**CHALLENGES TO THE COMMERCIALISATION OF MEMS DEVICES –**

**KEYNOTE PRESENTATION 21/06/06 SHERATON HOTEL EDINBURGH**

## 12th Annual International Mixed Signal-Testing Workshop organised by Systems Level Institute in Livingstone.

Hello and Good Morning. May I extend a warm welcome to you all here in Edinburgh. It is a pleasure to be invited here today to deliver the keynote presentation at this 12th Annual International Mixed Signal-Testing Workshop organised by Systems Level Institute in Livingstone.

My name is Allan James. I am the founder and managing director of Semefab (Scotland ) Ltd – an indigenous wafer fabrication facility in Glenrothes Fife. I am also Chairman of Semelab plc, a power semiconductor solutions company serving the defence, aviation, industrial and telecoms sectors based in Lutterworth, England. Semelab is the parent company of Semefab.

Semefab celebrates its 20th anniversary this year, and it is particularly appropriate for me to be able to deliver this talk today on the 'Challenges faced in the Commercialisation of MEMS' at this stage in our company's evolution, since MEMS is at the core of our future strategy.

I use that word – evolution rather than development, because of the continuous pressure and need to adapt to the commercial environment in which we find ourselves. It is an ongoing survival issue. Semefab has recently stepped out of a comfort zone in which we have operated successfully and profitably for many years because we see that the business model will be failing us in a few years time. We are currently going through a major expansion phase in MEMS.

I will now discuss the various factors at work and some of the tasks and challenges that we face ahead. Please note that where I use the term MEMS, I am referring to silicon based MEMS, however the generality of the message usually still applies.

Firstly, to set the scene and context, Semefab was established as a private venture in 1986 with £500k investment from our parent company, followed by a further £1M of working capital over the early years when we were establishing our customer base. We acquired a 4 inch CMOS facility and set to work designing and building ASICs in both metal and silicon gate CMOS and turning our hand to bipolar transistors, photodiodes, lateral mosfets, RF MOS. To this array of processes, we added a Linear IC capability, acquiring the designs and processes of Seagate Microelectronics in Livingstone, and also some High Voltage DI BiCMOS foundry for Burr Brown – now Texas Instruments in Tucson.

You would not be surprised to learn that we describe our core competency as semiconductor processing as distinct from design, although we have had very successful relationships with external houses who have designed our MSI mixed signal CMOS and Linear ASICs.

Things were going well, and the company weathered the peaks and troughs of the 90's eventually moving into MEMS foundry 6 years ago, obtaining several customers in the Neuchatel area of Switzerland in for pressure sensors in a broad range of applications ranging from heavy industrial in the 100's of bar, to 10's of bar for sports dive watches, millibar for altimeter, engine management, blood pressure monitoring and barometers. And also for gas sensors - NO2 and CO for in-car climate air quality control. To this we added a German customer in MEMS foundry for thermopiles – used for non contact temperature measurement e.g. the ear thermometer

Typically these customers would require only a few thousands of wafers per annum and retained some IP in processing by keeping the back end manufacture, assembly and test to themselves. Of course they avoided the high overhead of wafer fabrication.

Today MEMS foundry accounts for 30% of Semefab's revenue stream. Our involvement in MEMS has been quite successful – more so than some less fortunate than ourselves.

Which brings me to the first Challenge that I want to discuss:

The need for realism in commercialising MEMS, coupled with sound financing.

This sounds obvious, but there is a legacy issue which the MEMS industry is having to face – certainly in Europe and the UK. Less so I believe in the USA.

There have been many new company start ups in the MEMS arena over the past 10 or so years which have either gone out of business, or which have (of necessity ) morphed away from their original remit.

They all have one thing in common – they have burned their original investors – be they VC's, Pension Fund Managers, Business Angels, Government Agencies, Private investors.

Of course, the telecoms crash and dot com bubble of the early years of this decade certainly did not help matters. However there has been a great tendency to underestimate the time and cost required to develop, package and qualify MEMS based products for the market. Equally, new start - ups have been over optimistic concerning forecast sales figures and the rate of market acceptance.

The legacy situation in UK and Europe today is that it is extremely difficult if not impossible in many cases for originators of a new MEMS based product concepts to obtain the scale and continuity of funding necessary to establish the entire manufacturing process, including the wafer fabrication aspect and to cater for the vicissitudes of the market and the inevitable delays, twists and turns that accompany any major undertaking.

These issues, realism in forecasting and sound financing, are at the root of this particular challenge.

The alternative model which has been demonstrated at Semefab and others and shown to work quite well, is for customers to partner with versatile and flexible silicon wafer foundries which are financially sound ie those which already have substantial base loading.

