PRIORITY 3
NMP

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Section 1 - Project execution

1.1 Project objectives

Project's objective is to demonstrate new transducers concept of Micro-machined Ultrasonic Transducers (MUTs) performances beyond state of the art.

This will be done through exploration of the two different MUT concepts, the capacitive micromachined ultrasound transducers cMUT and the piezoelectric micromachined ultrasound transducers pMUT, all based on MEMS technology, but with four different actuation modes: 2 electrostatic (SiN cMUT and SOI cMUT) and 2 piezoelectric (Bm pMUT and Tm pMUT).

Studies on MUT concepts and actuation modes are finalized to output results on 5 different evaluation devices covering the main spectrum of MUTs expected advantages:

- Dm1: linear array, 5 MHz, for medical imaging
- Dm2: similar to Dm1, but for NDT in water
- Dm3: linear array >10 MHz ophthalmology
- Dm4: similar to Dm3 but single element for NDT and general purpose
- Dm5: air transducer

Devices will come trough activities of design, foundry qualification trough test devices, MUTs wafer manufacturing, wafers packaging and interconnection, acoustical characterisation and evaluation on specially adapted system platforms.

The final objectives of the project is to develop two types of systems based on the studied technologies: for medical application and for non-destructive testing.

The first application directly contributes to the increasing need from ageing European citizen for world-class **health diagnostic systems**. On this aspect, the proposed study addresses two issues, obtaining affordable acoustic probes, and realising higher frequency probes for new applications (eye imaging…).

The development of new improved performances and lower cost probes will make significant inroads into the areas of medical screening. Poor image resolution is the main drawback of today's equipment. If image resolution can be improved the pre-screening tests may be carried out for early tumour detection (e.g. mammography and testicular cancers) and better detection of pre-natal defects. This would have considerable benefits both socially and from a safety point of view. Another important expected social impact of high resolution probes at lower cost is the wider accessibility to screening facilities to less developed areas of the EU where the present cost of ultrasound machines in the quantities required for comprehensive population screening remains today prohibitive.

The second application field is dealing with material or structure control. It can contribute to the increase the safety level of every day life. A an example, AIRBUS structures are controlled all along the assembly production line to **improve flight safety.**

An added benefits is the creation or preservation **of new jobs in EU for MUTs manufacturing** as today state of the art probes, requiring a lot of manual assembly operations is significantly using subcontracting in low labour cost countries outside the European Community.

1.2 Contractors involved

The composition of project consortium is the following:

Participant name	Country	Role in the project

End users having main role to specify, integrate, and experiment MUTs validation devices:

ESAOTE	I	Medical imaging applications, project coordinator
IMASONIC	F	Non destructive testing and medical imaging applications
INOSON	G	MEMS air sensor device
TELEMED	LA	High frequency medical imaging applications

SME aiming to develop on-wafer piezo films foundry:

IR-Microsystems	CH	Piezo film deposition technology

Technology providers in charge on MUT front end design and realisation that are labs with MEMS foundry expertise and facilities tightly teamed with lab having expertise in acoustical design:

EPFL	CH	Design and fabrication process of Bm pMUT
CNRS-FEMTO	F	Design and fabrication process of cMUT and pMUT
ACULAB	I	Acoustical and MUT design of SiN cMUT
CRANFIELD	UK	Design and fabrication process of Tm pMUT
CEA-LETI	F	Design and fabrication process of SOI cMUT
IFN-CNR	I	Fabrication process of SiN cMUT

MEMS back end technology provider:

THALES	F	MUT packaging and interconnection

The MUSTWIN consortium is for a large part **built on an existing basis of co-operation**, in particular originated from the support of EU growth project Parmenide and Eureka project UMIC. Thank to **Growth Parmenide** EU project, and **Eureka UMIC** project several partners in the actual consortium acquired significant expertise both in cMUT and pMUT.

This well experimented partnership was here reinforced by IR Microsystems as a future supplier of on-wafer piezo films, CEA-LETI, as MEMS foundry expert linked to MEMS manufacturer industry, and Telemed as a new end user bringing high frequency medical imaging expertise.

The 4 SME (IR-Microsystems, Imasonic, Inoson and Telemed) are very well matched to the specialities markets of NDT, MEMS, and High Frequency Imaging.

