Epson Toyocom's QMEMS Devices Take Quartz Crystals into the Twenty-first Century

By John Boyd

The eighteenth century English poet William Blake wrote of seeing the world in a grain of sand. Engineers in the twenty-first century have not progressed quite that far, but some impressive devices and machines they are building are no bigger than a grain of sand. Many of these constructions incorporate a technology called microelectromechanical systems or MEMS, and the materials used to create them are silicon, polymers, and metals. Now, Epson Toyocom Corporation ("Epson Toyocom") has added a new material to the list—quartz crystal—to create an additional category of devices it has dubbed QMEMS.

As a material, quartz crystal possesses some particular advantages. Its inherent hardness lends itself to precision manufacturing, meaning that it can be produced to a highly uniform quality level. The material is stable from a physical and chemical point of view with little moment-to-moment change. Furthermore, it has minimal internal loss of vibration and is highly stable during changes in temperature. However, a sophisticated processing method involving substantial miniaturization is needed to best bring out these advantages. It was MEMS technology that made this possible.

MEMS devices are at work all around us, taking on the roles of sensors, switches, and gyroscopes. They control safety features in cars and other vehicles, help GPS equipment navigate and printers print, as well as operate in telecommunications equipment including mobile phones. To build them, engineers employ fabrication technologies similar to those used in producing microchips. First, thin films of material are laid down on a wafer, upon which photosensitive masks are used to create device designs. When radiated with lithographic equipment, exposed and unexposed regions are produced and the unwanted material is then etched away with the help of chemical washes, leaving behind the desired shapes. Finally, the wafer is cut and diced and the resulting MEMS chips are ready for packaging.

"The benefits of using MEMS semiconductor production processes with quartz crystal materials are considerable, compared to the standard machining methods," says Teruhisa Miyazawa, manager of strategic product planning at Epson Toyocom. "For one thing, it's a batch production process and this results in higher productivity." Also, the same plants and equipment can be used to produce a variety of QMEMS products, unlike conventional production methods, which require different machine tools for each category of device. "And wafer-level production," adds Miyazawa, "means that the more we miniaturize our devices, the higher the number we can obtain from a single wafer."

Contrast this approach to the conventional mechanical machining method, where a crystal wafer is first cut and diced to produce individual chips. These single pieces must then each be machined to the required shapes, after which they will be inspected, then sent on for assembling and packaging.

But the benefits of QMEMS stretch well beyond improved yields and productivity. By using modified semiconductor production processes, Epson Toyocom now has the tools to fabricate much smaller quartz devices than were previously practicable with conventional production methods. It has also succeeded in preventing a hike in power consumption despite the miniaturization, making the devices ideal for use in cell phones and other portable equipment.

Increased precision in fabricating devices also helps improve their stability, while they exhibit fewer deviations in shape compared to mechanically machined pieces. Miniaturization, energy savings, and a high degree of stability and accuracy are therefore the standout features of QMEMS. At the same time, greater precision has opened the way for more sophisticated designs.

Miyazawa points out that with machine-

Miniaturization through QMEMS Technology

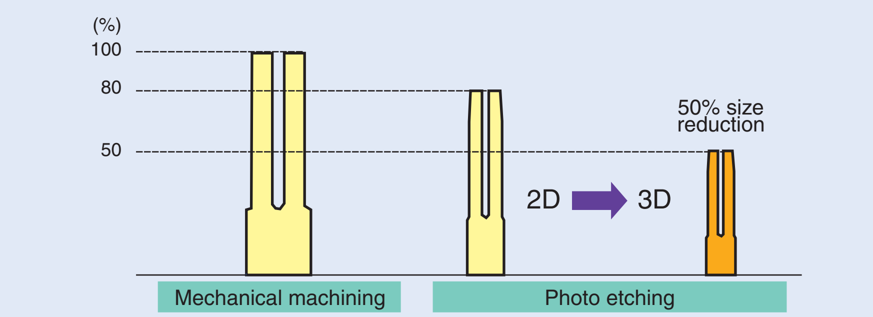


Photo etching technology enables a 20% reduction in the size of tuning fork crystal units. Applying 3D MEMS technology can further downsize the devices to half their former levels without sacrificing stability or precision.

