Generic RF-MEMS technology platform for mobile and satellite communications

-Case study: Switchable filters for GPS-Galileo band switching-

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Outline

- Introduction
- Integration of passives
  - Multi-layer thin film technology platform for microwave passives (MCM-D)
  - RF-MEMS technology platform
  - Hybrid integration
- Case study: Switchable LC-type BPF for GPS/Galileo band switching
- Wafer-level (or 0-level) packaging of the MEMS
- Conclusions and future work

RF transceiver: Present solution

So many discrete passives…..

>350 passives

- inductors, capacitors, resistors
- varicaps
- filters (ceramic, SAW, ….)
- quartz crystal
- switches (antenna select, T/R)

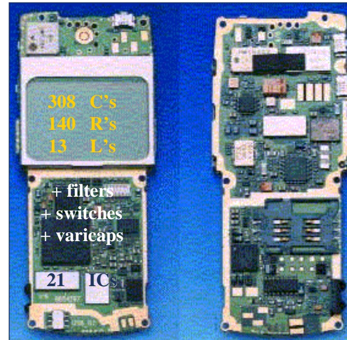
~ 95% of components (5-10% actives)
~ 80% of PCB space
~ 70% of cost

Needed is a reduction in

- size&weight
- power consumption (to extend battery life)
- cost

And in addition,

- higher data rates
- more functionality
  (multiband/standard, video, e-commerce, GPS, wireless link to other devices)



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How?

- New Architectures
- Passive Integration

- *fixed (R,L,C)* → *MCM-D, LTCC*
- *variable (switch, ..)* → *RF-MEMS*

Multilayer Thin Film Embedded µW Passives based on Imec's MCM-D technology

0.72 nF/mm²

Ta_2O_5 capacitor

5.5 pF/ mm²

BCB capacitor

0.7-37 kΩ

TaN resistors

25-100 Ω/□

L = 0.6 - 80 nH; Q = 30 - 150

Spiral Cu inductor

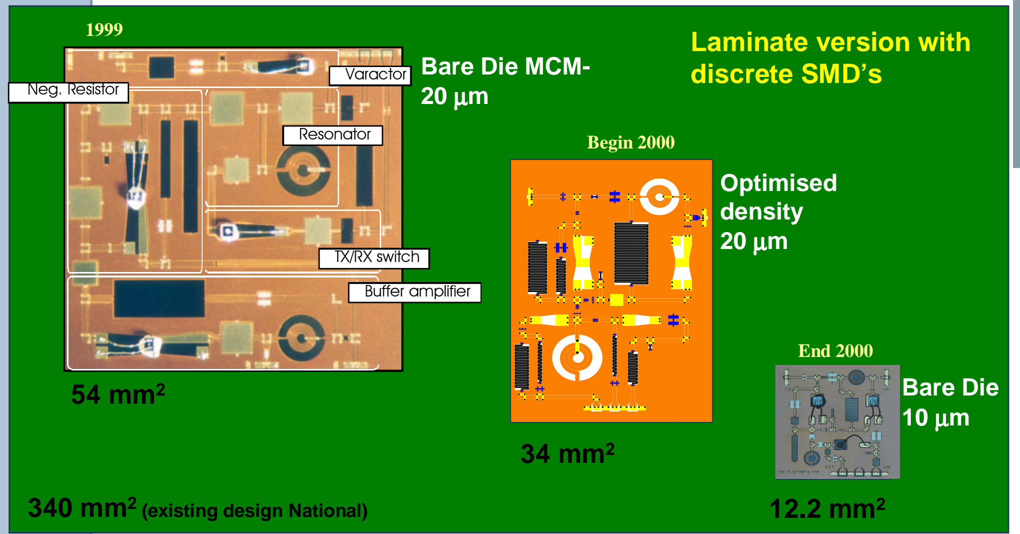
pHEMT (LNA)
BPF
BPF
mixer

SoP: WLAN receiver (5.2 GHz)

