RF MEMS and flip-chip for space flight demonstrator

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The next generation of telecommunication satellites payloads will require higher performances and higher functionality for multimedia applications with still stronger constraints on cost and size. That means higher operating frequencies (Ka band), higher flexibility, (reconfigurability, on board processing...) and further miniaturization.

In such a context, RF MEMS – Micro Electro Mechanical Systems – offer new degrees of freedom for the realization of integrated filters, tunable LC circuits, and reconfigurable antennas… They could replace solid-state components thanks to their good microwave performances and even create new functions due to their electromechanical behavior and small size.

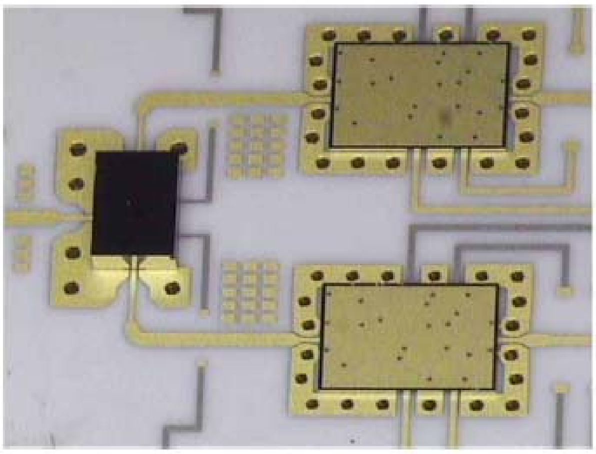
An example of an expected redundancy function is showed on the following figure.

- to have the visibility of the new technology for new internal or external customers,
- to go from mid to high TRL (Technology Readiness Level) i.e. to move from "Component and/or breadboard validation in laboratory environment" status to "prototype demonstration in a space environment",
- to enhance the know-how of such a technology and the associated risk assessment.

A space flight equipment has been defined to demonstrate, in flight condition, RF MEMS capability. This demonstrator has been designed to be full independent and to preserve the payload immunity.

The aim of this experience is to assess the failure modes for RF switches based on

Flip-Chipped MEMS Switch
(self-packaged)



Flip-Chipped MMIC LNA

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Fig.1 – Example of future trends: self redounded Ka-Band LNA with MEMS

Reliability in orbit

For RF MEMS switches, one of the main problems to be addressed is the reliability for missions more than fifteen years and the capability to survive at the space environment. A flight demonstration could allow:

ohmic contact technology, which are dealing with the stiction metal-metal at the contact level, the creep for the membrane and the dielectric charging effect due to the electrostatic activation. This will be done through DC measurements using advanced RF switch intrinsic characteristics: the contact resistance Rc during On position and the Vp (pull down voltage).

Twenty MEMS will be used for covering three functioning modes :

- 4 switches with rapid cycle 1 switching per second,
- 4 switches with medium cycle 1 switching per day,
- 4 switches with long cycle 1 switching per year,
- 4 switches will be actuated by remote control from Ground, after 10 years,
- 4 switches where pull-in voltage is monitored to estimate their eventual degradation.

The concept of the demonstrator is illustrated on the figure 2.

Stud bumps and flip-chip assembly

The principle of stud bumps is described on the following figure.

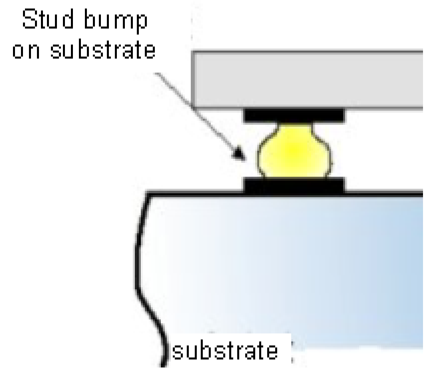

Fig.3 – Principle of flip-chip with stud bumps and thermocompression

The choice of using stud bumps is driven by several reasons: shortest connections, the use of “standard” device (i.e. with only gold pads for bonding), the capability to make those bumps on any type of substrates, including in the openings of multilayer structures.