Due to creation of a common research laboratory involving THALES and CEA-LETI in the field of RF-MEMS where all THALES personal dedicated to this common laboratory, including personal working on MUSTWIN, will be employed by CEA, starting October 1st , 2004, all THALES activities in MUSTWIN project are transferred to CEA.

1.3 Work performed and results

Resulting devices are obtained trough activities of design, foundry qualification through test devices, MUTs wafer manufacturing, wafers packaging and interconnection, acoustical characterisation and evaluation on specially adapted system platforms.

The pathway to achieve the first two steps (design and foundry process) to get a minimally stable technological platform for MUT was full of critical aspects. The infinitesimal dimension of the structures, the quality and combination of the material selected, the way they are deposited in thin film and worked are some issues generating criticism in implementing the designed MUT model. Any technological approach has its own peculiarity and then the results obtained with a SiN cMUT approach are not straight applicable to similar SOI cMUT, less more to a pMUT approach. Then we could have establish a good modelling of MUT to be realised with a detailed design supported by solid simulation. Still the most critical part is to assess a foundry platform where to fabricate the prototype. Imperfection possible in a fabrication procedure theoretically defined can vanish the quality of the results. Maybe it is only a minimal detail but sufficient to have a result theoretically good but practically faulty. It is necessary an iterative scientific investigation to come out from it and to get a successful valid result. At any iteration a small parameter or condition, individuated as critical, is experimented with a supposed better adjusted condition. Outcome is compared with the previous one and a new iteration is then defined until a functioning results as expected by theoretical model is obtained. This is to indicated that an effective and reliable result for a MUT demonstrator can be obtained with a "little steps" process and the indication of big planned step is only a schematic simplification to evaluate periodic substantial advance of a project.

Then, the step to go from the assessed technological foundry platforms and design (done by project mid-term) to the silicon chips production of the validation device Dm1 and Dm2, as with SiN cMUT as with SOI cMUT, Dm3 and Dm5 with Bm pMUT and Dm4 with Tm pMUT impact with all critical aspect above outlined to make stable the technological platforms causing a delay in its achievement, more longer as less mature was the technology used. After a delay of 10 months (by December 06) on scheduled deadline consortium was able to produce the planned evaluation devices.

Looking to the promising results obtained, and considering that already many of preparatory working for packaging and characterising the evaluation device was done, the MUSTWIN Consortium consider when the validation devices could be ready and the minimum time next necessary to execute a reasonable evaluation of performances to arrive to close the project performing all scheduled actions. From this the request, accepted by EC, to extend project end of 5 months respect to the scheduled deadline of 28 February 2007.

Thanks to this extension, we could complete the specific packaging studies and get the evaluation device packed and for some case also assembled in device respecting requisites for being usable on their target applications evaluation. The level of assembly will depend from the target application and from the maturity of achievement of each technological solutions. This will be analyse in the following for each technology/device realised. In parallel was completed the work to set up evaluation platform for realised validation device probes with different MUT technologies and for the different individuated application domains, in particular the essential set up for medical applications. The feasibility study performed for Dm2, Dm4 and Dm5 demonstrators indicates, that a specific validation set up was not necessary but only more extensive testing to compare MUSTWIN results with today available solutions. Then involved partners compress activity on set-up of evaluation platform to increase correspondently their activity on performances evaluation.

Then the packed devices was characterised and evaluated within the extended deadline of the project.

The level of result achieved for each demonstrator device obtained. confirms the complete achievement of the 5 different evaluation devices covering the main spectrum of MUTs expected advantages.

The evaluation device obtained and tested at end of the project are:

- Dm1 and Dm2 using SiN cMUT technology.
- Dm1 and Dm2 using SOI cMUT technology.
- Dm3 and Dm5 using Bm pMUT technology.
- Dm4 using Tm pMUT technology

The general objective to get a sound know how on MUT concepts and actuation modes and to demonstrate that the feasibility to get results on 5 different evaluation devices covering the main spectrum of MUTs expected advantages can be considered achieved.

In particular from evaluation arises that the most advanced technology explored is the SiN cMUT one developed by ACULAB/CNR. This was expected as far as the research on this technology has already begun for years before MUSTWIN. However recent developments realised during MUSTWIN project lead to interesting performances measured.

