New cleanroom design concepts for bringing original MEMS sensors to market efficiently

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Key words

Cleanroom, MEMS, MEMS sensor, development, development efficiency, productivity, safety

As a development base for MEMS sensors, Azbil completed the construction of a new cleanroom at its Fujisawa Technology Center in September 2022. The cleanroom's purpose is to efficiently develop MEMS sensors and to support their mass production. The cleanroom, along with the young engineers who have grown through their involvement in its construction and equipment installation, is expected to be a long-term foundation for the development of technology for Azbil's sensing and control business.

1. Introduction

In 1986, before the term MEMS (microelectromechanical systems) was first published, Azbil began MEMS development at its Fujisawa Factory (the current Fujisawa Technology Center) located in Fujisawa, Kanagawa Prefecture. With the completion of a cleanroom it obtained the basic technology for creating MEMS, and within a few years used the technology to produce temperature/humidity sensors for buildings. In the early 1990s, we produced a micro-flow sensor [1] [2], piezoresistive pressure sensor [3] [4], and humidity sensor for building air conditioning [5], and expanded our cleanrooms with the purpose of expanding production. After that, we added models such as the sapphire pressure sensor [6] [7] and magnetic angle sensor. In addition, we have been expanding the cleanrooms to enhance the unique MEMS sensor wafer processing and packaging processes.

At the same time, in MEMS-related markets, where market needs had been strong, MEMS sensors with even more originality are now in demand, not to mention more types and quantities of sensors, in response to the recent IoT and DX boom. It is becoming increasingly necessary, in this field that amounts to a core business of Azbil, to create a development environment that can create a higher-quality product more quickly, and also to improve the production capacity and update the equipment for MEMS sensors that are currently being mass-produced.

In addition, it is becoming essential to ensure cleanroom functions that enable continued business operations even during natural disasters that exceed our expectations, like the Great East Japan Earthquake, the repeated landfall of large typhoons, and torrential rains.

Given this background, we decided to obtain facilities that can continuously supply products to the market over the long term by constructing a new cleanroom building to serve as a development and production base for Azbil's MEMS sensors.

2. Challenges for efficient introduction of new unique MEMS sensors to the market

Azbil has been offering solutions based on measurement and control to the building and factory markets, in the main. Our cleanrooms, which supply the MEMS sensors that are the key components of our measuring devices, have also been expanded in response to market needs. However, for MEMS sensors, there has been an increasing need for non-conventional types of measurement and for measurement data that promotes DX at manufacturing sites, along with increasing demand to meet the specifications for various applications, and to do so with shorter delivery times. It is predicted that the global MEMS market will have an average annual growth rate of 8.7 % from 2021 to 2026, reaching 18.9 billion USD [8]. To satisfy the growing demand we will need to continue increasing the production of existing products while maintaining high quality, and at the same time to efficiently develop new products in a short period of time. For newly developed products, it will be necessary to shift to stable production quickly. To meet these challenges and respond to market needs, building new cleanrooms was a necessity.

3. Goals for overcoming the challenges, and the results

3.1 Creation of a new MEMS sensor development environment

We have been developing new types of MEMS sensors ever since we began working on MEMS in the late 1980s. We have repeatedly expanded our cleanrooms to keep pace with increasing development and production. However, it became difficult to expand them further, and there was a need to create an environment appropriate for, and with sufficient space for, the equipment necessary for future MEMS development.

The 1,336 m^2 cleanroom building that we built for development and production has 3 stories and a total floor area of 4,217 m^2.

The area where cleanrooms can be installed is on the second and third floors. We will begin creating an installation environment for cleanrooms on the second floor, where we will install equipment for developing and manufacturing superior MEM sensors. We have reserved the third floor as space for flexibly arranging cleanrooms according to future developments and for introducing the best equipment as we acquire it. The first floor houses the utility facilities necessary for operating the cleanrooms, as well as a calibration laboratory for measuring instruments, including sensors [9]. The exterior of the cleanroom building is shown in figure 1, and a cross-section diagram is shown in figure 2.

In the calibration laboratory, precision control of temperature, humidity, atmospheric pressure, and also cleanliness is provided by Azbil's air-conditioning technology.

Fig. 1. Exterior of the new cleanroom building

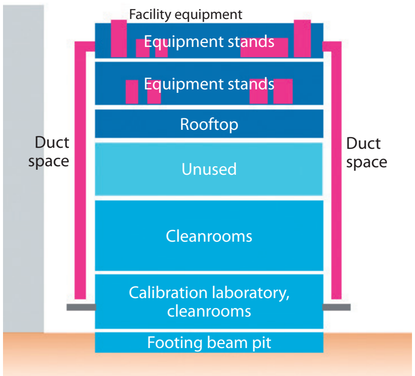

Fig. 2. Cross-section diagram of the new building

3.2 Continued development of existing mass-produced products

Since we offer products and services mainly for industrial applications, we need to provide our MEMS sensors (fig. 3) continuously for a long period once they are adopted. Our products that incorporate MEMS sensors have very long periods of use, in line with trends in the target markets. For example, we have supplied basic industrial measuring equipment like pressure transmitters to the market for about half a century and micro-flow sensors, which are relatively new, for approximately 30 years. Even within the same product group, it is not rare for new applications to appear during the long period while products are being supplied. As a whole, our production volume is on an increasing trend, like the MEMS market in general. To keep pace with the increase, upgrading our production equipment is necessary not only for development efficiency but also to improve mass production productivity.

