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SUCCESSFUL DEVELOPMENT OF HIGH PRECISION SILICON-BASED MEMS RESONATOR

Development of New Packaging Technology

Seiko Instruments Inc. (SII) has succeeded in developing a high precision silicon-based MEMS resonator. In addition, SII, in collaboration with the Institute of Microelectronics (IME), a research institute of the Agency for Science, Technology and Research (A*STAR), has also succeeded in the development of a new wafer level packaging technology for vacuum sealing MEMS devices.

High Precision Silicon-based MEMS Resonator

The resonator is a device that is indispensable in modern electronics products such as computers, digital appliances and telecommunications devices. Currently, resonators using quartz crystals are the mainstream due to its light weight, highly precise and stable frequency properties. Research for new silicon based resonators shows that further miniaturization and reduction in cost may be possible through the use of MEMS processes to fabricate with silicon material.

High temperature dependency of the resonant frequency of silicon-based resonator poses a major challenge. More specifically, due to factors like thermal expansion and Young's modulus temperature dependence, its resonant frequency fluctuates when there is a change in temperature and generally has a temperature coefficient of -40ppm/°C. This means that for its operating temperature limit (-40°C~80°C), the resonant frequency will fluctuate in the 5000ppm range, making it very difficult to ensure precise output frequency in the resonator.

In order to ensure precise output frequency, electrical circuit has to be used to compensate for the change in resonant frequency as a result of temperature fluctuations. This creates a problem in the design for low power consumption and miniaturization. Furthermore, the use of electrical circuit to substantially compensate for temperature fluctuations will also lead to the occurrence of noise in the output.

Now, SII has successfully developed manufacturing technology that can greatly improve the problem of temperature dependence of the resonant frequency in silicon-based MEMS resonator by adding a layer of silicon dioxide film to the MEMS resonator fabricated on the SOI (Silicon On Insulator) substrate, and employing a structure that would produce residual stress within the resonator. (Please refer to Annex, Figure 1.)

The temperature coefficient of resonant frequency fluctuation has improved from -40ppm/°C to ±2ppm/°C. The frequency accuracy could also be controlled to a range with a maximum of 500ppm at operating temperature range (-40°C~80°C) (Please refer to Annex, Figure 2 and 3.) This will reduce the need for temperature compensation to the minimal and allow for application in low power consuming, miniaturized and high precision resonator.

Development of new wafer level packaging technology for vacuum sealing MEMS devices

In MEMS devices such as a resonator, a vacuum has to be present when in operation and low cost vacuum packaging technology for devices are desired. SII, in collaboration with IME, has developed a new vacuum sealing wafer level packaging technology by bonding the silicon substrate which acts as a cover, to the MEMS resonator device.

Usually, anodic bonding is used for sealing processes for MEMS devices with silicon substrate. However, this application is limited to the high temperature (400~500°C) and high voltage (600~1000V) needed for the bonding process, which might cause warping of the device. In addition, gases such as oxygen are produced during anodic bonding, making it necessary to include getters in the sealing process to remove the gases produced during the vacuum packaging process.

SII and IME have jointly developed vacuum packaging technology using gold-tin eutectic bonding processes. (Please refer to Annex, Figure 4.) With gold-tin eutectic bonding, the process can take place at low temperatures making it possible to inhibit the release of gases during bonding. This indicates that a higher level of vacuum sealing below 26Pa can be achieved without the use of a getter and external electrode can be drawn out laterally without passing through the substrate. This method not only improves the mechanical strength but also lowers fabrication cost.

SII and IME have successfully tested the performance of the aforementioned silicon-based MEMS resonator vacuum-sealed with the new wafer level packaging technology. With the newly developed silicon-based MEMS resonator and the new wafer level packaging technology, it would be possible to achieve miniaturization and low power consumption.

SII will conduct further performance evaluation to verify the possibility of a miniaturized and low power consuming resonator for future application in resonator devices. Silicon MEMS resonator devices are very compatible with ICs, making application in high frequency resonator, which would otherwise be difficult to achieve with quartz crystals. Its practical application will make low cost, high-mix low-volume production and miniaturized single chip high frequency resonator possible.

Application for the packaging technology in MEMS devices with various functions is also currently under review, with the aim to continue development for more compact and low power consuming devices. SII has set up a representative office in Singapore and has been collaborating with IME since 2007.

Enclosure:

ANNEX

Figure 1: Microscopic image of the developed silicon resonator

Figure 2: Thermal property of commonly used Silicon Resonator’s

Figure 3: Thermal properties of developed silicon resonator

Figure 4: Cross section of Vacuum Package with Gold-Tin Eutectic Bonding

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About Seiko Instruments Inc. (SII)

Seiko Instruments Inc., based on more than seven decades of dependable precision timepiece design, development and manufacturing, has extended its business domains by developing advanced micro mechanical, low power consumption, and nano-scale technologies leveraging its precision instrument manufacturing expertise.