CHIP
Cu
R
C
L
BCB
MCM carrier substrate

Integration of passives leads to miniaturisation

Example: VCO circuit



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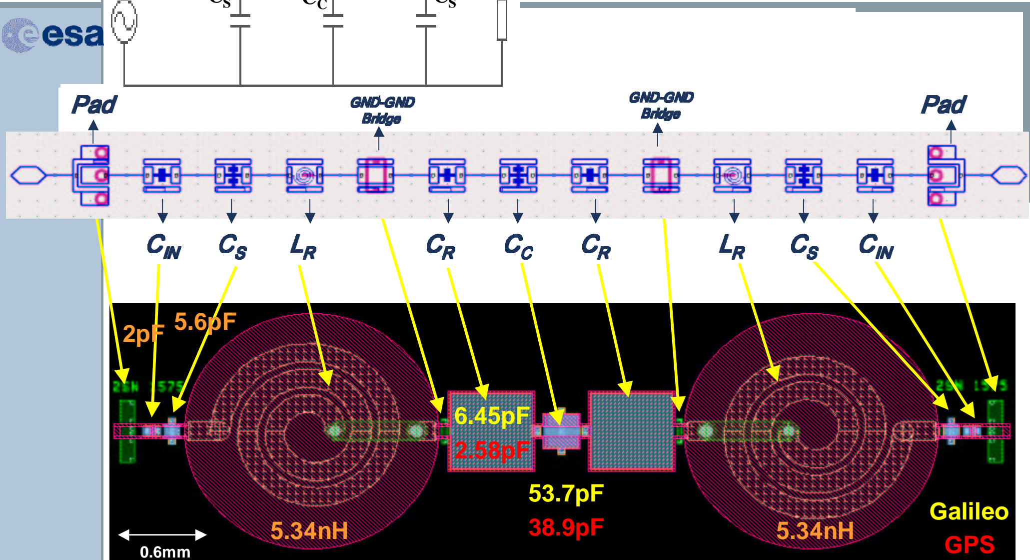
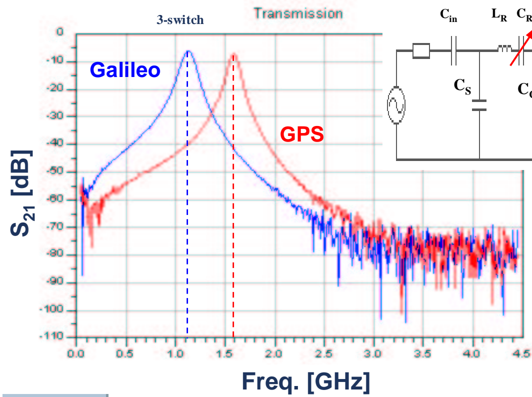
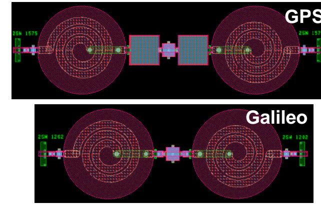
Example MCM-D circuit:

LC-type BPF (GPS and Galileo)



2nd order LC-type BPFs in MCM-D:
for GPS and Galileo





(…) simulation

	IL (dB)	CF (MHz)	BW (MHz)
Galileo (1202MHz)	6.0 (4.3)	1130 (1203)	109 (105)
GPS (1575MHz)	7.3 (5.1)	1587 (1576)	90.5 (94.3)

MCM-D:

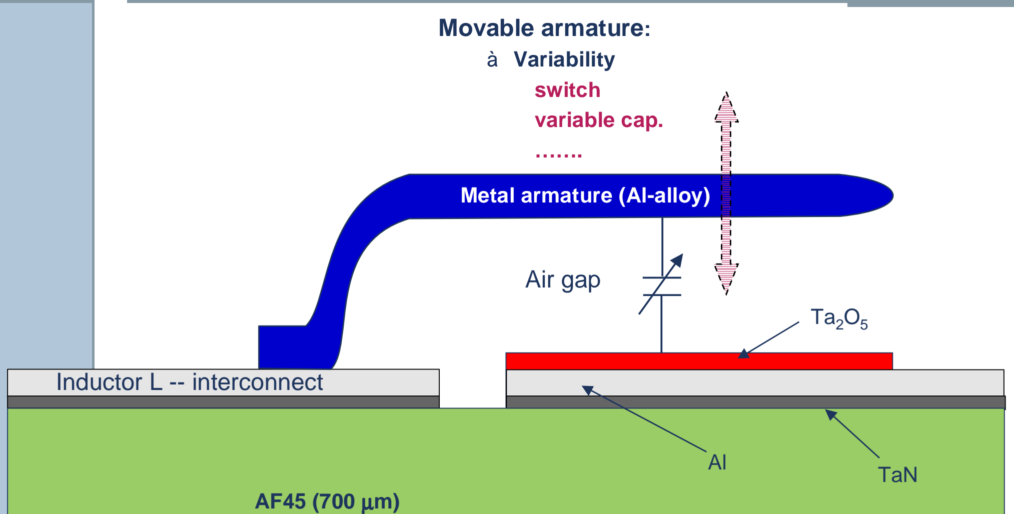
Ø Two separate filters for both bands
à increased size