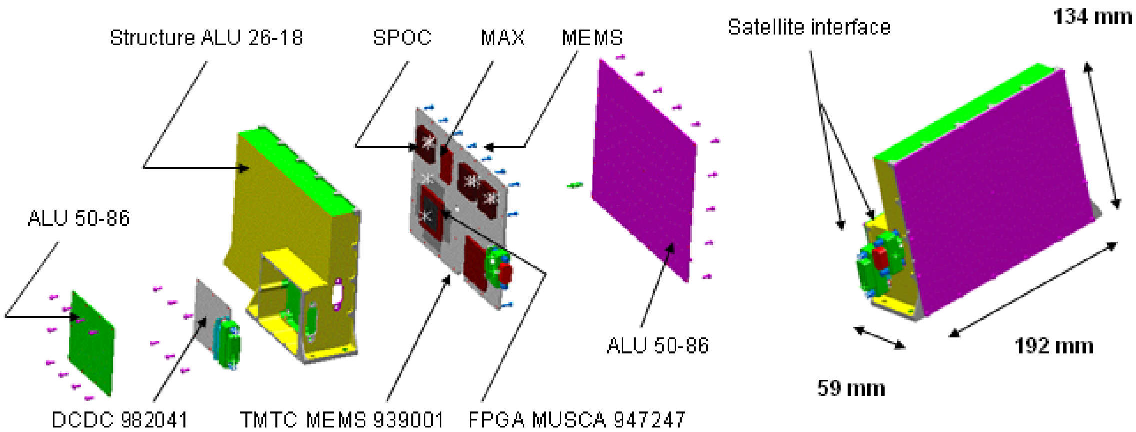

Fig.2 – Concept of the Flight Demonstrator

The RF switches are very small components that require connections as short as possible to preserve all the RF characteristics. So, flip-chip has been selected for assembling and connecting the RF switches. As the objective of this demonstrator is to measure and follow, in flight, the reliability of the RF MEMS switches, those devices will not be measured at the RF performances level. However, the use of flip-chip bonding has been confirmed to be as close as possible to the real application.

This paper focuses on the assembly of the RF switches and the associated hybrid; so, we are first going to discuss about flip-chip based on stud bumps and thermocompression assembly.

From a high frequency point of view, the size of the bumps, and specially the diameter, is compatible of the electrical performances. The capability to make double even triple bumps is also a key point to manage the gap between the component and the substrate. For microwave, the proximity of the substrate with the active face of a device could influence the electrical performances.

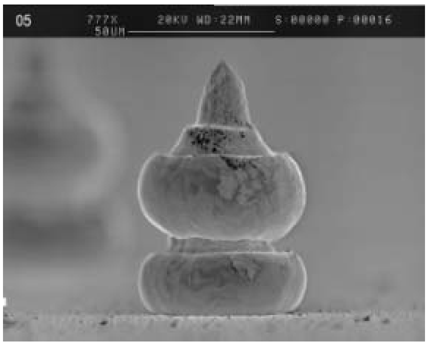

Fig.4 –double stud bump (Ø 50 µm - hbase = 50 µm - htotal = 80 µm)

The stud bumps are made on a standard ball-bonder, with a modification of the software to allow the break of the wire at the ball level. The wire is doped with palladium to make it more brittle.

The different steps are described on the figure 5

The size and geometry for a bump is detailed on the following figure. One could note than the visible diameter (Dv) is smaller than the diameter (De) of the contact at the substrate level.

For the specification application described in this paper, we need to have higher bumps to be compliant with the thickness of the caps for the MEMS.

The sizes of those bumps and the die shear have been tested for two different lots.

	1st lot	2nd lot
High (µm)	87	76
Diameter DV (µm)	61	57
Force (g)	21.3 g	26.6 g

For information, the minimum required by JEDEC and MIL-STD_883D is a force of 5g/bump.

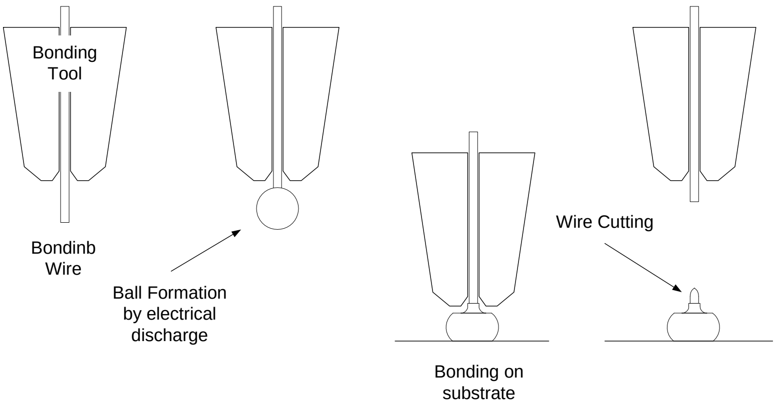

Fig.5 - Principle for stud bump manufacturing

A DoE (Design of Experiment) has been implemented to characterize the limits of the main parameters, which are: chip and substrate temperatures, force per bump and time of pressure. The retained criteria's are the electrical performances, the holding of the dice (including the type of break.