The characterisations done on the Sin cMUT from ACULAB demonstrate the ability of cMUT technology to answer to medical and NDT probes requirements from an electro-acoustical point of view. By using cMUT technology, increased bandwidth and shorter impulse response should be obtained without any compromise on other characteristics. Furthermore, the integration and packaging realised for this prototype was robust and reliable, allowing the easy manipulation and use of the device. Further packaging and engineering effort is required before getting a commercial probe, but this task does not present large difficulties.

These performances are of interest for an industrial exploitation and MUSTWIN industrial partners are interested in considering this point with the owners of the technology

SOi cMUT technology was totally new at the beginning of the project. This results in a level of achievement that is not as high as for the SiN technology at the end of MUSTWIN. Considering the difficulty of mastering the design and technology of cMUT concepts and fabrication processes, this conclusion is not surprising and was expected.

However, complete Dm2 demonstrators were fabricated during the project based on 2 different technological approaches: one by FEMTO-ST, one by CEA-LETI. Both approach lead to the conclusion that the SOi cMUT concept is valid and represents a promising route, potentially an alternative to SiN cMUT, providing a simpler implementation of processes.

Before considering the industrial exploitation of this SOi cMUT technology, further technological developments are still to be done to improve current design and process mastery. This could be the subject of another R&D project.

The conclusions for Bm pMUT technology are similar to those for SOI cMUT but more it is envisaged new potential application as inkjet print-head.

Tm pMUT technology represents a new opportunity for the design and manufacturing of high frequency transducers, especially arrays of transducers. It allows a better geometrical definition of the electrode patterning defining the geometry of the elements and makes possible thinner inter-element spacing with a high precision. It is demonstrated that the fabrication of annular arrays working above 30 MHz are possible with this technology. They could be mainly used in high frequency medical imaging applications such as imaging of the eye. At the moment only single element are used in mechanical scanner with a fixed focus. Annular arrays would improve this kind of imaging by providing a good resolution over a larger depth inside the eye. This will be possible when dedicated multi-channel HF scanners will be available to test and use the 50 MHz annular array in real working conditions.

Furthermore, intravascular imaging could also benefit from the work done in this project on Tm pMUT. The developed technology is very suitable for applications where the size of the transducer is a critical point and where integration and packaging in miniaturised structures are necessary.

This is also the case for very specific application in industrial Non Destructive Testing (NDT) where the space around the inspection area is very limited and the miniaturisation effort is therefore higher than usually.

However, before considering an industrial exploitation of this technology, some more studies are required. More demonstrators are to be fabricated and characterised. The packaging of the pMUT has to be improved. The possibility of the industrial transfer of the processes used at Cranfield University has to be considered. And the cost analysis of this solution with respect to the market constraints has to be performed. This could be the subject of another project.

In conclusions, all above prototypes show interesting performance, indicative of their positive application potential but critical technical aspects of realibility of the process still have to be overcome before to get devices industrially exploitable from them. The progress obtained in fabrication, production and characterisation of the evaluation devices demonstrate that we are very near to get it and to have the road open toward results of industrial exploitation potential.

In this general contest of the whole result, one technological approach is demonstrated to be more mature for industrial exploitation in very near future: SiN cMUT devices are already at the level of feasibility and reliability prospected for going toward an effective industrial exploitation as proofed by the tested evaluation done in target application, in particular in medical imaging.

Among the difficulties to be faced by a similar technological challenge, it should be consider a very relevant success of this project that we not only we proof that all demonstrators could match the specifications initially established but for some of them, we get mature solutions from which it is possible to proceed toward the establishment of an exploitation plan like for the Dm1 and Dm2 based on SiN cMUT technology and Dm3 but for the ink-jet printer application (not considered among possible demonstrator in this project). For the other this will be possible only after a more research that could lead to most reliable and stable working configurations, but this is not matter of feasibility but only of proper optimisation of results.

1.4 Project impact

The MUT concept appears to be the **first real opportunity for a technological breakthrough** in the area of Ultrasonic Transducers working in the 1-30 MHz range. It is bringing **innovative** and **affordable solutions,** especially in the upper part and above this range (high frequency arrays), where the existing technology encounters considerable difficulties.

The MUT research is involving several labs in the world, the most advanced being at Stanford in the USA. An U.S. start up (Sensant Corp.) has also been created to try to commercialise some of these devices. Prototype shows interesting performance and the potential relevant industrial interest is proofed by the fact all major U.S. competitor tried to get Sensant know-how and that, among them it was Siemens to buy the Sensant property to have the exclusive industrial right to exploit Sensant know how.