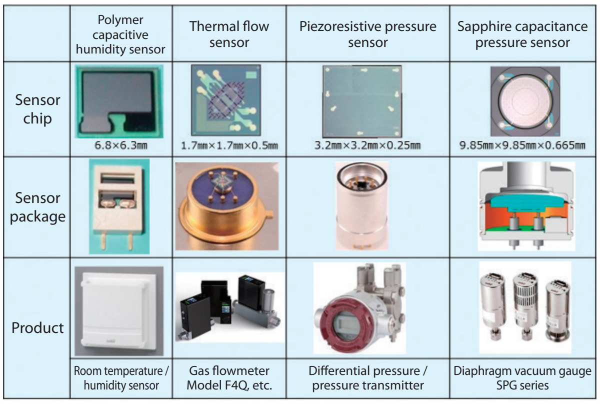

Fig. 3. Azbil MEMS sensors and product groups

In order to ensure a stable supply of MEMS sensor products that meet the growing demand, we have begun to install equipment that is suitable for our MEMS processes and that enables stable production in terms of both volume and quality, with improved productivity. We focused on functions that were causing problems in the existing equipment and addressed them in the required specifications, while taking maintainability into consideration. When selecting equipment, we placed importance on whether the equipment had a mechanism to prevent wafer contamination during transport, and on whether the equipment's interface minimizes the chance of setting errors by operators.

3.3 Planned installation of manufacturing equipment that meets our needs

3.3.1 Equipment selection policy

MEMS sensor manufacturing can be thought of as one application of the semiconductor manufacturing process. However, MEMS sensor manufacture includes not only the cleanliness and microprocessing required for semiconductors, but also processes unique to MEMS. These include processing with a high aspect ratio using 3D silicon processing technology and the materials' mechanical characteristics, and the high-precision bonding of different materials. Utilization of equipment that can provide such technology is the key to development and mass-production in a short period of time. In addition, it is also essential to select equipment that is usable for continuing development and production over an extended period of time. We have begun introducing equipment that can fulfill these specifications.

3.3.2 Improvement of development efficiency and productivity

For operational efficiency and quality improvement, wafer handling is basically performed by an automatic loader. In setting manufacturing process conditions, there are many processes for which the implementation of one condition takes several hours. We have set multiple conditions simultaneously to improve the efficiency of experiments and selected equipment that enables continuous automatic processing.

3.3.3 Effective utilization of an equipment engineering system (EES)

Online utilization of process data is an effective tool for creating a high-quality manufacturing process. Downtime can be minimized by detecting and dealing with potential process equipment failures in the warning-sign stage before they actually materialize. To this end, it is necessary to automatically collect and analyze data for each process, predict performance while the process is ongoing, and provide that feedback to the following process.

Since the 2000s Azbil has accumulated know-how and systems for the effective utilization of an EES [10] for which we have built up a track record with customers in the industrial market.

In recent years, it has become possible to predict the performance of manufacturing processes using dynamic time warping (DTW) [11] [12] in addition to the customary manual feature-extraction methods in the EES area that involve mainly time-series process data.

Also, at an early stage we applied the concept of local computing [13], in which sensed signals are processed on the spot as quickly as possible, and we have demonstrated its effectiveness. This includes our attempt to detect signs of abnormality directly from the sensor signals [14]. Additionally, we utilize online frequency analysis [15] of acoustic or vibration data with high sampling rates.

3.4 Improved countermeasures for earthquakes and flooding

The new cleanroom building was built at the Fujisawa Technology Center in Fujisawa, Kanagawa Prefecture. For long-term safe operations, it is obviously important to prepare for various scenarios, including an earthquake occurring directly beneath the Tokyo metropolitan area, major typhoons, and localized torrential rains.

For earthquakes, we opted to construct a building with high-grade seismic resistance by applying the latest technology. This means that our new cleanroom building will be able to avoid severe damage and continue business operations even in the event of a major earthquake with a strong 6 seismic intensity (*shindo*).

Regarding floods, it is necessary to consider countermeasures for flooding of nearby rivers due to localized torrential rains in recent years, as well as the possibility of a large tsunami caused by an earthquake. Therefore, we designated the second and third floors of the new building for cleanrooms containing the main manufacturing process equipment, and set the tide protection level of the first floor to T.P. +7.48 [16]. This has made it possible to avoid damage from any currently conceivable floods.

