Silicon Passive Components: one of the ways to improve reliability and miniaturization of medical implantable devices

1/ Medical Implantable Devices: where are we?

Medical implantable devices do represent one of the key innovations of the past 20 and more years, allowing to improve or lengthen peoples lives as well as cure and recover some non existing or disabled functions. The best-known examples are cardiac rhythm management devices (which role is obvious) and cochlear implants, which are composed of an implanted part and an external part. The latter devices have even been enabling non-hearing people to recover some normal hearing functions. There are more and more examples today of functions that can be stimulated or recovered thanks to implanted electronic devices. Millions throughout the world now count these devices. Like many electronic devices they have seen their power and number of functions increase thanks to miniaturization technologies and software innovation.

The most recent devices are not only efficient but they can also be communicating data (like some diagnosis pills discussed later) or be programmed wirelessly. For example, sound processing implants and devices can be adapted to the complex patient's response when installed.

These many new functions do impose further miniaturization of basic functions, including active integrated circuits, memory chips, etc… as well as the main boards of these devices.

Integration of the discrete passives can bring a lot here, as illustrated in the next paragraph.

Two other key technical issues with these implanted devices are the duration of their batteries and their reliability, which cannot be compromised.

Here too, the integration of discrete passives into Silicon will bring some significant improvements.

2/ IPD PICS technologies: a reliable solution to space constraint

Some companies have used or reused Integrated Circuit processes and capacities to develop new technologies to create what is now referred to as Integrated Passive Devices (IPD).

IPDIA is one of these companies and has chosen to develop Silicon based 3D-IPD technology. One of the most critical elements in our medical devices as well as one of the most difficult to integrate passive component is the capacitor, especially high values (above 1 μF). IPDIA has concentrated a significant portion of its efforts to develop 3D high-density capacitor technologies named “PICS” (Passive Integrated Connective Substrate). The first process generations with an integration density of up to 80nF/mm^2 have been in production for several years. The newest generation is using innovative 3D structures and reaches 250nF/mm^2 allowing the making of miniature Silicon capacitors of several μFarads.

Intrinsic performances linked to the material used make these technologies very attractive in terms of stability (with temperature and voltage) as well as size and cost of the application.
This is illustrated in the next graph:

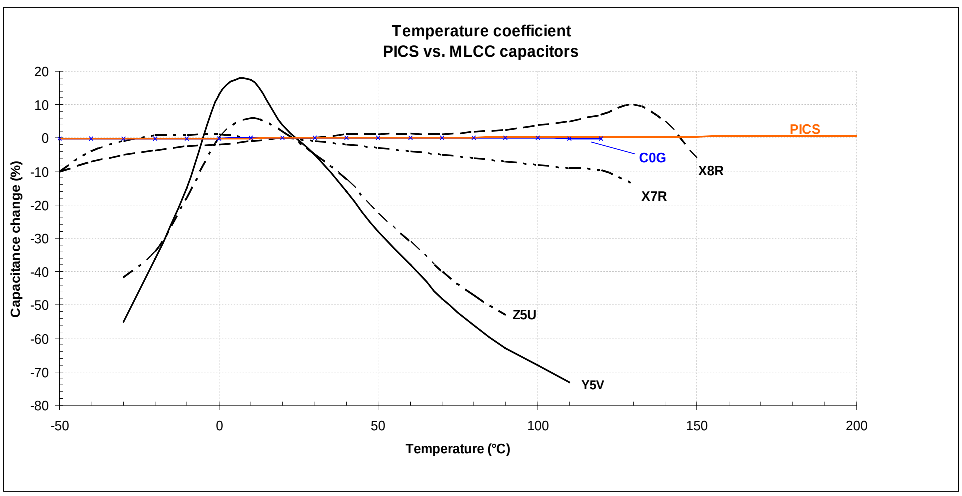
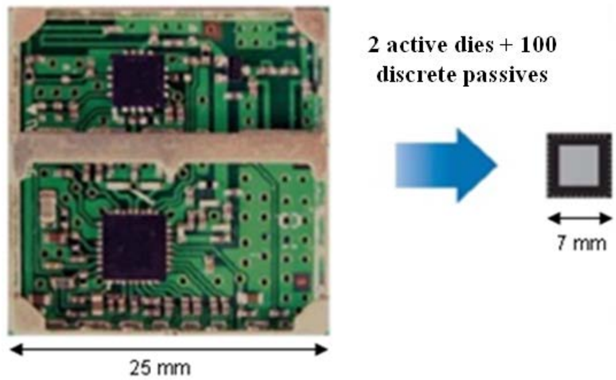


Fig.1 Temperature performances comparison with various types of MLCC capacitors

The materials used in the IPDIA PICS technology are similar to the one used in the manufacturing of integrated chips. The main consequence is the very high reliability that can be expected from these products. The second technical added value is the low leakage current inside the capacitors, thanks to very clean and pure materials used for the dielectric layers. To illustrate this we can give the example of the leakage current of a 33 nF PICS capacitor which is below 70 pA at nominal voltage use.