After Stanford and Sensant, it is in Europe, and in particular in the MUSTWIN project group of partners, that he could be find the most advanced know how toward an innovative and affordable solution in the area of Ultrasonic Transducer based on MEMS technology.

Studies on MUT concepts and actuation modes performed by partners in MUSTWIN project was finalized to output results on different evaluation devices covering the main spectrum of MUTs expected advantages in medical imaging, NDT, air sensor transducer. This was done through exploration of the two different MUT concepts, the capacitive micromachined ultrasound transducers cMUT and the piezoelectric micromachined ultrasound transducers pMUT, all based on MEMS technology, but with four different actuation modes: 2 electrostatic (SiN cMUT and SOI cMUT) and 2 piezoelectric (Bm pMUT and Tm pMUT).

The success of the project is the availability, at its end, of a complete process tool box (or technological platform), to produce the different evaluation devices, i.e, it was possible to fabricated each of the planned different evaluation device with at least one the technological pursued MUT approach and to characterise each evaluation device for its target application. In conclusion we have assessed foundry platform and design to realise Dm1 (linear array cMUT for medical imaging) and Dm2 (linear array for NDT) as with SiN cMUT as with SOI cMUT. We have also assessed foundry platform and design to realise Dm3 (high frequency linear array for medical imaging) and Dm5 (air sensor transducer) with Bm pMUT and Dm4 (high frequency linear array for NDT) with Tm pMUT.

The obtained result are very positive. Prototype shows interesting performance, indicative of their positive application potential but critical technical aspects of realibility of the process still have to be overcome before to get devices industrially exploitable from them. The progress obtained in fabrication, production and characterisation of the evaluation devices demonstrate that we are very near to get it and to have the road open toward results of industrial exploitation potential.

In this general contest of the whole result, one technological approach is demonstrated to be more mature for industrial exploitation in very near future: SiN cMUT devices are already at the level of feasibility and reliability prospected for going toward an effective industrial exploitation as proofed by the tested evaluation done in target application, in particular in medical imaging.

Thanks to this, we can affirm that MUSTWIN Project is not only a scientific success, consolidating the European MUT know-how at the fore-front of the world knowledge but that the project has also a payback of knowledge ready to generate new innovative product in the market. This knowledge will open the possibility to the development of new improved performances and lower cost probes, making significant inroads into the areas of medical screening. Poor image resolution is the main drawback of today’s equipment. If image resolution can be improved the pre-screening tests may be carried out for early tumour detection (e.g. mammography and testicular cancers) and better detection of pre-natal defects. This would have considerable benefits both socially and from a safety point of view. Another important expected social impact of high resolution probes at lower cost is the wider accessibility to screening facilities to less developed areas of the EU where the present cost of ultrasound machines in the quantities required for comprehensive population screening remains today prohibitive.

Section 2 - Dissemination and use

2.1 Publishable result

This section provides a publishable summary of **exploitable result** the project has generated and therefore ready to publicise having taken the appropriate measures to protect their IPR[1].

ECHOGRAPHIC IMAGING with a CMUT PROBE

A result of EC Project MUSTWIN

The overall objective of the MUSTWIN project was to investigate the new MUT technologies for ultrasound probes both for medical and non destructive control applications. This was done through exploration of two different MUT concepts, the capacitive micromachined ultrasound transducers cMUT and the piezoelectric micromachined ultrasound transducers pMUT, all based on MEMS technology, but with four different actuation modes: 2 electrostatic (SiN cMUT and SOI cMUT) and 2 piezoelectric (Bm pMUT and Tm pMUT).

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After Stanford and Sensant, it is in Europe, and in particular in the MUSTWIN project group of partners, that he could be find the most advanced know how toward an innovative and affordable solution in the area of Ultrasonic Transducer based on MEMS technology.

The MUSTWIN consortium is made of 13 partners (Esaote, Imasonic, Inoson, Telemed, IR-Microsystem, EPFL, CNRS-FEMTO, Roma 3 University. Cranfield University, CEA-LETI, Thales, IFN-CNR) and it is for a large part built on an existing basis of co-operation, in particular originated from the support of EU growth project Parmenide and Eureka project UMIC.