Need for *on-chip* switchable capacitor
(for C_R and C_C)

→ RF-MEMS

IMEC's metal thin film RF-MEMS technology:
Basic layer built-up (5 masking steps)

Movable armature:
à Variability
switch
variable cap.
…….



RF-MEMS Technology Platform:

multi-layer thin film metal surface micromachining RF-MEMS

0.7-37 kΩ

TaN resistors 25-100 Ω/□

0.72 nF/mm²

Ta_2O_5 capacitor

L=0.6-80nH Q=5-40

Spiral Al inductor

Transversal shunt

Longitudinal shunt

Capacitive switches/ switched capacitors (5-50GHz)

Tunable capacitor

Wafer-level packaging

shunt

series

Boosted Capacitive switches/switched capacitors (0.5-50GHz)

probe

Cu 2µm/ Ni 3 µm / Au 300nm

Probe pad

Metal armature (Al-alloy 1µm))

Air gap

Ta_2O_5 (0.3µm)

Interconnect (Al-1µm)

AF45 (700 µm)

Al (0.3µm)

TaN (0.2µm)

Switchable filter in RF-MEMS:

between GPS and Galileo bands

C_{in} L_R C_R L_R C_R C_{in} C_S C_C C_S

Inductor type C1 (TaN/Al/TaO/float Al/bridge Al)

3-switch

m2 m1

m1 freq=1.570GHz dB(c59_f2_01..S(1,2))=-10.651

Galileo

GPS

m2 freq=1.270GHz dB(c59_f2_02..S(1,2))=-11.866

MED4.2.3

S21 [dB]

