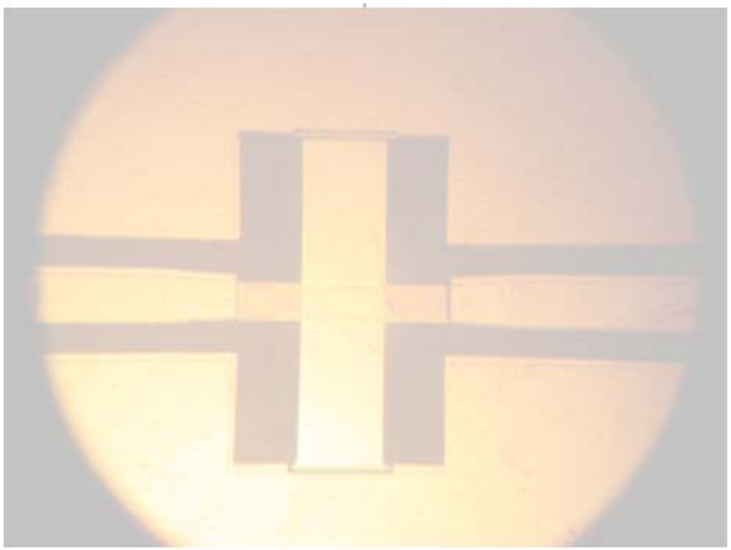
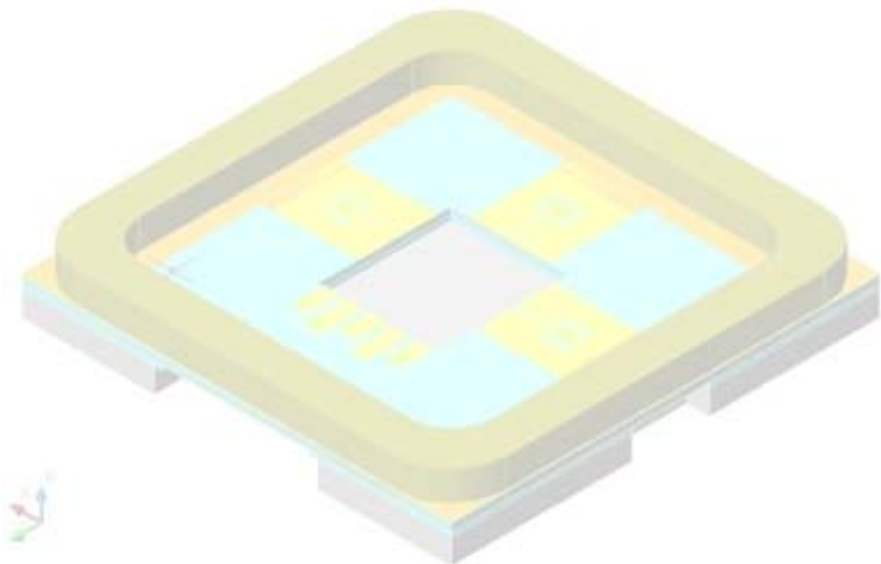
Development of RF switches MEMS using LTCC technology

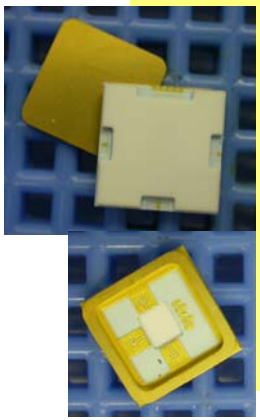




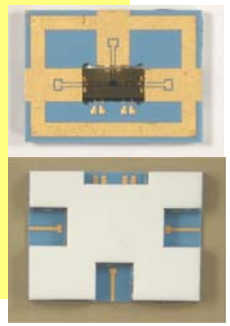
S. Di Nardo; ***Alcatel Alenia Space – Italia; Via Pile 60, 67100 L'Aquila (Italy)***

The RF MEMS switches need a controlled environment to operate (dust free, dry environment, controlled pressure,…)

the MEMS devices have to be hermetically sealed



LTCC technology has been demonstrated by ALS to be a good packaging solution for RF MEMS switches



ALCATEL

Evaluation of coplanar-microstrip micropackages for RF switch MEMS

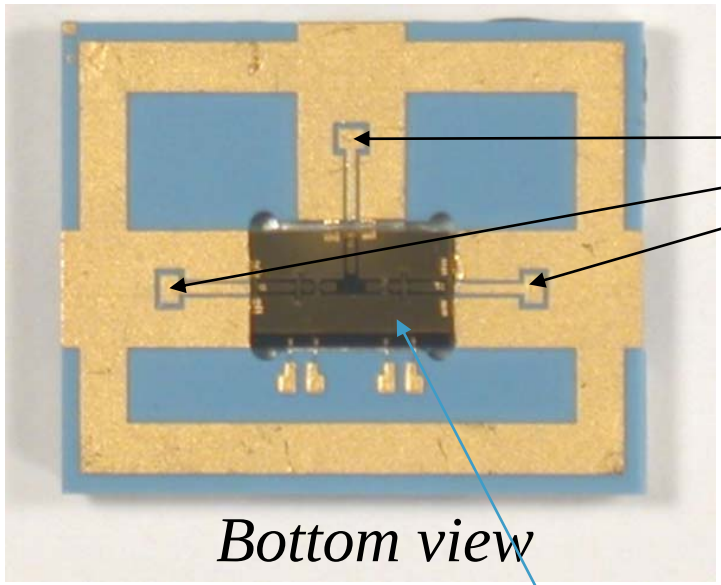
DAD 3.10.02
Activity Responsible: S. Di Nardo
Alcatel Alenia Space – Italia
Via Pile 60, 67100 L'Aquila (Italy)

Objectives, purpose and scope of the activity

In the last years there is a growing interest about MEMS switches. The design of this kind of device can be very different depending on user needs. The differences can involve both technological and electrical (RF) aspects. So MEMS switches need custom packages, with the right pin-out, working at the right frequencies. Such a kind of problem has been already solved for commercial telecommunication applications by using ceramic packages. In particular, for this kind of application, special materials working at high frequencies have been developed for LTCC technology. Moreover, the easier way to build a MEMS switch is to design it on coplanar technology, but it is better to have a microstrip in/out on the package. So a coplanar-microstrip transition have to be designed.
Alcatel Alenia Space - Italia has an heritage on basic LTCC technology that has been used as starting point to acquire the know-how necessary to develop custom RF packages for MEMS switches and to evaluate them for space applications.