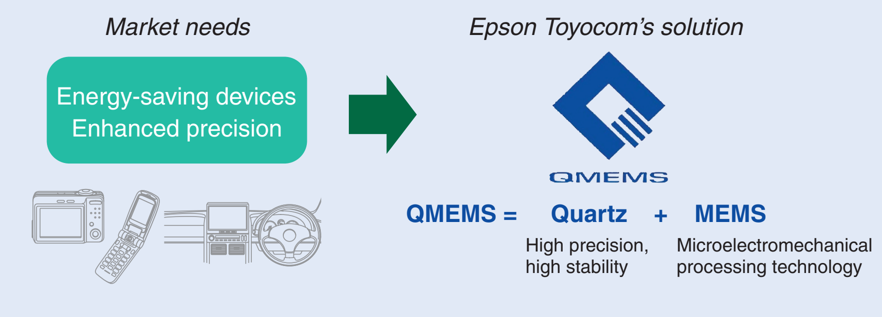
processed tuning fork crystal units (used as timing devices in watches, computers, and cell phones), designs were essentially two-dimensional constructions. The result was that the smaller a tuning fork was made, the greater the increase in impedance in the quartz material, a factor that adversely affected performance.

"Photo etching, though, has enabled us to achieve three-dimensional designs for tuning fork crystal units and other devices," says Miyazawa. Fabricating a device's electrodes in three dimensions increases their overall surface area and helps hold down the increase in impedance that would normally follow the reduction of a device's size. In addition, the material's impedance can be further controlled by incorporating grooves into the design of the device.

Research and development of three-dimensional photolithographic processing got underway some six years ago, just as the machining process began to approach its limits. The first subminiature three-dimensional devices marketed under the QMEMS name were launched after the concept was announced in October 2006, just one year after Epson Toyocom was established through the integration of Seiko Epson Corp. ("Epson")'s crystal device business with Toyo Communication Equipment Co., Ltd. ("Toyocom").

With nearly 80 years of experience working with quartz crystal, Toyocom was a leader in producing specialized high-accuracy crystal devices. Epson had some 40 years of experience in producing turning-fork crystal devices based on photolithographic processing technology, and launched the world's first commercial quartz watch using such a device in 1969. Given these complementary skills and focuses,

What Is QMEMS?



The market is demanding compact, high-precision quartz devices. QMEMS is Epson Toyocom's answer to such needs. QMEMS combines the high stability and precision of quartz with MEMS microfabrication technology to offer new levels of performance in a compact package.

Epson Toyocom has quickly established itself as a leading supplier of a wide range of quartz devices to the global market.

But the challenge of producing QMEMS had engineers from both companies calling on all their experience to overcome the obstacles of working with quartz at the subminiature level and achieving the requisite high levels of stability and accuracy.

"We started by growing synthetic quartz crystals to an even higher standard of purity than for machine processing," says Miyazawa. Similarly, while mechanical production requires chip surfaces with a high degree of flatness, this becomes even more critical when using photolithographic processes. Also, the semiconductor production equipment has had to be adapted to deal with quartz material, rather than silicon, for which it was designed.

"But our biggest challenge was creating three-dimensional designs," notes Miyazawa. "It was a case of much trial and error before we were able to refine the shapes to the exactitude that QMEMS devices require."

Because it was impractical to produce batch after batch of wafers in the pursuit of such accuracy, Epson Toyocom engineers worked with Epson's software engineers to develop a computer simulation program that could achieve what they were looking for at a virtual level. "This software helped us to come up with the optimum designs necessary to build QMEMS with the required degree of accuracy," says Miyazawa.

This technological breakthrough is now being applied to QMEMS devices other than tuning fork crystal units, including high-frequency fundamental crystal units and oscillators, gyrosensors, and photo AT crystal units and oscillators. In January, Epson Toyocom began shipping the FC-13F, the industry's thinnest tuning fork crystal unit with a maximum thickness of just 0.6 mm—roughly two-thirds the thickness of its predecessor.

"To retain our leadership position," says Miyazawa, "we intend to launch between 10 and 20 new QMEMS devices each year."

John Boyd is a freelance writer based in Kawasaki. He writes for a number of publications and covers technology and business news and issues in Japan and Asia.