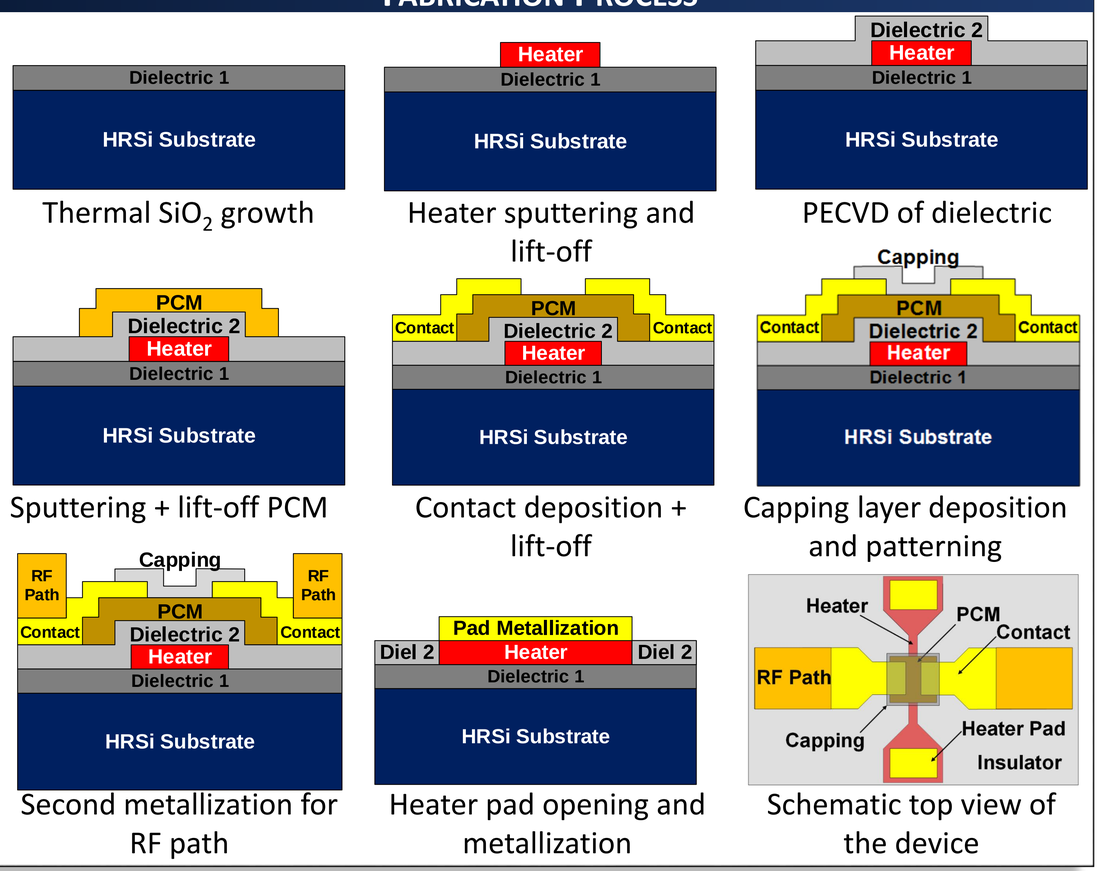
Indirectly Heated PCM RF Switch



- State-of-the-art FOM*
- Non-volatile
- Low-energy switching
- Fast-switching
- BEOL-compatible
- High linearity
- High endurance
- Low R_{ON}
- Small C_{OFF}