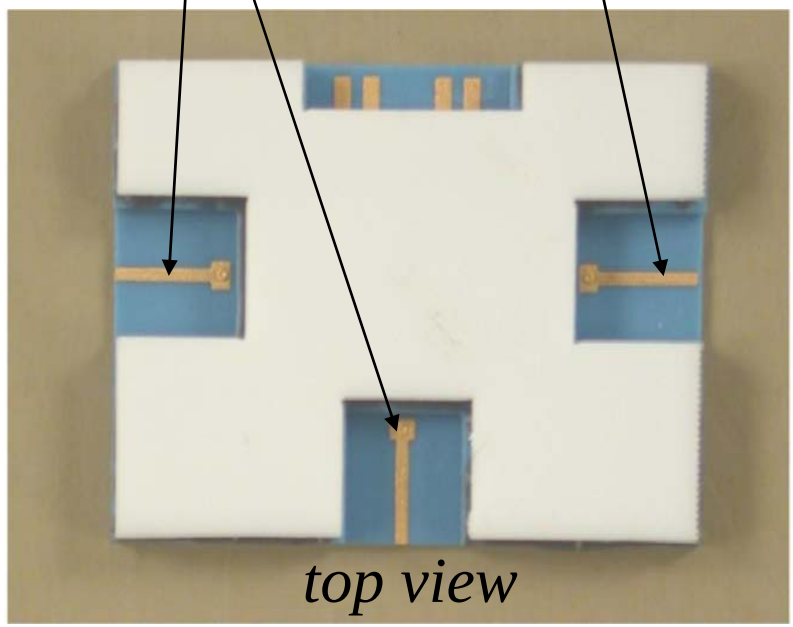
DAD 3.10.02: Evaluation of coplanar-microstrip micropackage for switch MEMS

old version



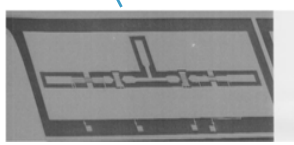
Bottom view

CPW-MS transitions on LTCC
DuPont GreenTape 951



top view

old version
SPDT mems switch

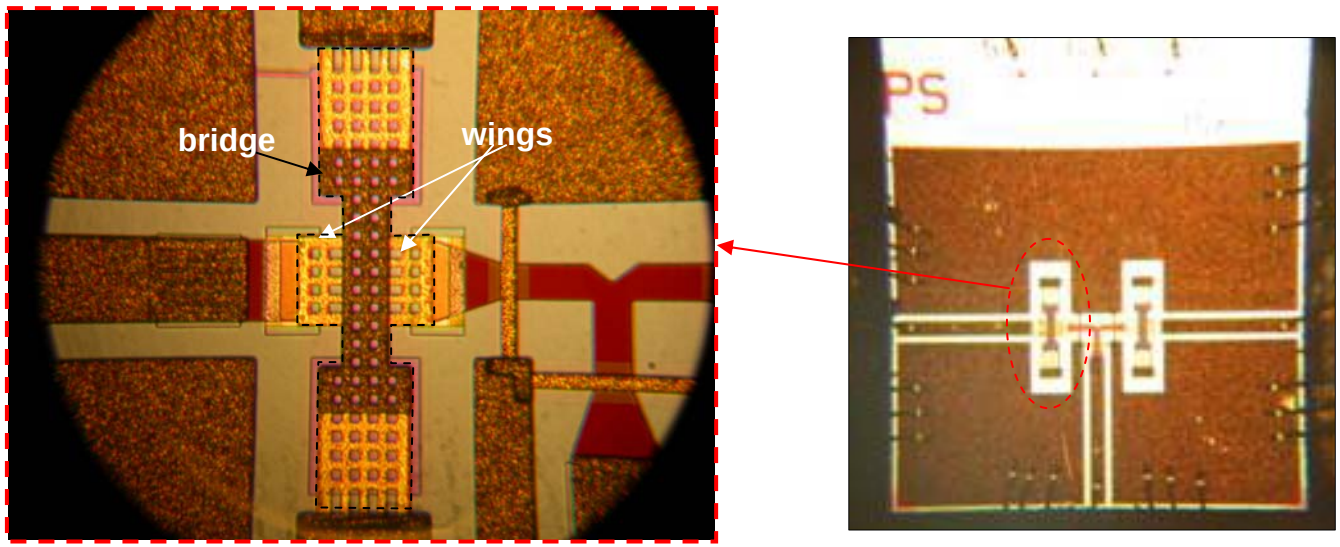


ALCATEL

DAD 3.10.02: Evaluation of coplanar-microstrip micropackage for switch MEMS

Switches to be packaged (new version)

Single Pole Double Through MEMS, with series ohmic switches, working up to about 40GHz, have been packaged. The switches are built on silicon and have DC control pads, other than coplanar RF in/out lines.