I was interested to hear at the Semiconductor 2006 conference held here in Edinburgh 2 weeks ago that Malcolm Penn of the analyst firm Future Horizons was stating that the foundry model is now starting to become accepted in the wider MEMS community as the way forward.

The second challenge is to find a partner wafer fabrication facility that has the required versatility and flexibility.

MEMS devices may contain novel structures requiring specialized fab equipment. There may be exotic materials to be deposited and defined. All wafer fabs have a view on the issue of versatility, i.e. number of processes they are prepared to undertake versus degree of process optimisation and process control. It takes a very skilled team of process and equipment engineers to operate a wafer fab in this manner successfully.

They also have strict rules regarding the type of process they will carry out. There are real concerns about the introduction of heavy metals and ionic contaminants into the fab.
Heavy metals destroy PN junction integrity and minority carrier lifetime whilst mobile ions such as the alkali metals cause threshold drift and instability in MOS devices.

As the underlying business model relies upon maintaining the integrity of the entire operation, this kind of flexibility is only likely to be achieved by those wafer fabs which have separate clean room facilities with completely isolated services, DI water, gases and waste treatment for those processes dealing with so-called contaminating materials.

Even in such a segregated facility, which Semefab brought on stream 12 months ago, it is still necessary to consider the cross contamination potential from different customer’s products processed on common sets of equipment.

The major fabs of the Far East serving the fabless semiconductor community are of course aware of the potential of MEMS. Structures which can be accommodated by using CMOS equipment have been the first to be supported, to be followed by those where there is a new equipment need but the process is demonstrably non contaminating.

Finally, if at all, they may cater for exotic materials and contaminating processes in the manner I have discussed. However the business model for the major foundries relies upon large wafer diameters, high minimum wafer volumes and state of the art or close to - technologies.
These constraints fly in the face of many new MEMS opportunities and may place an unduly high cost burden at the outset.

The third Challenge relates to the need to assemble, test and qualify a new MEMS device.

Whereas for a CMOS or a Linear IC, these tasks are fairly prescriptive once the chip development is complete, there are major obstacles to be overcome for the novel MEMS device.
The task of assembly may well be on a par with the device development itself and should be considered as a parallel development at the outset.
Most MEMS devices interact physically with their environment in some way, and it is this interaction that poses key challenges for product assembly.

How do you introduce body fluids, blood for example, to a silicon chip, How do you get gas to a sensor interface yet protect the integrity of the metallisation interconnect from moisture corrosion.
How do you assemble moving parts such as micro-relay contacts or cantlilevers without introduction of particles or debris that could affect their function. How do you define and control the atmosphere within a hollow package.

In virtually all cases the packaging will need to be customised and subjected to development and trials.  In time we may see the emergence of some standardised packaging formats for example in the interfacing of optical fibre to silicon, in microfluidic lab-on-a- chip type products and in the encapsulation of free vibrating structures such as cantilevers, gyros and membranes.

Testing poses an equally tough set of challenges. The nature of a MEMS device is interaction of some sort. An appropriate stimulus must be given to the device during test to ensure that it is working. Do you apply a direct calibrated stimulus eg gas at x ppm concentration or light of y frequency and z intensity – or do you employ a simulated test with an equivalent electrical stimulus based upon device characterisation.

Also, we have to consider testing over the temperature range required of the device and reliability assessment. Activation energies of failure mechanisms in CMOS and Linear IC’s are well understood. So the Arrhenius equation and accelerated testing at elevated temperature are routinely used to give confidence in terms of reliability. Activation energies for failure mechanisms on MEMS devices are generally not well understood and this leads to reliability data having to be obtained often in real time.

In a recent conversation on this subject with a gas sensor manufacturer – the answer given was simply that we have to build our data base by having devices on test for extended periods of time and he was talking years. Clearly this can have serious implications for time to market and return on investment, especially in a start up situation.

In the case of a novel MEMS device the developer will find him or her self having to pioneer the approach, taking into account the requirements of the particular market sector at which the device is aimed.

When considering device qualification we also have the process variability to contend with.
Fabs are generally fairly blunt instruments – sheet resistances vary +/- 10%, capacitances the same, Op amp offsets depend on design and process and can vary by +/- 50%. For cost reasons you can't put an instrumentation grade op-amp in a consumer product.

So the issue of whether or not the device requires trimming or calibration needs to be considered. Also the cost of this step.

One exciting challenge for MEMS is the potential to develop a minimal area, low process overhead structure with low temperature coefficient, capable of being rapidly trimmed or adjusted in some way during electrical test to compensate for fab process variation. Already I have seen some interesting MEMS possibilities to rival EPROM and fusible links or zener zapping but to my mind there is still significant scope for process simplification and cost reduction.