In terms of reliability figures, we can also illustrate the behaviour with a simple value of MTTF (mean time to failure) : PICS capacitors show typical values of xxx, improving the typical values of discrete passives by more than 100.

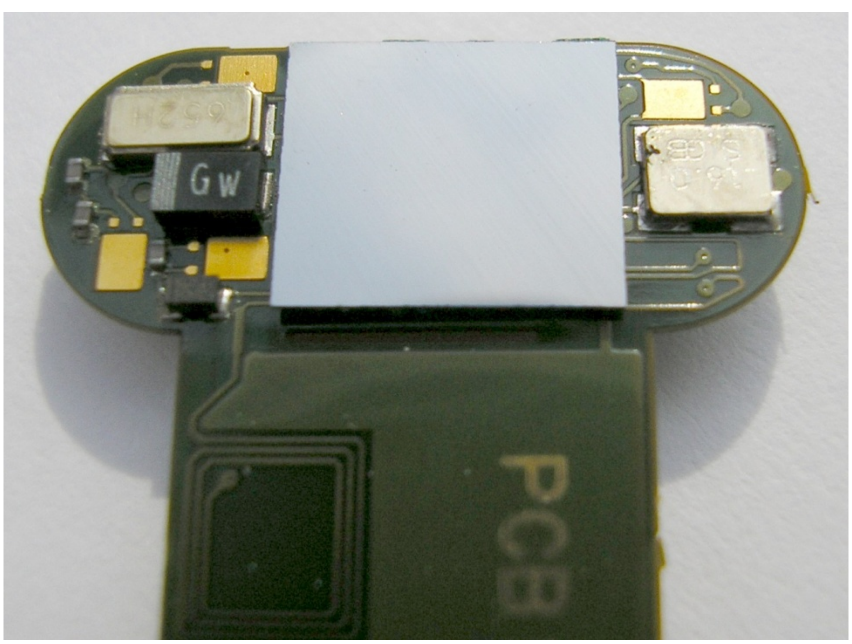
Coming now to space saving and miniaturization of electronic applications thanks to using Integrated Passives into Silicon, the picture below shows an example of integration of radio frequency communication circuitry.



The integration of passive based filters and of decoupling capacitors allows a reduction in size by a factor of yy, meaning a space saving of more than 80 mm2. It is also very obvious that in such an integration approach, the replacement of around 100 discrete components by a single Silicon chip will reduce significantly the number of interconnections, hence improving the reliability of the final product.

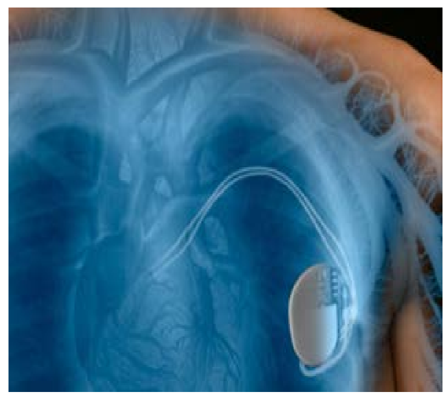
3/ Application examples

IPDIA has already started to work with many companies in the field of miniature medical devices through direct cooperation and through some advanced R&D partnerships too. One interesting example of a very innovative prototype device is shown below.



This device is an electronic pill including a sensor, a secured wireless communication module and of course its source of energy. It is only measuring 15mm long and 6mm in diameter. Making possible the realization of this product has been made with the use of Integrated Passives. In this product, the 5x6 mm PICS die is incorporating more than 150 passive components. Without these technologies, such a device could not be made.

It is presently being tested in various evaluation programs with large companies and used as well in several preclinical tests programs.



Many other evaluation programs have been started with IPDIA's partners making implantable cardiac defibrillators and pacemakers. The two complementary functions that Integrated Passives in Silicon are used for are : capacitors and wireless communication modules.

For capacitors, the main drivers are : stability (vs voltage and temperature), low leakage currents and reliability. The values of leakage currents obtained with Silicon capacitors are unprecedented. The immediate consequence is the increase in the battery lifetime of the device.
For wireless communication modules the main drivers are : miniaturization (generally 50 to 90% saving) and reliability.

These evaluation programs are covered with confidentiality clauses, so not yet public.

4/ Conclusion

Integration of Passives into Silicon for Medical devices is a new technology that will bring a lot of new possibilities like it has brought in the Mobile Communication.

Thanks to technologies based on advanced structures like the PICS platform this set of new possibilities will also be backed by improvements in reliability, lifetime and performance of the devices. In this domain, lifetime and reliability directly translate into a reduction of the number of exchanges of these devices.

We are here just at the edge of an era of new possibilities. The R&D programs and technology roadmaps allow us to imagine many new functions or improvements of existing functions thanks to the potential for integration.