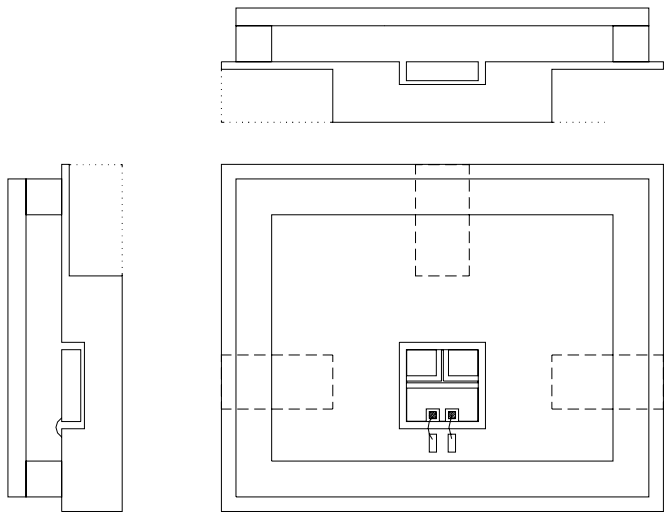
Pictures of a Alenia Spazio SPDT MEMS switch

DAD 3.10.02: Evaluation of coplanar-microstrip micropackage for switch MEMS

Preliminary technological design of micropackages

A preliminary design of the micropackages has been discussed in order to fit the following requirements:

- Dimension of the chip to be packaged
- Dimension of the proposed microstrip-coplanar (MS-CPW) transition
- LTCC technological limits (line/gap, mechanical requirements,...)
- Hermeticity of the package
- Cost

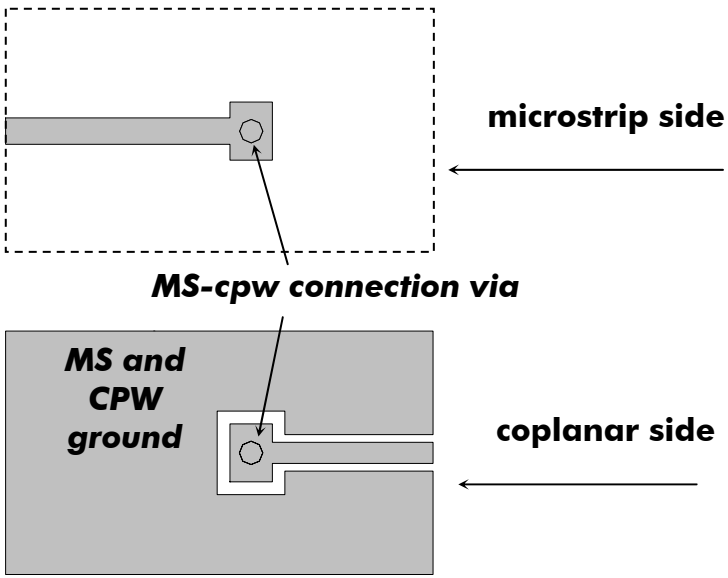


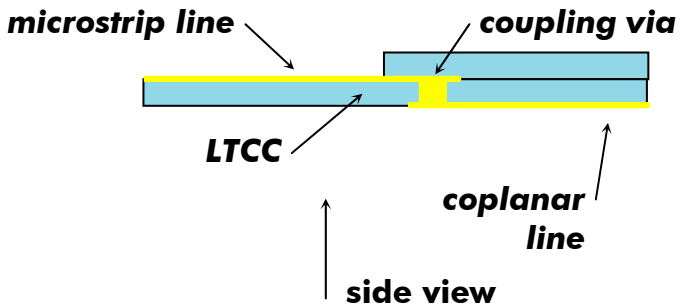
Preliminary layout of the package

DAD 3.10.02: Evaluation of coplanar-microstrip micropackage for switch MEMS

Simulation of microstrip-coplanar transition on LTCC

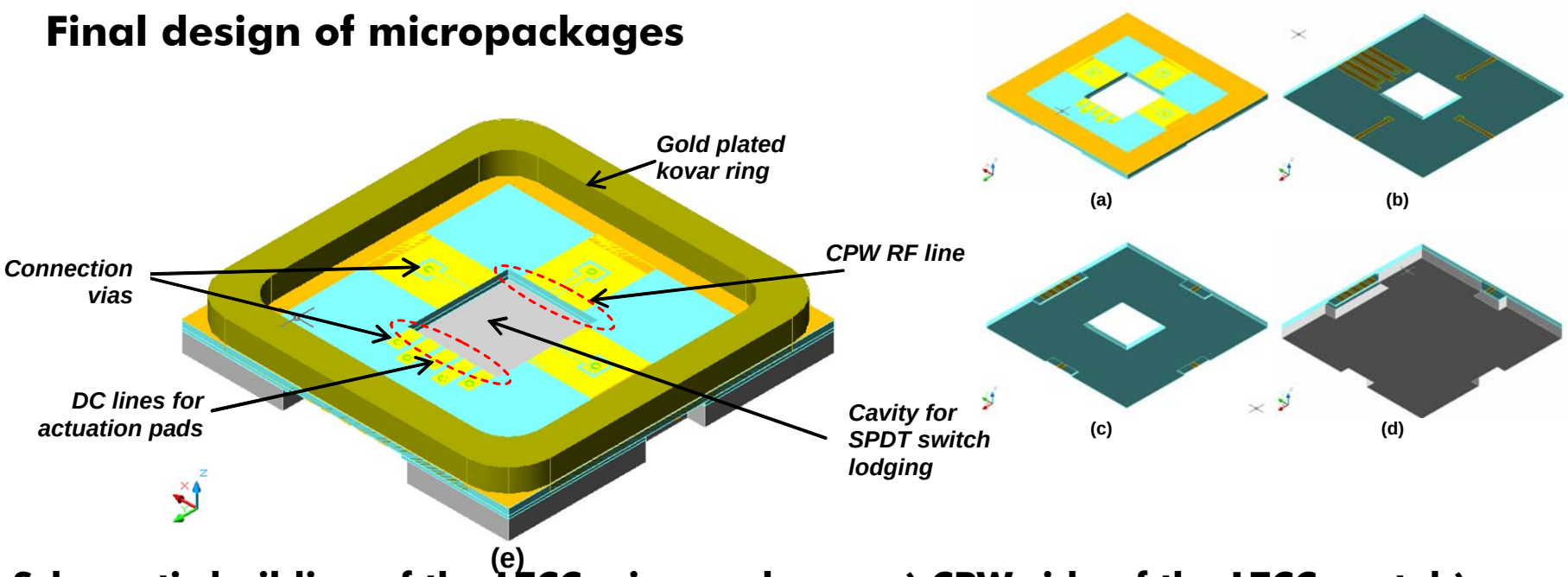
Once the preliminary design of the micropackages has been decided, the MS-CPW transition has been simulated. The design of the transition takes into account the LTCC technology limits and the preliminary package design.
The materials used come from DuPont 943 low loss gold system.