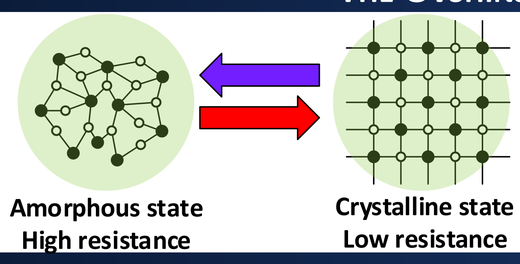
$* FOM = (2\pi R_{ON} C_{OFF})^{-1}$

Fabrication Process



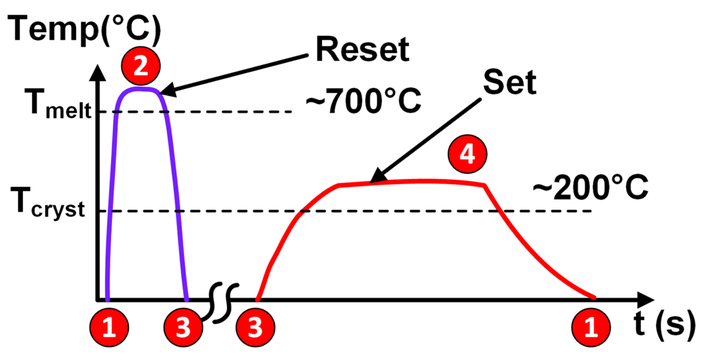
Phase-Change Materials

The Ovshinsky Phenomena

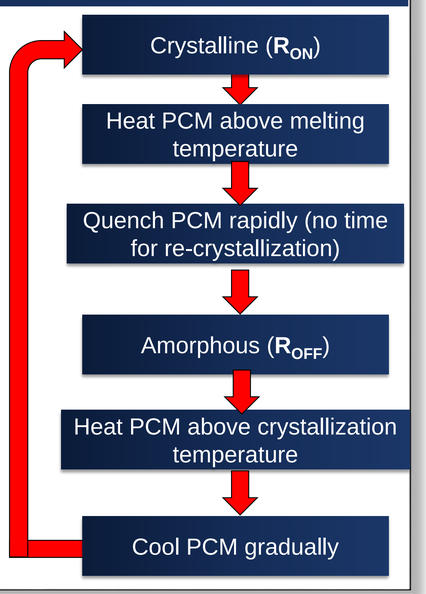


- Use of chalcogenide compounds
- Large R_{OFF}/R_{ON} contrast ($>10^3$)
- Commercial applications:
  - Non-volatile memories
  - Re-writable DVD's and CD's

Phase Transformation

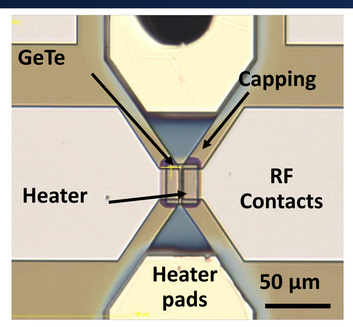


- $t_{set} \approx 1\ \mu s$
- $t_{reset} \approx 100\ ns$

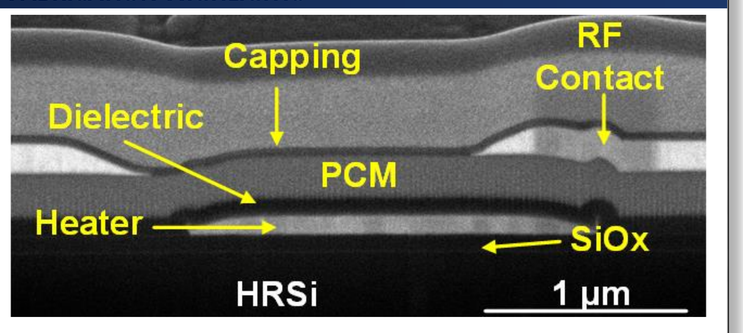


Results

Fabrication Highlights

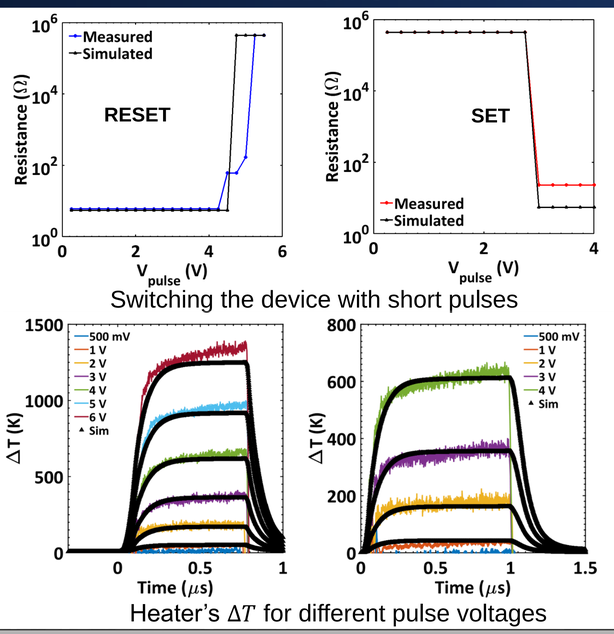


Optical view of fabricated PCM RF switch



FIB cross-section of fabricated PCM RF switch

Electro-Thermal Characterization



Switching the device with short pulses

Heater's ΔT for different pulse voltages

- $R_{OFF}/R_{ON} > 10^4$
- $V_{SET} \cong 3.5\ V$
- $V_{RESET} \cong 5\ V$
- $R_{ON} = 2.3\ \Omega$ for $W = 40\ \mu m\ L = 2\ \mu m$
- $\Delta T_{RESET} = 915\ K$
- $\Delta T_{SET} = 360\ K$

Summary and Future Work

- Developed process for high-performance PCM RF switch fabrication
- Electro-thermal modeling and characterization
- Design and fabrication of PCM-based reconfigurable circuits
- Exploration of the design space to optimize for different applications

References

[1] R. Singh *et al.*, IEEE MTT, 2017. [2] N. El-Hinnawy *et al.*, IEEE EDL, 2013. [3] N. El-Hinnawy *et al.*, IEEE CSICS, 2014. [4] J.S. Moon *et al.*, IEEE MTTS, 2018. [5] M. Rais-Zadeh *et al.*, Proc. IEEE, 2015. [6] N. Wainstein et al., IEEE TCAS I, 2018. [7] N. Wainstein et al., IEEE TNANO, 2018. [8]N. Wainstein et al., ISCAS 2017. [9] N. Wainstein et al., ISVLSI 2019. [10] N. Wainstein et al., Proc. IEEE (submitted). [11] N. Wainstein et al., IEEE EDL (submitted).

Acknowledgments

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