Special Issue Dedicated to Professor Toshitsugu Ueda for his Achievements in Sensing Technologies

Preface

Computer and machine technologies are developed to reproduce the function of human muscle and intelligence, respectively. On the other hand, sensor and sensing technologies are developed to enable the expansion, diversification, and quantification of the human sensory function. Sensors are essential to allow actuators and computers acting as muscle and intelligence to function exactly more efficiently. At first, sensors were devices that converted physical chemical quantities of human senses, e.g., weight, temperature, and odor, into electrical signals. However, with industrial development, the kinds of sensing that human beings are incapable of have become important.

Historically, the demands for sensors and sensing technologies occurred because of the necessity of maintaining fair social relationships. For example, the tribute equivalent to the current taxes was proportional to the area of farming fields. In ancient Japan, the government precisely measured the area of fields such that all the people understood and issued laws concerning the tribute based on the measurements. Another example was related to business. For example, a mutual understanding between people of business is necessary to buy and sell goods that cannot be counted as simple numbers, such as rice and oil. Therefore, common measures that everybody understands are necessary. As measures to establish such mutual understanding, sensor and sensing technologies have been indispensable techniques up to this day.

In sensor and sensing technologies, a field of particularly active development in recent years is micro-electromechanical systems (MEMS). The distinguishing characteristic of MEMS is small size. For example, the Reynolds number, which is the ratio of the inertial force to the viscous power, is a large value of the order of 10^{10} in a large object such as submarines, which can be hundreds of meters long, but it is a very small value of the order of 10^{-5} for bacteria with a size of around 1 μm. As for the large difference of the Reynolds number, we generally handle the physical phenomena in terms of inertial force in a large object, but in the field of MEMS, the physical phenomena are handled in terms of viscous power and frictional force. Because the equation of motion is based on viscous force in MEMS devices with moving parts, there are numerous different points in their development and design.

In the Ueda laboratory, we have developed various processing, industrial, and medical sensors. Above all, we have been researching and developing quartz crystal MEMS continuously for many years. With the research results, for example, the basic data and practical use of devices using quartz crystals, I believe that we were able to contribute to society. The topics of sensor development using our recent quartz MEMS technology are one- and two (plane)-axis declination sensors with sensitivities of 1/1000–1/10000°. These general-purpose sensors are very small (40 g) and can be connected to a computer via a USB or wireless

connection (Bluetooth 4.0). We can apply this declination sensor in a landslide monitoring system and a deterioration monitoring system of public infrastructure because it is small and highly sensitive.

Another application of quartz MEMS is in hydrogen sensors that are essential in monitoring the security of hydrogen stations that are planned to be constructed in more than 200 locations in the next 5–10 years. This sensor consists of quartz resonators with special cut angles and a platinum black catalyst. Using the proportional resonance frequency change in the sensor resonator with hydrogen concentration, we can measure the atmospheric hydrogen concentration. The major difference compared with the conventional hydrogen sensor is that this hydrogen sensor has digital output and a self-diagnosis function.

In this special issue, there are articles by researchers in specialized sensor fields, other than those mentioned above. It would be my greatest pleasure, if these research results can be useful in future sensor studies.

Toshitsugu Ueda
Emeritus Professor of Waseda University
Japan

Editorial Prefaces

This special issue is dedicated to Dr. Toshitsugu Ueda, Professor Emeritus of Waseda University, Japan, on the occasion of his retirement from Waseda University and in recognition of his outstanding contribution to the field of sensing technologies, particularly micro-electromechanical systems (MEMS) device development over the years. The manuscripts were submitted in response to direct invitations from the guest editors, and mainly consist of contributions from young researchers in the above fields. All the manuscripts underwent the peer-review process of the journal. The guest editors are grateful to the authors for their excellent work.

This special issue contains seventeen articles: fifteen research papers and two technical papers in the following area.

- Optical sensing systems
- Hydrogen sensors
- Quartz crystal microbalances
- Quartz micromachining
- Quartz MEMS sensors
- Plasma applications
- Chemical and biosensors

This special issue commemorates the retirement of Professor Toshitsugu Ueda. However, he, of course, has not yet retired from his research career. We are certain that he will continue his innovative career during the next decades, and we wish him continued health, progress, and success.

We would like to thank all reviewers for their time spent on reviewing. We believe their insightful comments and valuable suggestions have helped to improve the articles.

We would like to take this opportunity to sincerely thank Professor Kiyoshi Toko, Kyushu University, for proposing and helping us to publish this outstanding special issue and Ms. Misako Sakano of the Editorial Department of MYU K.K. for her unfailing support and patience during the review and publication process of this special issue. We are highly privileged to write this editorial at such a significant moment for *Sensors and Materials* as this journal celebrates its 30th tradition.

Satoshi Ikezawa
Kyushu University
Japan

This special issue is dedicated to Professor Toshitsugu Ueda on the occasion of his retirement and in celebration of his significant achievements in the fields of sensor technology, micromachining technology, and sensing systems.

Toshitsugu Ueda was born in Nara, Japan, in 1945. He received his Ph.D. degree from Tokyo Institute of Technology in 1988. After joining Yokogawa Electric Corporation in 1971, he engaged in developing low-noise amplifiers, mechanical resonators, micromachining technologies, and sensors, using the above-mentioned technologies, for temperature, pressure, and displacement measurements. In 2003, he returned to the Graduate School of Information, Production and Systems (IPS), Waseda University, as a professor. Professor Ueda focused on developing quartz micromachining technologies, quartz MEMS-based sensors (tilt sensor, hydrogen sensor, high-frequency quartz crystal resonator), laser-induced breakdown spectroscopy, and photonic-bandgap fiber-based sensors. On his retirement (March, 2016) he became an Emeritus Professor and still maintains his research activity at the research center of IPS, Waseda University.

Many of his former doctoral students and post-doctoral researchers are working in Japanese or foreign universities. Most of the papers in this special issue have been written by them, and some papers have been contributed by other related researchers who co-researched with or knew Professor Ueda.

This special issue contains 17 papers, two mini-review papers and 15 original research papers. Among these papers, there are six papers on quartz-based devices, five papers on the design or application of quartz crystal resonators, and one paper on the etching simulator. There are three papers on the optical- or fiber-based sensor or a sensing system. Two papers present MEMS-related sensors, one for the design concerns of accelerometers and the other for surface texture characterization. Two papers report on the effect of plasma treatment on the polymer material wettability. The remaining papers concern taste sensors, pH sensors, gas sensors, and uric acid biosensors.

Basically, all the research topics of the collected papers fall in the research fields of Professor Ueda. We thank the authors for their contributions. We also hope these articles will be useful reference to related researchers.

As the first student to receive Ph.D. degree under the supervision of Professor Ueda, I feel a great honor in co-editing this special issue with Dr. Satoshi Ikezawa.

We thank Professor Makoto Ishida, Editor-in-Chief of *Sensors and Materials* and Professor Kiyoshi Toko, the Editor of this journal, for providing us with the opportunity to oversee this special issue. We would like to express special thanks to Ms. Misako Sakano of MYU K.K. for her kind support and assistance in organizing this issue. We also take this chance to commemorate the 30th anniversary of *Sensors and Materials*.

Jinxing Liang
Southeast University
China