The heart of the micropackage

Final design of micropackages

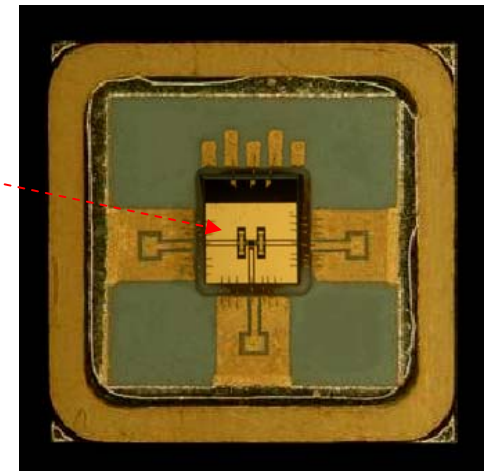


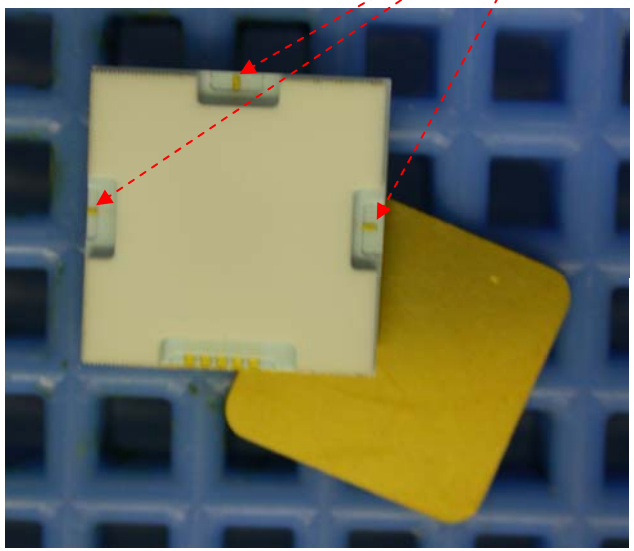
Schematic building of the LTCC micropackage: a) CPW side of the LTCC part, b) intermediate LTCC layer between the MS and CPW side, c) MS LTCC side, d) MS micropackage side after the glass sealing of the alumina part onto the LTCC part, e) complete package with gold plated kovar ring brazed onto LTCC (CPW side). The electrical contact between the CPW side and the MS side is performed by conductive vias.

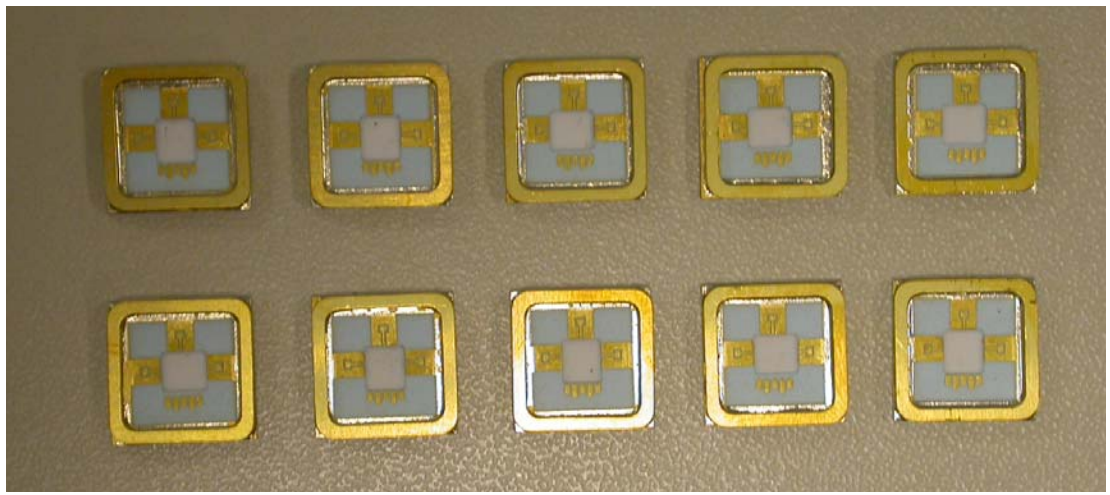
DAD 3.10.02: Evaluation of coplanar-microstrip micropackage for switch MEMS

Manufacturing of micropackages

- The micropakages are suitable to lodge **CPW SPDT MEMS switches**
- The micropackage body is made of LTCC low loss material.
- The micropackages can be hermetically sealed.
- The in-out RF ports are **microstrips**.







Environmental testing (as per MIL-STD-883F)

- ***Vibration test (50 g, 20-2000 Hz)***

External visual inspection didn't show any macroscopic damage after vibrations. Moreover all the packages submitted to vibrations remained hermetic.

S/N	Initial values	Final values
2	pass	pass
3	pass	pass
G	pass	pass
E	pass	pass

*Leak test before and after vibrations (pass: < $5*10^{-8}$ atm*cc/s).*

Environmental testing (as per MIL-STD-883F)

- ***Mechanical Shock test (1x1500g)***

Loss of package hermeticity has been shown after the first mechanical shock at 1500g.