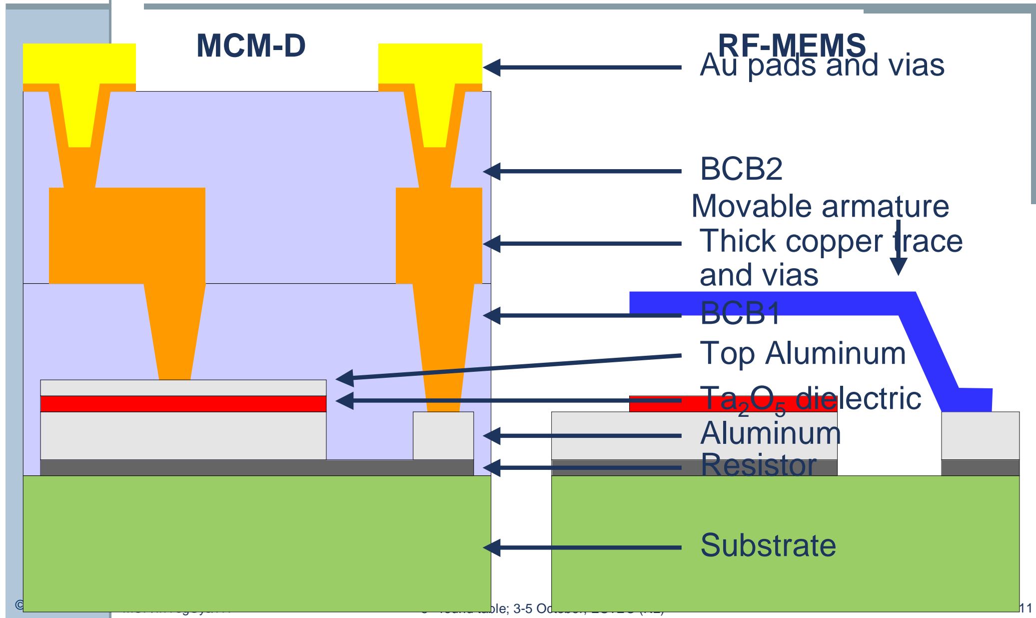
freq, GHz

Comparison MCM-D/RF-MEMS

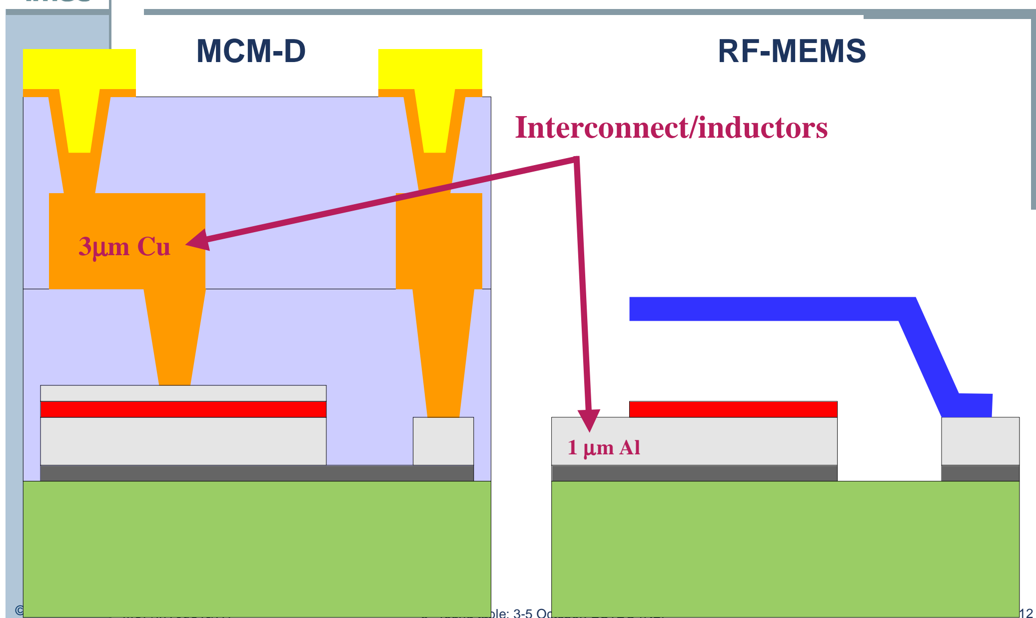
- (+) Reduced size (by factor 2)
- (-) Increased loss