Studies on MUT concepts and actuation modes performed by partners in MUSTWIN project was finalized to output results on different evaluation devices covering the main spectrum of MUTs expected advantages in medical imaging, NDT, air sensor transducer. This was done through exploration of the two different MUT concepts, the capacitive micromachined ultrasound transducers cMUT and the piezoelectric micromachined ultrasound transducers pMUT, all based on MEMS technology, but with four different actuation modes: 2 electrostatic (SiN cMUT and SOI cMUT) and 2 piezoelectric (Bm pMUT and Tm pMUT).

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[1] Please beware that only information which is readily available in the public domain should be included as this might affect the owner's right to seek protection (eg patent) the results.

The final result are very positive. Prototype shows interesting performance, indicative of their positive application potential but critical technical aspects of realibility of the process still have to be overcome before to get devices industrially exploitable from them. The progress obtained in fabrication, production and characterisation of the evaluation devices demonstrate that we are very near to get it but more research are necessary to have the road effectively open toward results of sure industrial exploitation potential. Only one boost really over the other: SiN cMUT technological platform originated result ready for potential industrial exploitation right now, in particular for medical imaging, thanks to the most mature development achievement and the new relevant original improvement worked out on the basic production process known at project start.

In the last decade, cMUT have shown promising characteristics for medical imaging. They have rapidly emerged as an alternative to conventional piezoelectric transducers in many areas of application, especially in the field of medical imaging, because they provide several advantages over piezoelectric transducers: better acoustic matching to the propagation medium, resulting in wider immersion bandwidth and improved image resolution, the easiness of fabrication, the ability to be integrated with electronic circuits on the same wafer and the expected reduction of production costs.

The cMUT consists of many electrostatic cells connected in parallel that essentially work as parallel plate capacitors, with a fixed electrode (backplate) and a free standing membrane supporting the second electrode. If an alternating voltage is applied between the membrane and the backplate, the modulation of the electrostatic force results in membrane vibration with generation of ultrasounds. Conversely, when the membrane is subjected to an incident ultrasonic wave, the capacitance change can be detected as a current or voltage signal (superimposed to a biasing voltage). The cMUT arrays are commonly fabricated by means of the surface micromachining technology, using standard integrated circuits fabrication techniques.

Several technological processes for the fabrication of 1D and 2D cMUTs have been presented, which only differ in the used materials and the involved fabrication process steps. Generally, all cMUT arrays present some disadvantages, inherent in the micromachining fabrication process, that is the presence of holes on the active surface of the transducer, necessary to etch the sacrificial layer and to release the membranes, or the presence of the silicon substrate, on which the transducers are build up, that severely degrade the acoustic performances. The presence of etching holes for evacuating the cavities on the active surface of the device introduces some drawbacks: the holes strongly affect the filling factor, especially for high frequency transducers, limiting the possibility to achieve large bandwidth and good sensitivity. Moreover, they have a negative effect on both the uniformity of the membranes and the sealing of the cavities underneath. Because of its high acoustic impedance, the silicon substrate generates ringing in the pulse-echo signal; therefore, it is useful to substitute the silicon substrate with a new backing material that presents better acoustic properties.

The current technology provides the interconnections pads on the same surface of the active elements. For packaging problems, it is more convenient to have the interconnections pads on the back side of the device.

The novel technology worked out in MUSTWIN project provides the interconnections pads directly on the back side of the die, making the device ready to be soldered on a flexible (or rigid) circuit, using the well-known flip-chip bonding technique. Our different approach consists in inverting the function of each layer and in building a cMUT capacitive cell starting from the membrane, made of LPCVD silicon nitride deposited on the silicon wafer, up to the bottom electrode. In this way, the holes used to evacuate the cavities are not opened in the structural layer preserving its uniformity. The silicon substrate is removed to release the membranes and a suitable acoustic material is added for mechanical support of the device. The interconnections pads are just fabricated on the rear of the structure.

Generally, the cMUT devices realized with the conventional technique require the use of a large number of lithographic masks. The novel technique also allows to reduce the number of masks to four, and it is even possible (for a particular configuration) a further reduction of the lithographic steps to three.

A further innovation concerns the acoustic backing. Because of the high acoustic impedance of silicon, the use of a silicon device for acoustical emission is tricky: in fact, it is difficult to find a good material as backing layer to prevent the ringing of the pulse-echo signal [11]. In all the reported technologies, a relatively thick silicon bulk (> 350 µm) is always supporting the active cMUT membranes. In the reverse process there is only a few micron thick silicon nitride layer under the cavity (~ 4 µm), and a classical acoustic backing material is used, also acting as a mechanical support for the device. Therefore, we fabricated an acoustic device overcoming the unwanted effects of the bulk silicon.