It has to be noted that at component level this is a very hard test.

S/N	Initial values	After 1x1500g mechanical shock [atm*cc/s]
6	pass	$5,4*10^{-4}$
4	pass	$1,1*10^{-4}$
C	pass	not hermetic
I	pass	$7,5*10^{-5}$

*leak test measurement before and after 1x1500g mechanical shock (pass: < $5*10^{-8}$ atm*cc/s)*

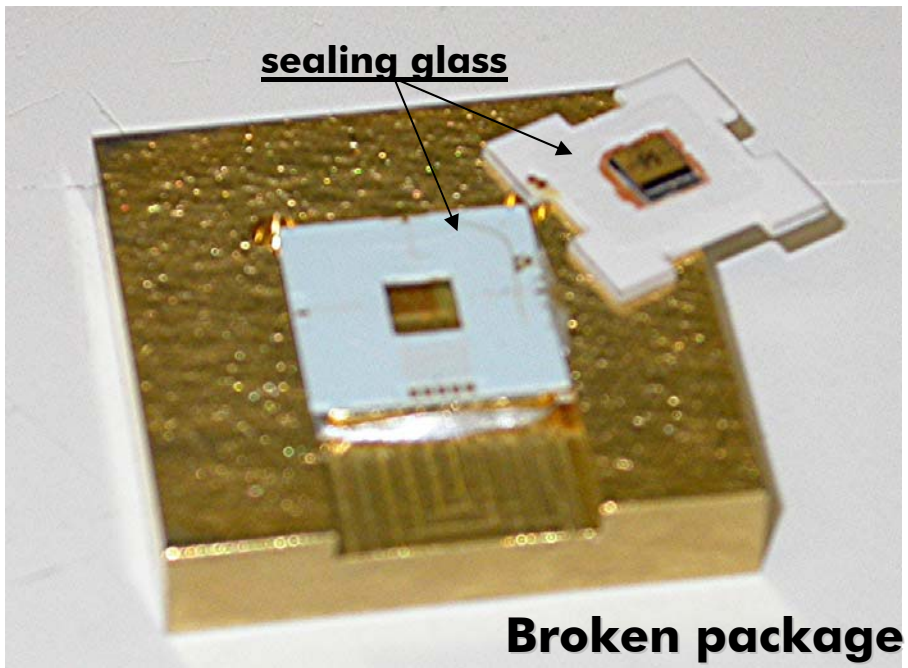
Environmental testing (as per MIL-STD-883F)

- ***Mechanical Shock test (+ 5x3000g)***

Nothing anomalous has been noticed by external visual inspection, after the first mechanical shock at 1500g. S/N I and 4 have been submitted to further 5x3000g mechanical shocks, in order to increase the damage and to find the cause.

S/N	Leak test after further 5x3000g mechanical shocks
4	not hermetic (package broken)
I	not hermetic

After more 5x3000g, both the S/N 4 and S/N I, were not hermetic. In particular the S/N 4 has been broken in two parts; the alumina part has been detached from the LTCC at the sealing glass level (see picture).



Broken package

Environmental testing (as per MIL-STD-883F)

- ***Thermal cycles test (100 cycles -55°C/+125°C)***

External visual inspection didn't show any macroscopic damage after 100 thermal cycles.

However the leak test revealed a loss of hermeticity for 2 of the 4 packages.

S/N	Initial values	After 1x1500g mechanical shock [atm*cc/s]
5	pass: $2.4*10^{-9}$	pass: $1,1*10^{-8}$
A	pass: $3.8*10^{-9}$	$1,0*10^{-7}$
H	pass: $3.7*10^{-9}$	pass: $2,0*10^{-8}$
F	pass: $3.2*10^{-9}$	$1,0*10^{-7}$

*leak test measurement before and after thermal cycles test (pass: < $5*10^{-8}$ atm*cc/s)*

Conclusions

The glass sealing of the alumina part to the LTCC body of the package has been found to be too weak. In fact it fails both after hard mechanical shock and after thermal cycling.

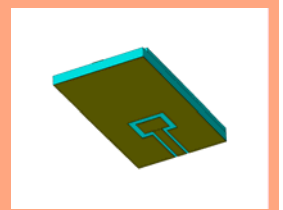
The gold plated kovar ring AuSn brazed to the LTCC body of the package and the gold plated kovar lid seam welded to the ring seems to be suitable with space requirements.

So, in order to improve the micropackage strength, a readjustment of the technological design should be done. One solution could be to braze the alumina part to the LTCC body of the micropackage with a AuSn alloy. A better solution is to build the ceramic part of the package completely in LTCC in one step. The latter solution requires some more experimental trial.

RF MEMS switches directly integrated onto LTCC

=

- reduced number of connections /transitions
- reduced number of total items
- lower losses with respect to silicon based MEMS
- 3D RF and DC integrated routing
- possibility to built a SoP