3.5 Streamlining foot traffic and ensuring an open and safe work environment

Since the start of the development in the late 1980s, we have repeatedly expanded our cleanrooms both to acquire new technology and to improve mass production. As a result, the flow of people and material in cleanrooms has become complex, raising concerns of quality degradation due to unnecessary transport work. In order to eliminate this problem, in our new cleanrooms we designed an efficient flow of foot traffic and tried to create an environment where closed spaces are minimized.

To ensure the necessary cleanliness for each area, we improved the control of airflow and reduced the number of walls and doors of the clean areas as much as possible. As a result, foot traffic patterns have become simple and usability has been significantly improved.

Fig. 4. Reduced number of walls in clean area

A cleanroom is basically an enclosed space, since it is necessary to ensure airtightness. Because of this, the sound of machinery and air conditioning tends to cause physical and psychological stress for workers. To alleviate this stress as much as possible, we designed the rooms to increase workers' sense of satisfaction. For example, to impart at least some small feeling of freedom, the rooms contain windows from which workers can directly see the outside world. In addition, there are windows that allow people to see inside the cleanrooms, not only for safety, but also for tours given to visitors.

Fig. 5. Window in a cleanroom

Cleanroom operations involve dangerous chemicals and high pressure gases. In order to ensure that operators are safe at all times, there are approximately 40 cameras and an automatic monitoring system, making it possible to check the condition of operators with no blind spots. In addition, we made sure that common hallways are sufficiently wide and straight in the event that emergency evacuation is needed, and to minimize the effect of transporting equipment on facility operation.

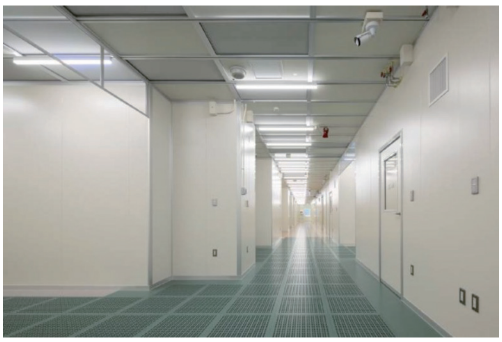

Fig. 6. Hall for emergency evacuation and equipment transport

3.6 Energy conservation in line with the Sustainable Development Goals

We are working to reduce the environmental impact of our business activity in order to bring about a carbon-neutral society, using the SDGs as a guide. The new cleanroom building is a relatively large facility at the Fujisawa Technology Center, so it must be energy-efficient in line with azbil Group targets for the entirety of the site.

We designed the cleanroom building so that energy use can be managed in each of its areas, with flexible setting of control points, by selecting an air conditioning controller with a track record in the building system business. In addition, we designed the building so that energy consumption would be kept to a minimum outside of operating hours. More specifically, energy consumption has been reduced by constantly monitoring the operating status of each utility facility, including air conditioners, which consume large amounts of power, and by utilizing know-how accumulated in the past.

3.7 Training of young engineers

Experiencing the construction of the cleanrooms and the selection and introduction of auxiliary facilities along with each piece of manufacturing process equipment has provided a once-in-a-generation opportunity to train engineers. Experienced engineers who have been responsible for our MEMS technology and young engineers who will forge the future have joined forces and put their heads together to make this major project a success. We have high expectations that the young engineers will be inspired by this experience and will go on to develop unique MEMS sensors based on new technology.

4. Future tasks

Even as we move forward generally with DX, there are still some aspects of IT utilization in the processes from MEMS sensor development to their manufacture that are undeveloped. The background or history of each product and the characteristics of the target market are some of the causes. Fortunately, as mentioned above, we have established a track record in the domestic market since the 2000s in the area of solutions for the semiconductor market, particularly for the realization of an EES. There are in-house resources that can be utilized now, and the latest information can easily be obtained from outside the company. Utilizing these advantages, we will promote the technology for using AI [17] to detect problems in facilities and equipment in the future. Moreover, by establishing a mechanism for effective advanced utilization of manufacturing process data, we will take development efficiency to the next level and achieve a rapid transition to high-quality production.

For the MEMS sensors we have been supplying, we have maintained high quality through methods that have been established for each generation of the sensors. However, there are variations in these methods. We can expect that, by utilizing the technology mentioned above to establish the production processes of the new cleanrooms and their future operation, we will be able to bring production quality to a higher level.

5. Conclusion

We have discussed the concepts behind the new cleanrooms at the Fujisawa Technology Center and the results that have been achieved. With the new cleanroom building, we have prepared the infrastructure for developing unique MEMS sensors that will play the key role in the next generation of Azbil's measurement technology, for sending the results of that development out into the world, and for furthering the development of existing MEMS sensors. In addition, we have developed a place where the young engineers who have been a part of the cleanroom building construction and are carrying the baton received from experienced engineers can continue to grow and achieve. We can expect to see a new era open up at Azbil, with MEMS sensor technology playing a major role.

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