Solving the jigsaw

Years of manufacturing development work is now paying off for MEMS companies. By **Paul Dempsey**.

The need for concurrent design and manufacturing development in the creation of microelectromechanical systems (MEMS) is self evident in the technology's name. It's that 'mechanical' word.

However, during the most recent phase of the MEMS 'hype cycle', many ideas and concepts went forward where manufacturability was not fully explored. This is not a universal truth. The MEMS based devices in Texas Instruments' Digital Light Processors, Analog Devices' accelerometers and Freescale Semiconductor's gyroscopes already ship in large quantities to many satisfied customers.

But these examples show what big players have achieved using closely guarded MEMS processes, typically developed at and run through their own fabs. By contrast, much innovation in MEMS comes through start ups, research organisations and universities with far less access to process research and deep pockets.

"There's a substantial cost involved in getting the manufacturing right, not just the mask, but also throughout product development. It has to start alongside the initial design work," says Andrew McCraith, head of marketing and business development for MEMS oscillator start up Silicon Clocks. "Because a new company faces a lot of financial restrictions, you could say that many have come out with [MEMS] products where they had not really done all that work."

The view of this relative newcomer is shared by a leading semiconductor industry veteran. Ray Burgess, former head of Motorola SPS, is now ceo of MEMS switching start up TeraVicta Technologies. He describes why earlier attempts to develop his part of the market failed.

"Around 2000, a few companies announced they were going to come out with MEMS switches. Some of them did; and they worked fine out of the box, but then quit working, typically after only a few weeks or a few million cycles.

"Conceptually, these things look easy. You make a source and a drain, a deformable element and you have some force that makes it close. A schoolkid could draw it. But they started hitting problems which they couldn't characterise."

Burgess cites two specific defects in first generation MEMS switches. First, they would stick closed. Why?

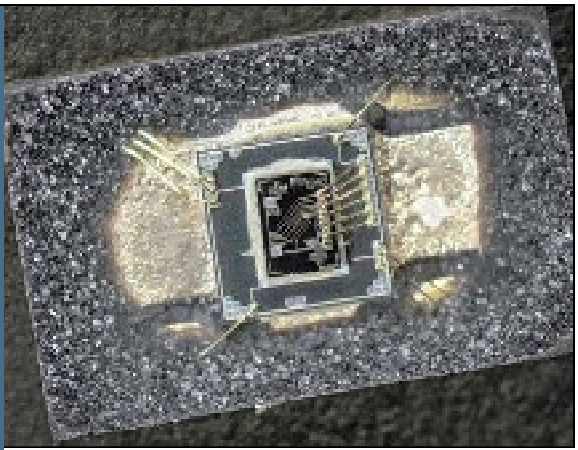
"You want to aim for the lowest contact resistance or the lowest loss, so you end up using soft metals, like gold. You then want a consistent force, so you end up with a high force and a soft metal. After multiple times slamming together, the switches stick closed. That was one thing," Burgess says.

The second failure mechanism was contact contamination. "In a small MEMS switch, there is the threat of gradual contact contamination, so resistance for the contact gradually went up and became infinity. It was then always open.

Burgess sees the second problem as 'organic'. "Semiconductor guys don't do organic; they do electromigration or particulate defectivity or moisture ingress."

So how TeraVicta did overcome these issues – the answer has both micro and macro aspects, although the macro angle is more surprising.

"I'm the guy who, at SPS, was one of the first to push for the 'fab lite' thing.