↓

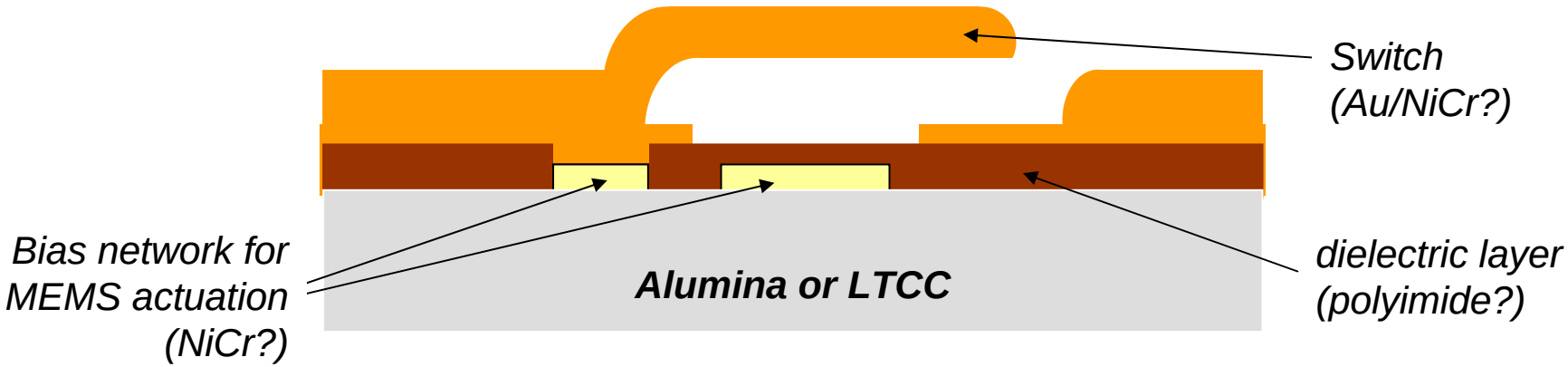
- better RF performances,
- higher integration
- lower productions costs

back next

RF MEMS switches built on LTCC

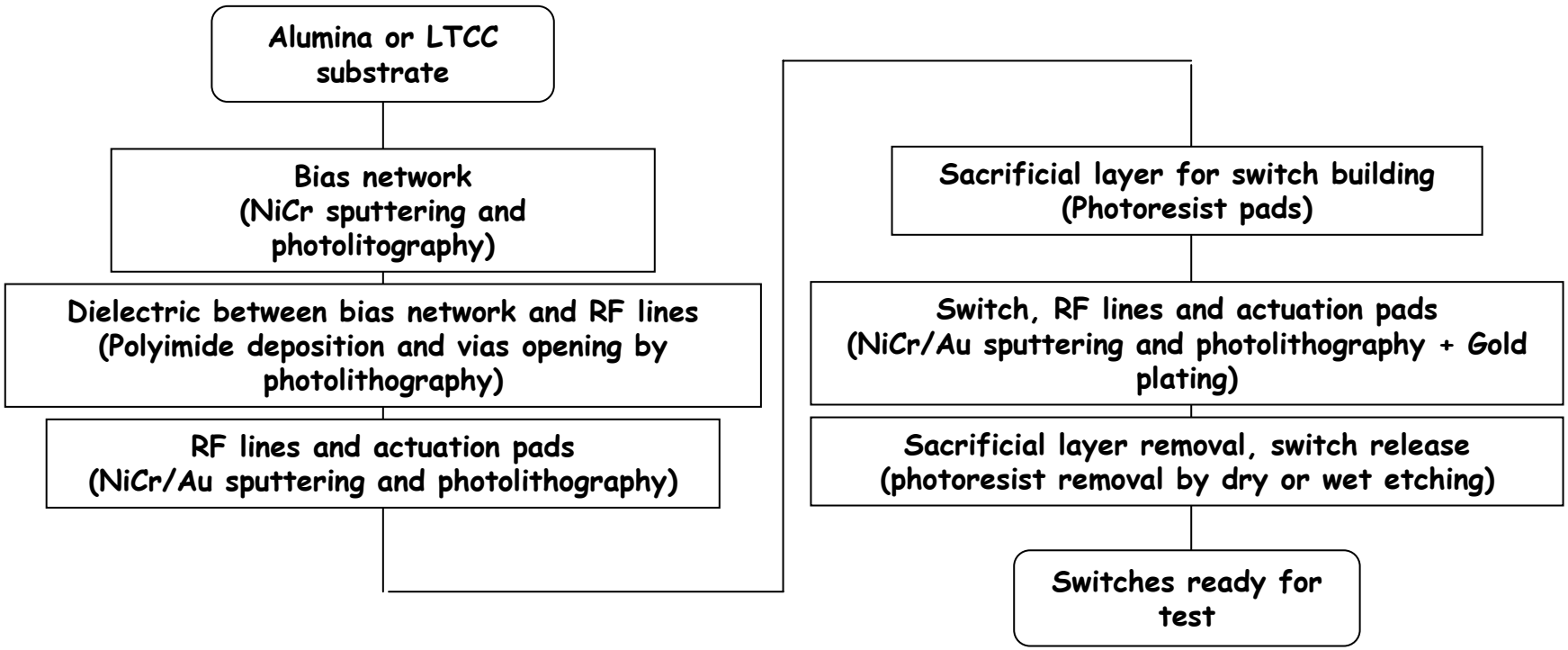
DAD 3.10.05
Activity Responsible: S. Di Nardo
Alcatel Alenia Space – Italia
Via Pile 60, 67100 L'Aquila (Italy)

DAD 3.10.05: RF MEMS switches built on LTCC



Preliminary design: MEMS switch side view (draft)