The novel "reverse" technology starts from these critical points, previously described, working on the back side of the silicon wafer and realizing a novel device to produce a cMUT with the fabrication step illustrated in fig.1.

One fabricated the device can be diced and soldered on a flexible circuit board (for example using a flip-chip bonding technique) or using a rigid PCB. At this step the transducer is electrically ready but not acoustically, being the membrane structural layer still attached to the silicon wafer. Mounted in a special case, we cast 2 mm (or more) of acoustic backing material which represents not only an acoustic layer, but also works as a mechanical base. The last step is the removal of the structural layer and of the bulk silicon on the back side of the wafer, to release the membrane; the device is now ready to operate.

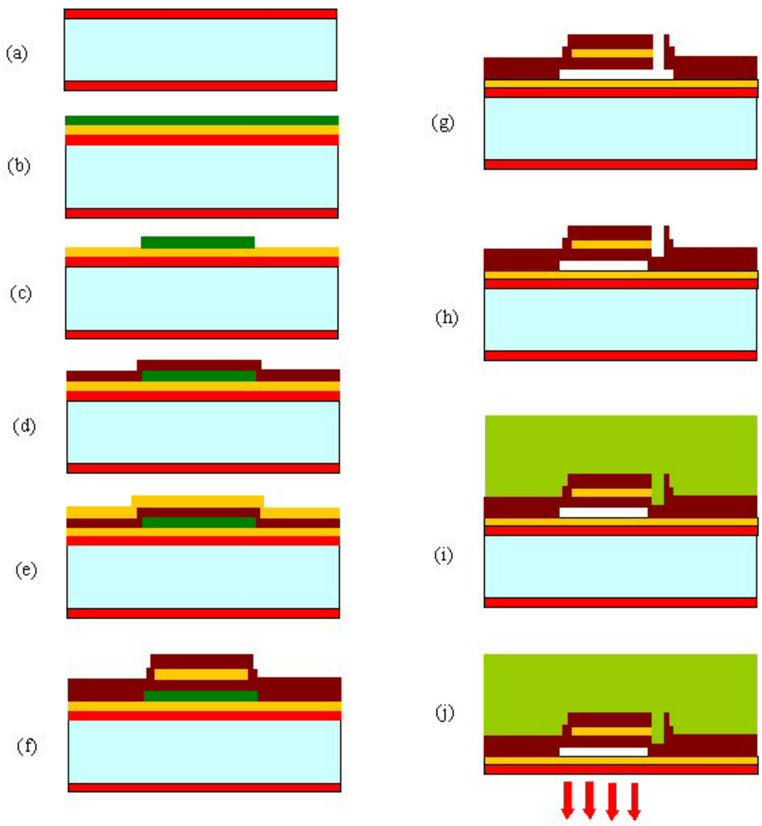


Fig. 1 Steps of the fabrication of a cMUT, using the "Reverse Fabrication Process".

To demonstrate its application validity, we realized some echographic probes using this new fabrication process concept. The probe is a 128 channels, 5 MHz center frequency, linear array, without acoustic lens. A picture of the final transducer, bonded to a PCB, is shown in fig. 2. Connecting the probe to a commercial echographic system (Esaote Technos) we obtained the images of the thyroid gland shown in fig. 3a.