Website: www.sii.co.jp/corp/eg/index.html

About the Agency for Science, Technology and Research (A*STAR)

The Agency for Science, Technology and Research (A*STAR) is the lead agency for fostering world-class scientific research and talent for a vibrant knowledge-based and innovation-driven Singapore. A*STAR oversees 14 biomedical sciences, and physical sciences and engineering research institutes, and seven consortia & centre, which are located in Biopolis and Fusionopolis, as well as their immediate vicinity.

A*STAR supports Singapore's key economic clusters by providing intellectual, human and industrial capital to its partners in industry. It also supports extramural research in the universities, hospitals, research centres, and with other local and international partners.

For more information about A*STAR, please visit www.a-star.edu.sg.

About the Institute of Microelectronics (IME)

The Institute of Microelectronics (IME) is a research institute of the Science and Engineering Research Council of the Agency for Science, Technology and Research (A*STAR). Positioned to bridge the R&D between academia and industry, IME's mission is to add value to Singapore's semiconductor industry by developing strategic competencies, innovative technologies and intellectual property; enabling enterprises to be technologically competitive; and cultivating a technology talent pool to inject new knowledge to the industry. Its key research areas are in integrated circuits design, advanced packaging, bioelectronics and medical devices, MEMS, nanoelectronics, and Silicon photonics. For more information, visit IME at www.ime.a-star.edu.sg.

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ANNEX:

Figure 1: Microscopic image of the developed silicon resonator

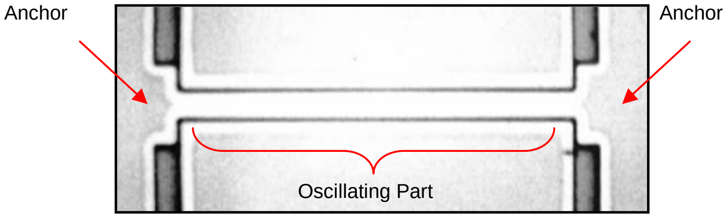

Figure 2: Thermal properties of commonly used silicon resonator

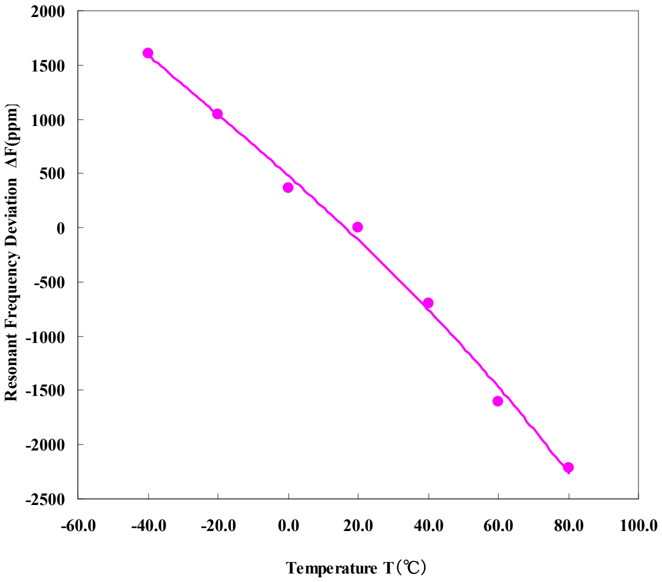

Figure 3: Thermal properties of developed silicon resonator

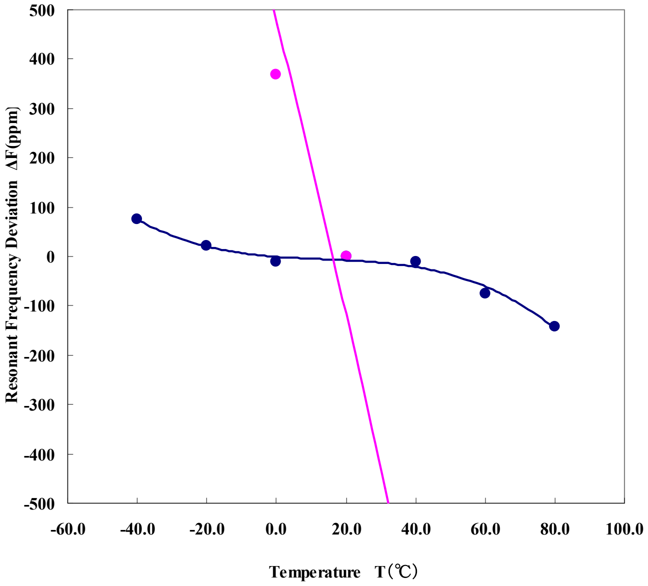

Figure 4: Cross-section of vacuum package with Gold-Tin eutectic bonding