DAD 3.10.05: RF MEMS switches built on LTCC



Manufacturing flow

DAD 3.10.05: RF MEMS switches built on LTCC

WP1 - Reporting of previous experience on LTCC Technology

WP2 - Definition of the switches to be built

WP3 - Design of a dedicated test equipment

WP4 - Manufacturing of MEMS built on LTCC

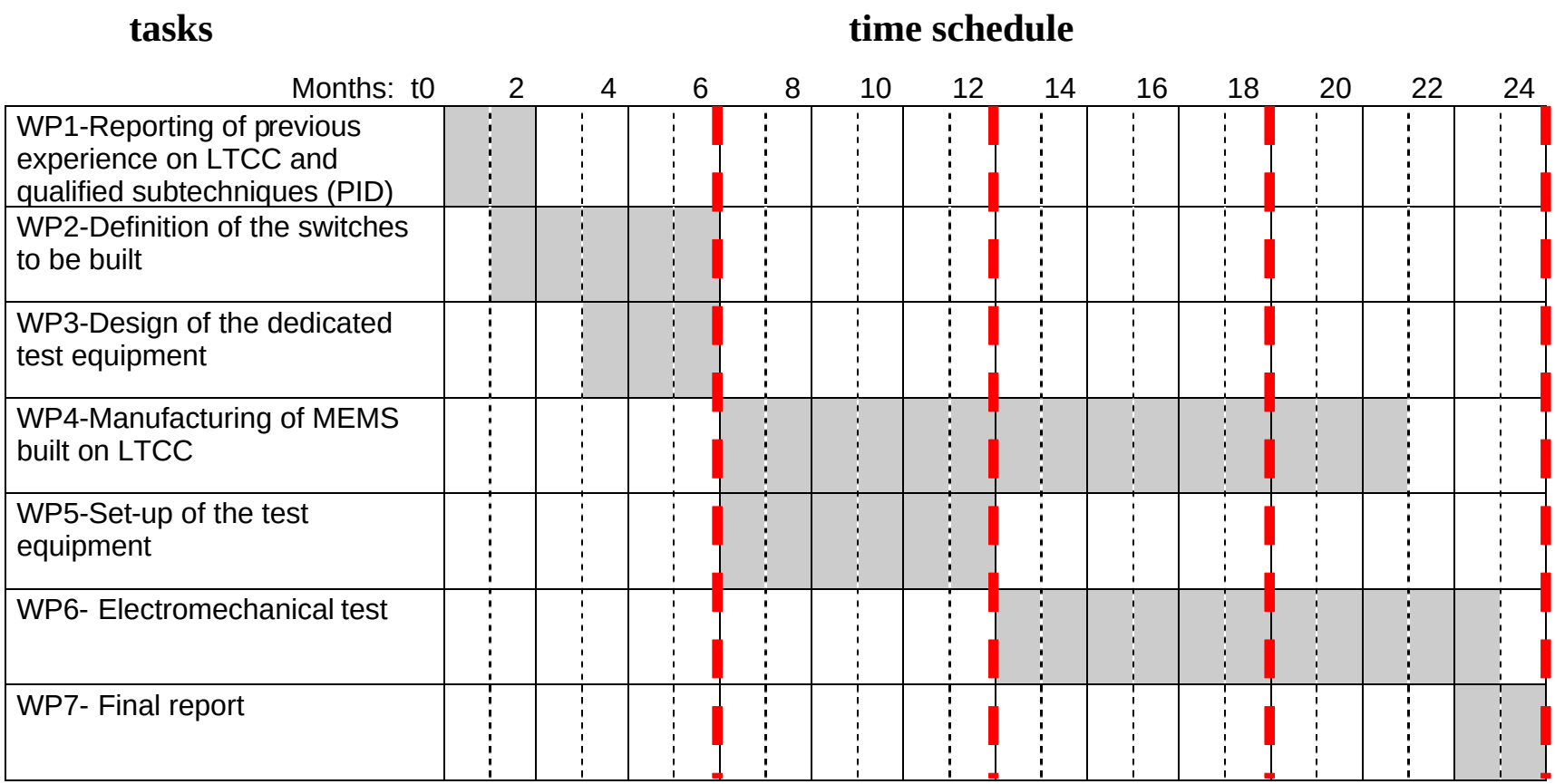
WP5 - Set-up of the test equipment

WP6 - Electro mechanical test

WP7 - Final report

MILESTONE DESCRIPTIONS	SCHEDULE DATES
Advance: upon signature of contract by both parties	November 2005
Progress: upon acceptance of WP1, WP2 and WP3	May 2006
Progress: upon acceptance of WP4 and WP5	August 2007
Final: upon acceptance of all deliverables	January 2008

DAD 3.10.05: RF MEMS switches built on LTCC



Estimate total budget: 200K€ (company contribution = 100K€)

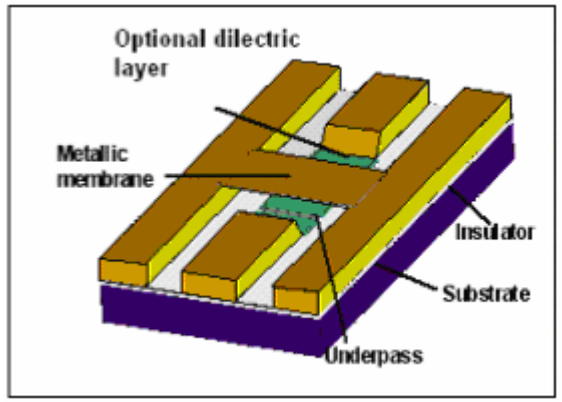
ACTIVITY STATUS

- ☑ **kick-off meeting ESTEC/Contract No. 19135/05/NL/PA: 02/11/2005**
- ☑ **WP1 - Reporting of previous experience on LTCC Technology: completed 02/01/06**
- ☑ **WP2 - Definition of the switches to be built: completed 14/03/06**
- ☑ **WP3 - Design of a dedicated test equipment: completed 14/03/06**
- ☐ **WP4 - Manufacturing of MEMS built on LTCC: alumina version manufacturing in progress;**
- ☑ **WP5 - Set-up of the test equipment: completed 07/04/06**
- ☐ **WP6 - Electro mechanical test: in progress**
- ☐ **WP7 - Final report**

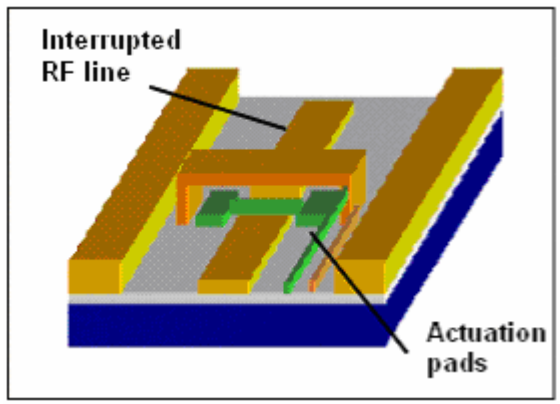
DAD 3.10.05: RF MEMS switches built on LTCC