	IL [dB] MCM-D	IL [dB] RF-MEMS
Galileo (1202MHz)	6.0	12
GPS (1575MHz)	7.3	11

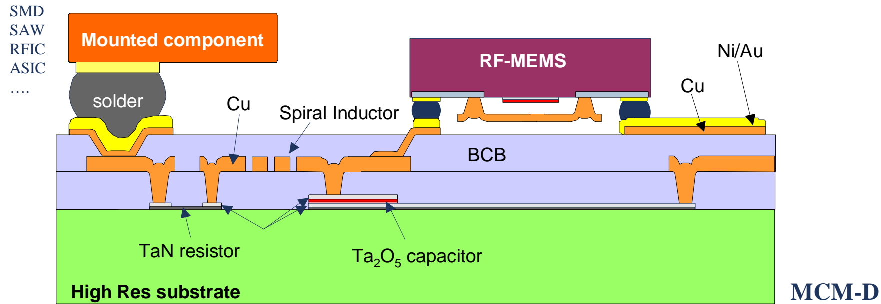
MCM-D vs. RF-MEMS



MCM-D vs. RF-MEMS



RF-MEMS System in-a Package (RF-SiP):
Hybrid Integration of RF-MEMS and MCM-D



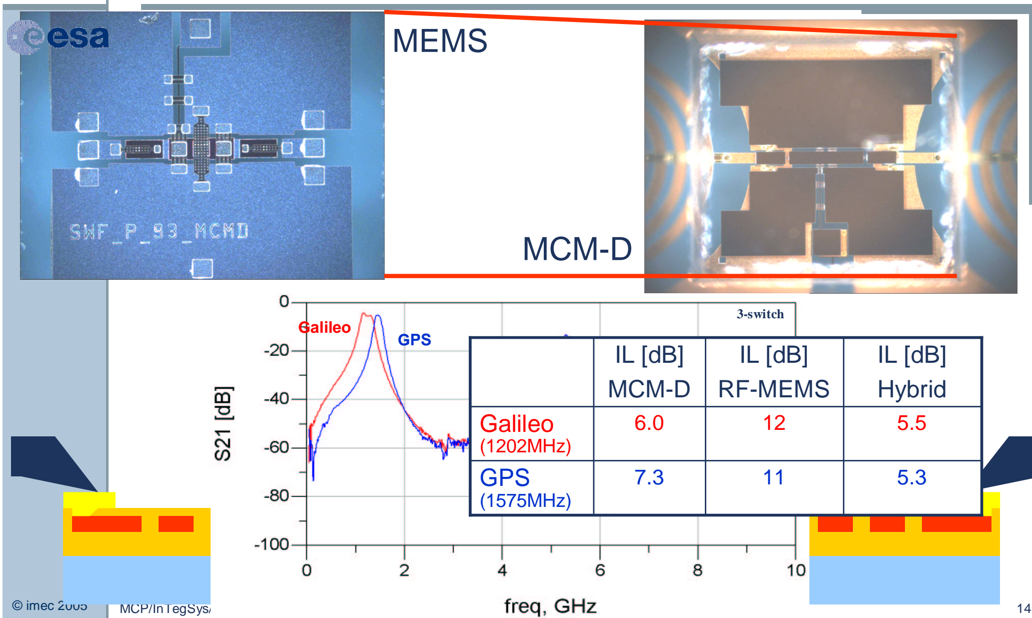
Source: Imec

MCM-D: high-Q inductors (passives)
low-loss interconnect
FC mounting

RF-MEMS: tunability/switchability

} Combine! à Best of both worlds

Switchable BPF filter (GPS/Galileo):
Hybrid integration RF-MEMS on MCM-D



	IL [dB] MCM-D	IL [dB] RF-MEMS	IL [dB] Hybrid
Galileo (1202MHz)	6.0	12	5.5
GPS (1575MHz)	7.3	11	5.3

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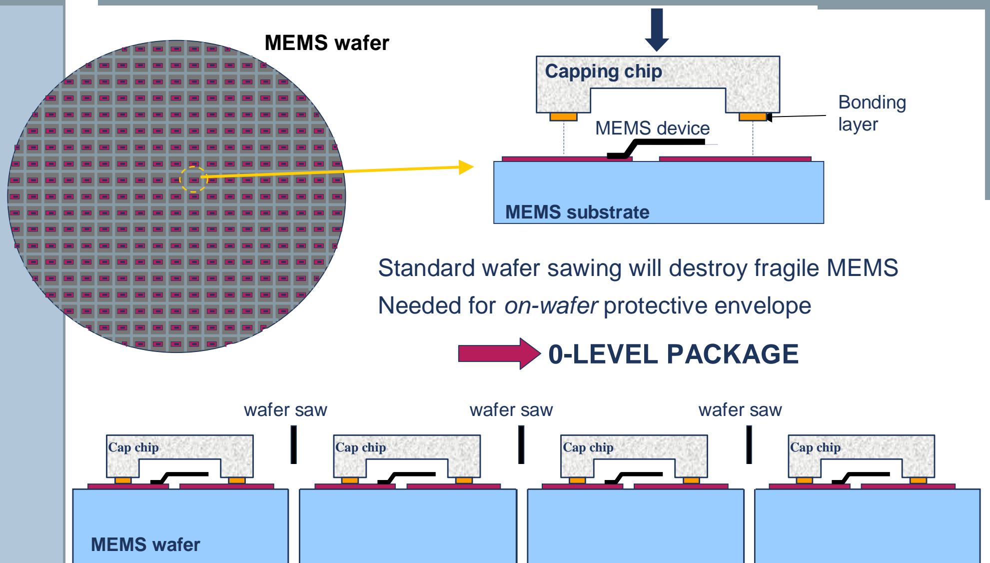
Need for on-wafer MEMS packaging