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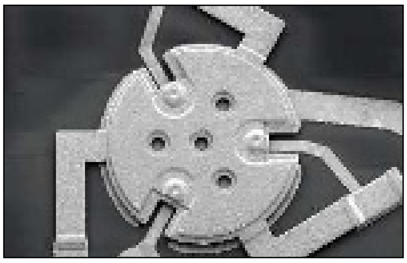
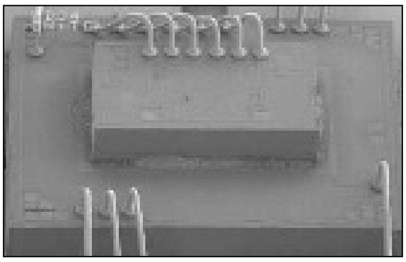
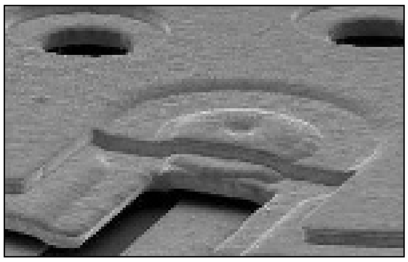
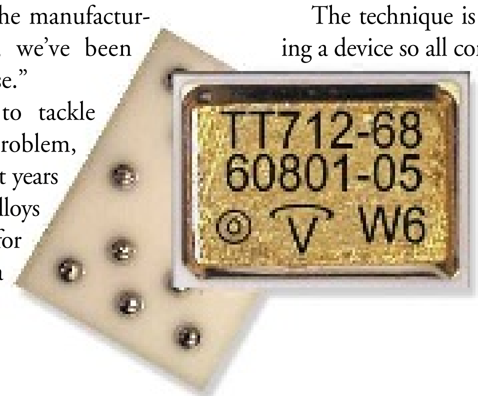






So, here's the irony; TeraVicta has built its own 12,000sq ft facility in Austin. We've got our own clean room where we make switches, then package and test them," says Burgess. "And we've got our foundry building; an exact replica in Hong Kong for volume production.

"As we've worked the manufacturing hard, we've discovered other defect mechanisms, such as contamination resulting from outgassing during soldering the package and organic leakage up the vias. With the manufacturing knowledge, we've been able to beat those."



Meanwhile, to tackle the materials problem, TeraVicta has put years of research into alloys that do not stick for – it claims – a mean 100million cycles to failure, based on gold, rhodium and copper.

"Obviously," said Burgess, "I think we've got a great product, because we've matched design and manufacturing in the right way. But, ultimately, we've just got to release what we have. There's a boneyard behind us and we have a lot to prove."

There is another technology path that recurs. Take a MEMS technology and wait for the semiconductor industry to catch up. This is how Analog Devices transferred and enhanced accelerometer technology for its high profile MEMS device in the Wii games console controller. It is also the thinking behind another silicon oscillator player, SiTime. It has licensed technology from Robert Bosch (in itself a MEMS heavyweight) which allows the resonator to be placed beneath a standard cmos wafer.

"We call the process MEMS First, because we build the MEMS first and then use the Bosch technology to seal a thin layer of silicon on top of the moveable mechanical structure," explains Joe Brown, SiTime's head of strategic alliances.

"The additional space that's required to put a zero level package around a MEMS product is almost nil. That's a huge real estate boost. In terms of performance, we are now on track to move with Moore's Law, albeit with some limitation. Nevertheless, we can look at scaling the elements in the design."

The technique is based on superheating a device so all contaminants are burnt away alongside the encapsulation. But even here, SiTime has had to get 'down and dirty' with process issues. MEMS First has been around for a while, but the combination of the 180nm cmos node and 200mm wafers was vital.

"For us, we are at a cost proposition point first," says Brown, "because with 180nm and 8in wafers, we are getting enough devices on the wafer that the numbers start to work. Beyond that, a shrink and other techniques then allow us to compete with quartz on performance and still further on size.

"I'd be the first to say that Bosch led the way with the process development, but the process refinement has been critical to SiTime having its market. The other advantage is that we can work with mainstream. rather than specialist. foundries."

The final word should perhaps go to one of MEMS' handful of eda vendors, softMEMS. According to ceo Mary Ann Maher: "Manufacturing can bring into play things that are counter intuitive to an engineer or beyond their scope. For example, a chip designer might look at thermal effects and see 'distortion', whereas in MEMS that might be what you need to make an element within the device perform. What's bad for one might be good for another.

"Then you have the materials issues and the fact that you are designing things that are meant to react to their environment. It becomes another layer of complexity. We can automate a lot of that. A good question though is how much you want the process to look to the engineer within it as though it is the same as designing a semiconductor."

On that last point, nobody as yet has the answer and there may be no definitive solution – just a realisation that MEMS' manufacturing and design is more complex than has, so far, been recognised.