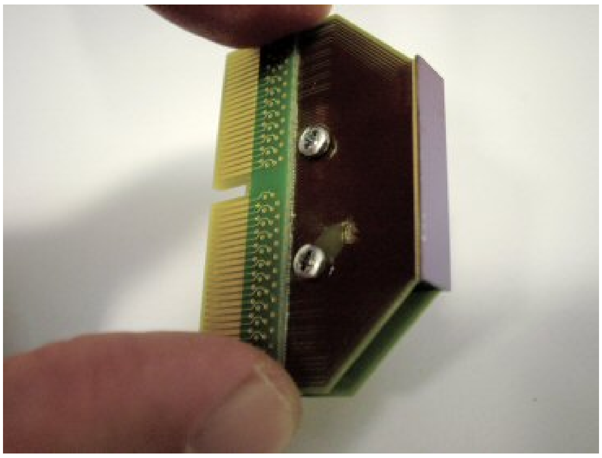
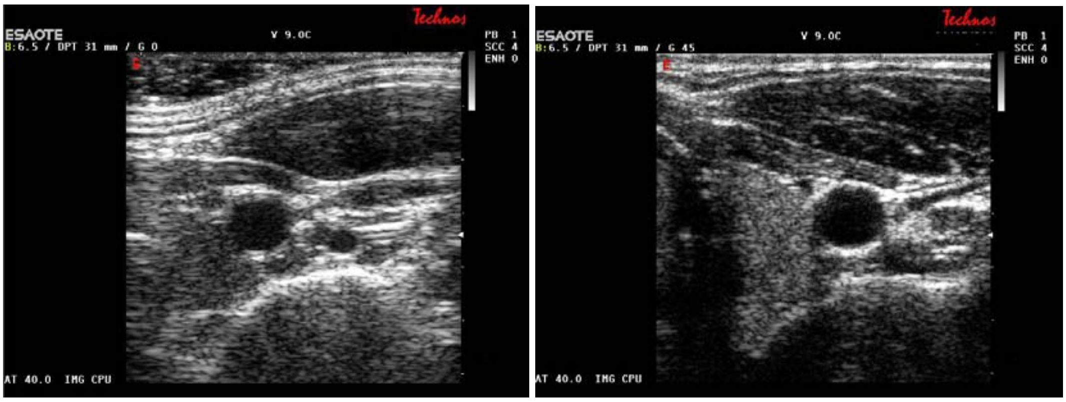


Fig. 2 cMUT transducer soldered to a rigid PCB circuit

The sensibility of the probe is very good, so that the gain of the echographic system was settled very low (to 0). The amplitude of the echo signal is very similar to that of a PZT, the classical probe. The scanning depth is 31 mm and the focus is at about 17 mm. In order to evaluate the improvements obtained with the new transducer, we report in fig. 4b, as a comparison, an echographic image obtained by a geometrically identical PZT probe (192 channels), commercially available from Esaote. Both images of fig. 4 are performed in identical conditions. A good improvement in contrast and definition, due to the higher bandwidth, can be clearly observed in the image obtained with cMUT, especially in the part of the sternocleidomastoid muscle, where it is possible to distinguish the striations of the muscular tissue.



(a) (b)

Fig. 3 Two echographic images obtained (a) using the cMUT probe and (b) the Esaote piezo probe: the right lobe of the thyroid gland, the sternocleidomastoid muscle, the common carotid artery, and the internal jugular vein.

This confirm that result obtained is a fundamental technology to give origin to industrially exploitable cMUT probes in medical imaging and (with some modification and adaptation) non-destructive testing field.

The advantage of the new cMUT probes toward to the conventional piezoelectric ones is:

- High level of miniaturisation and integration of components
- High performance level
- High control of fabrication process as for quality as for quantity
- Possibility to integrate other electronic circuit on board of transducer
- Lower cost

The preferred area for exploitation could be toward ultrasound probe with very large bandwidth (>100%) for harmonic imaging, bidimensional US probe for 4D imaging, disposable probe for intraoperative applications.

Roma 3 University, IFN-CNR and Esaote are the joint owners of result, protected through a deposited patent, and are also those involved in the exploitation of it.

The owners are now started the complementary research and development work necessary to get an industrially marketable product

Additional research will involve:

- Transducer driving with ASIC technology (in short-mid term MUSTWIN project follow-up)
- 1D array cMUT probe with high level of integration and miniaturisation
- 2D array cMUT probe for 4D imaging

Further the owners are evaluating the collaborative form and related business plan to make executable the exploitation procedure to be ready in combination with the conclusion of complementary research. No need for further collaboration are envisaged by the moment. If, by the case, it will be evaluated and token in charge by the result owners.

The development of new improved performances and lower cost probes, like the possibility offered by this new cMUT technology, could make significant inroads into the areas of medical screening. Poor image resolution is the main drawback of today's equipment. If image resolution can be improved the pre-screening tests may be carried out for early tumour detection (e.g. mammography and testicular cancers) and better detection of pre-natal defects. This would have considerable benefits both socially and from a safety point of view. Another important expected social impact of high resolution probes at lower cost is the wider accessibility to screening facilities to less developed areas of the EU where the present cost of ultrasound machines in the quantities required for comprehensive population screening remains today prohibitive.