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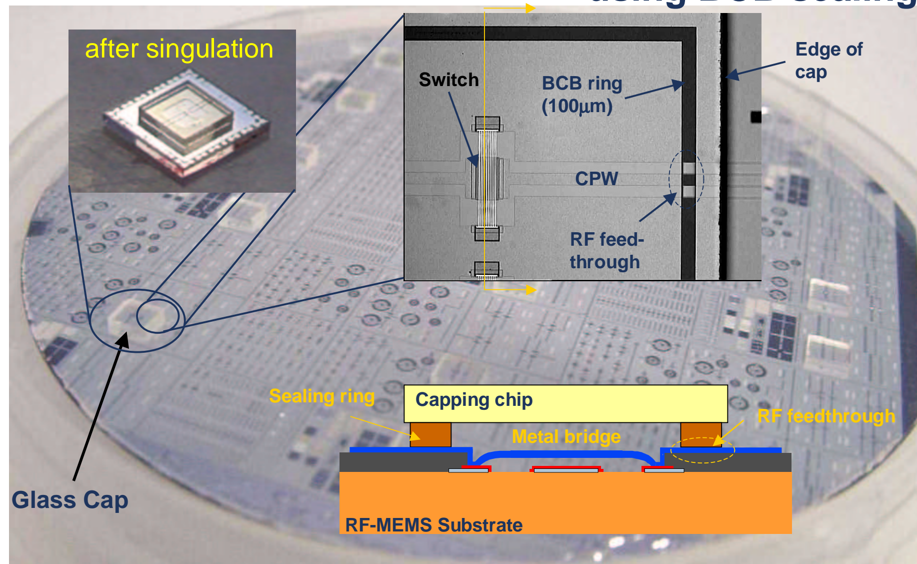
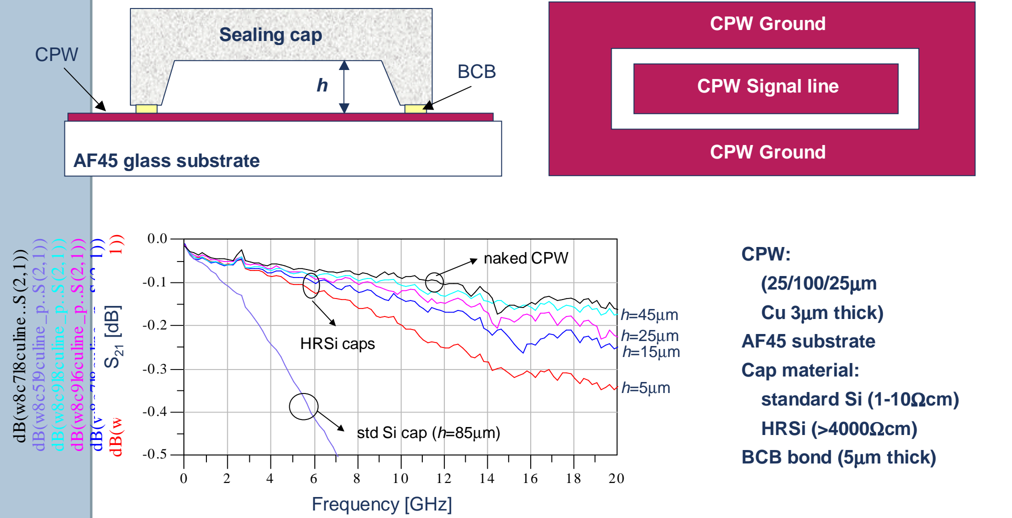
0-level packaged RF-MEMS switches using BCB sealing