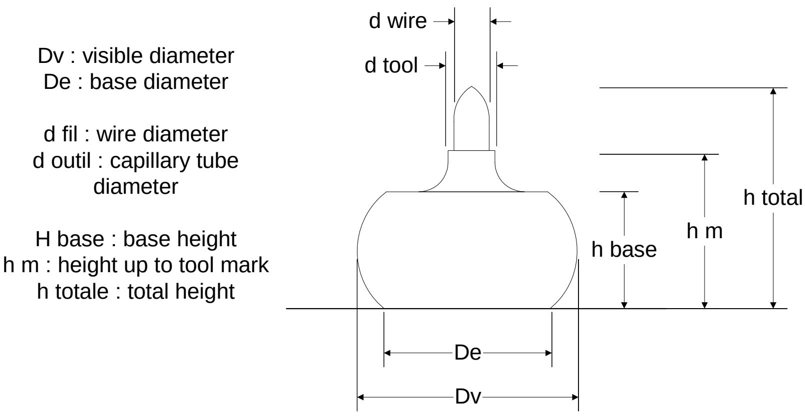

Fig.6 - Stud bump characterization

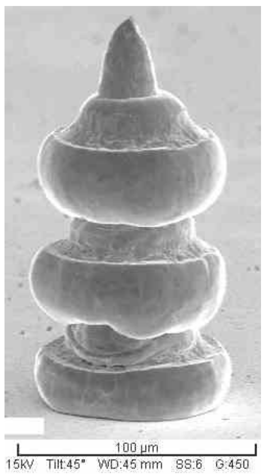

Fig.7 – Triple stud bump

Flip-chip assembly of the RF MEMS switches

20 RF-MEMS switches, from CEA-LETI, have to be assembled in hermetic packages.

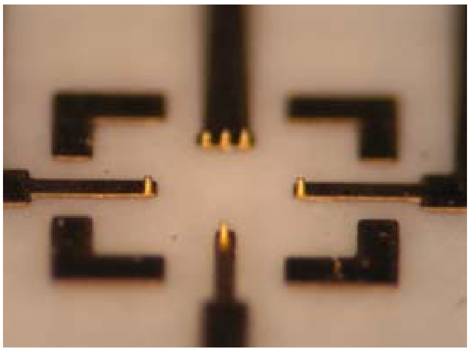

Fig.8 – Stud bumps at the substrate level

The stud bumps are implemented on ceramic substrates (see figure.8).

Then, a SET FC 150 die / Flip-Chip Bonder is used to make the thermocompression bonding on the substrate.

The good accuracy of this bonder allowed to use very small pads and, as a consequence, to minimize the desadaptation of the RF signal in a real application.

The substrate with the device is then bonded into a metallic package, which will be hermetically sealed under nitrogen.

Conclusions

A new equipment has been developed aiming at prove in-orbit operation for new RF MEMS switches. This equipment is using an autonomous flight proven interface to the platform and is compatible of GEO telecom satellite working at 36000km.

The use of flip-chip for the connection of the RF MEMS has reduced the length of the RF/microwave connection so that all the intrinsic characteristics are presserved.

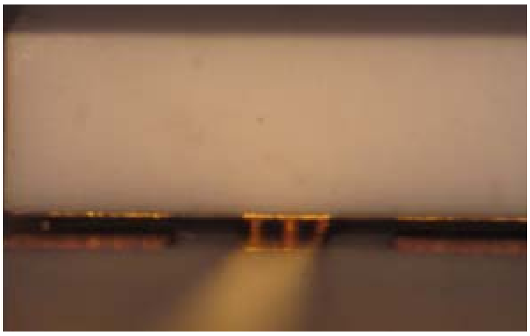

Fig. 10 – Bumps under the device

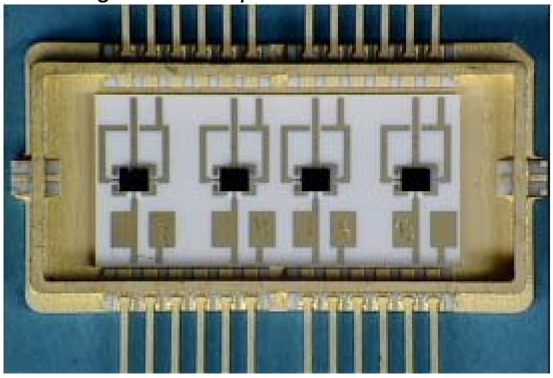

Fig. 11 – Hybrid package

The functionality of the electrical model is validated and passed all the standard procedure applied to commercial satellite equipment (EMC, thermal vacuum, vibrations and mechanical shocks).

The fly model is produced, waiting the end of the RF MEMS qualification.

Fig.9 – FC 150 bonder