Finally, I would like to move away from the sharp end of delivering a new MEMS product to the market and talk about possibly the most important challenge which is to harness the ideas and creativity of those working in academia and to establish the conditions under which product ideas can be proven, developed and moved into production.

This needs to happen in a way which a) allows this to happen far more frequently and b) in a way that avoids serious commitments having to be made by the start up to large scale infrastructure and equipment costs at too early a stage with the resultant 'pulling of the plug' if things do not work out quickly enough..

There was a lot of talk 5 or 6 years ago about MEMS being a disruptive technology – and they were right. But apart from sweeping away old methods and introducing completely new ones – take continuous tyre pressure monitoring and ESP in cars for example – dramatically improving safety, - there has also been serious disruption to the process of raising venture capital as I mentioned earlier and to those taking the risk and leaving academia to start their own businesses, - sadly many only to fail.

Since the telecoms crash and several notable company closures in the MEMS arena, there is now a markedly more risk averse mentality within UK Universities as a result.

However the huge potential for innovative MEMS structures and devices remains and as a reservoir of knowledge and ideas, the UK along with our partners in Europe are still in an excellent position competitively against the rest of the world to exploit them.

Today Europe and USA are roughly on a par and control 80% of the World's MEMS products – so we are in the vanguard of opportunity, in a sector which is expanding at greater than $1Bn per annum .

Two key issues in exploitation are improvement in connectivity within the supply chain and de-risking of the start-up process.

These issues are intertwined. About 4 years ago Lord Sainsbury commissioned the Taylor Report into the state of the UK's readiness to exploit MEMS and Nano-technology. It had been widely appreciated that the UK was falling behind Europe and USA in this key area. The outcome was a £90M fund - £50M to be spent on collaborative R&D projects between Academia and Industry, £40M (and this sum has since been increased) to provide improved capital infrastructure for the route to commercialisation.

A key finding of the subsequent due diligence that took place was that the UK was actually well set up from an R&D standpoint with excellent facilities located at various 'nodes' as they are now being referred to, including BAE Filton, Qinetiq Malvern, Imperial College London, Innos Southampton, SMC Edinburgh, iSLI Livingstone, Cranfield, Rutherford, INEX Newcastle. Not to mention the University base – and here in Scotland at Heriot Watt, Glasgow, Strathclyde and Paisley Universities there are particularly strong groups working on MEMS.

What was needed was to better publicise their presence and capabilities and to provide a focal point for enquiries.

The UK MNT Network was established 2 years ago for this purpose and the DTI now fund a directorate to maintain this facility and to guide and provide advice to the MEMS community. A further result from the initial diligence was the finding that the supply chain was in place given appropriate connectivity – in R&D circles, but that a chasm existed when it came to a product inventor or entrepreneur wanting to move from the proof of concept stage to pre-production quantities and on into initial production volumes from the device standpoint, and a similar gulf existed when it came to assembly and packaging facilities and expertise.

Partly as a result, my company, Semefab, has been awarded a substantial sum, around $12.2M, which we ourselves are matching, - to expand our equipment set for MEMS and to engage with the MNT network and wider European MEMS community on an ‘Open Access’ basis to fulfil the role of transitioning new products from early stage proof of concept through applied R&D and into production.

It is a unique initiative in my experience within the semiconductor industry of the UK to synergistically join the resources of the public and private sectors within State Aid guidelines to serve the interests of emerging MEMS companies and technologies.

This initiative has been augmented within Scotland through a complementary connectivity strategy under Scottish Enterprise, to link up iISLI and Heriott Watt and Strathclyde Universities for fundamental R&D leading to proof of concept designs and processes and linking Semefab and iISLI for MEMS design through to prototypes and production.

A further connectivity strategy is currently being pursued by Scottish Enterprise to link up the Scottish Microfabrication Centre here in Edinburgh, the Kelvin Nanotechnology Centre in Glasgow, the Institute of Photonics, the iSLI and Opto-Cap –the Livingstone based custom assembly company – again in an attempt to draw out the synergy to be derived from better networking and a common sense of purpose.

And as far as funding is concerned, in addition to the MNT awards mentioned earlier there are others such as Smart, Spur, Score, EPSRC, EU Framework 7 to mention a few of those that spring immediately to mind.

So in conclusion Ladies and Gentlemen there are great opportunities in MEMS here in the UK. There are many challenges to be overcome in developing and introducing new products, but I hope I have illustrated some of the aspects that should be considered.

There is clearly a large role to be played by the Mixed Signal Test community in helping to realise this potential. I go further – the decisions that you make in conjunction with your design partners will in many cases determine the cost effectiveness of the end products and their competitiveness on the World stage.

MEMS is one of the fastest growing markets available to us today. We have many problems to solve, but there are rich rewards. So I wish all of you who are engaged in MEMS one way or another, every success!

Thank you for listening to me and I have a great conference!

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