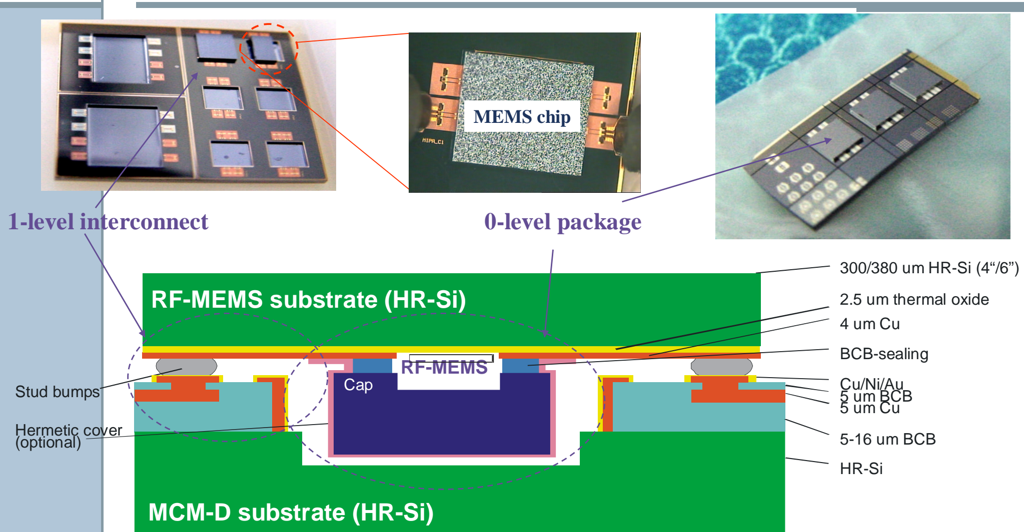
Source: H.A.C. Tilmans, et al., proc. IEDM2001, pp. 921-924

0-level package using BCB :
Influence of the cap material and cavity height (planar feedthrough)



Source: A. Jourdain, et al., proc. Transducers'03, pp. 1915-1918

Hybrid integration of RF-MEMS on MCM-D:
0/1-level packaging



Source: G. Carchon, et al., proc. ECTC2005, pp. 1664-1669

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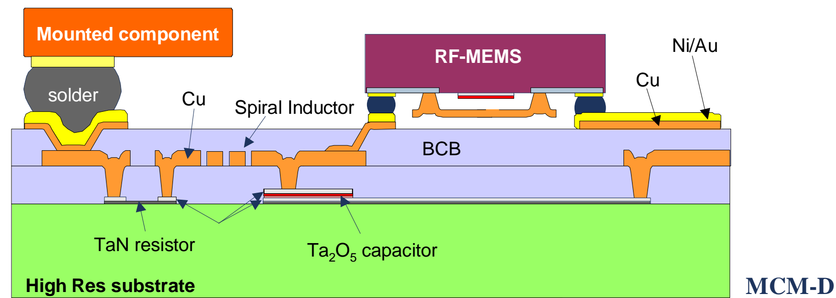
Conclusions and Future work

- Integration of high-Q Passives (R, L, C, couplers, TLs, filters, ..) in Imec's multi-layer thin-film (MCM-D) technology is an established technology
- RF-MEMS technology fills in the blancs of MCM-D by offering variability for switches, tunable capacitors, …..
- Integration of MCM-D and RF-MEMS is most conveniently done through hybrid integration, i.e., flip-chip mounting of RF-MEMS chip on MCM-D carrier substrate.



MCM-D

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Conclusions and Future work

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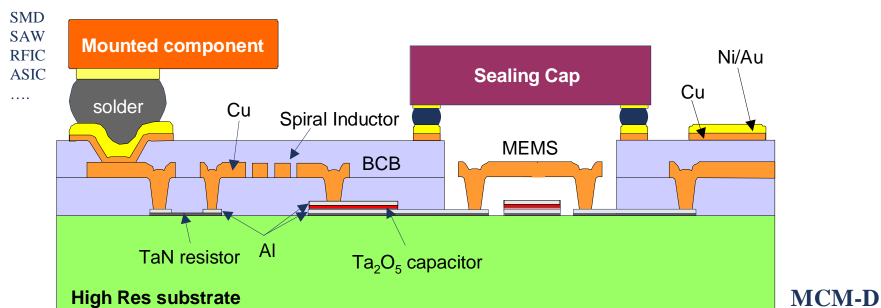
- RF-MEMS technology fills in the blancs of MCM-D by offering variability for switches, tunable capacitors, …..
- Integration of MCM-D and RF-MEMS is most conveniently done through hybrid integration, i.e., flip-chip mounting of RF-MEMS chip on MCM-D carrier substrate.
- Final objective = Monolithic integration of MCM-D passives with RF-MEMS

SMD
SAW
RFIC
ASIC
….



MCM-D

Source: Imec

Acknowledgements