Devices types

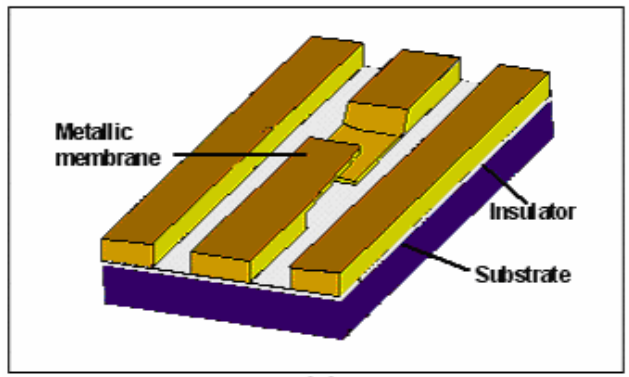
1) **Shunt Bridge (ohmic contact)**



2) **Series Bridge**

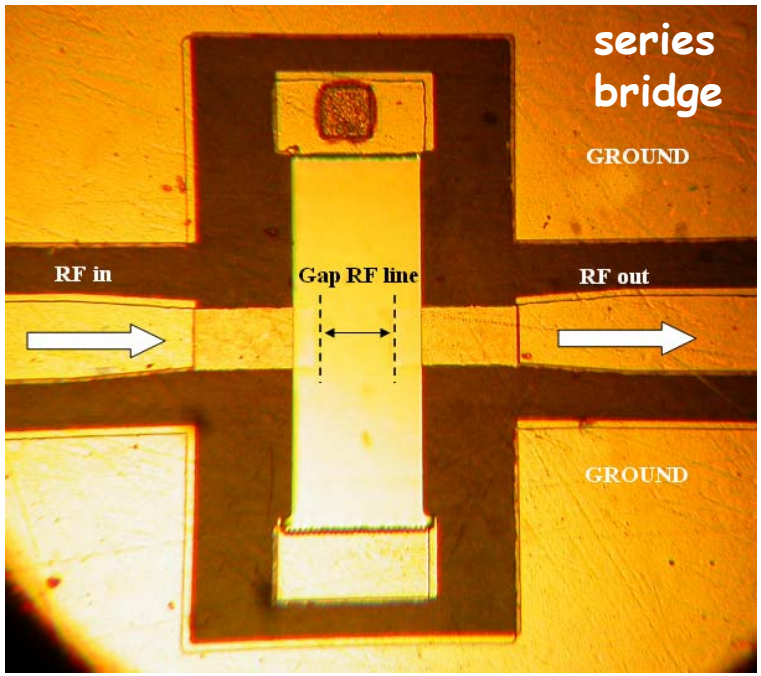


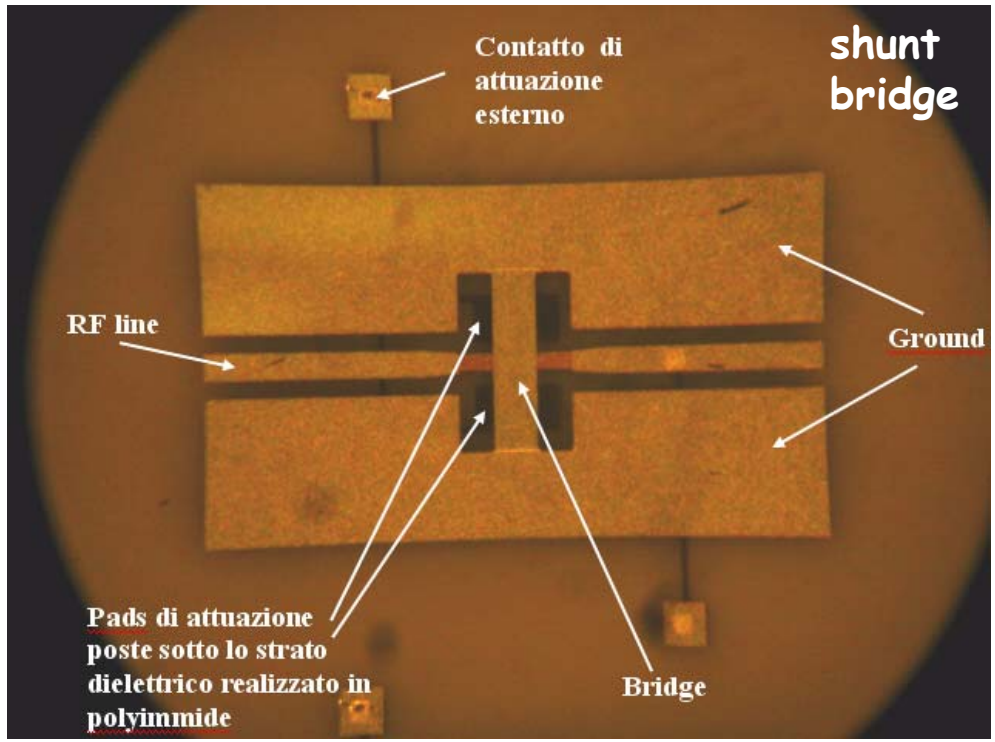
3) **Series Cantilever**



DAD 3.10.05: RF MEMS switches built on LTCC

Examples of MEMS manufactured on alumina





Preliminary results (series bridge):

Bridges actuation voltages: between 15V and 30V
Max number of actuations reached without changes in the actuation voltage: 18.350.000 (50hz switching pulses)