Preface to Special Issue "Sustainable Society and Advanced Technology"

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1. Introduction

Paul J. Crutzen, who was awarded the Nobel Prize in Chemistry in 1995 for his work on ozone layer depletion, also proposed using the term "Anthropocene" in 2000 to describe a new geological epoch when human actions have a drastic effect on the Earth and its environment. The Anthropocene epoch is characterized by advancing global warming and climate change, sedimentary changes caused by the burning of fossil fuels, an increase in plastics and other man-made materials, a loss of biodiversity, and other factors that threaten to endanger the sustainability of human society. The United Nations adopted the Sustainable Development Goals (SDGs) in 2015, and some of these goals are closely linked to features that characterize the Anthropocene Epoch. These features are expected to become increasingly important as described below.

Climate change is advancing rapidly at a pace observable in our daily lives and concrete measures are urgently needed to address it (SDG 13). Energy consumption continues to rise and a shift to sustainable energy sources is needed urgently (SDG 7). Increasing production and consumption is placing a heavy burden on the environment and calls for the effective use of resources and waste reduction (SDG 12). Industry structures that promote technological innovation are important for balancing economic activity with environmental protection (SDG 9).

This Special Issue presents Shimadzu's leading-edge technologies that help to achieve these SDGs grouped by each SDG.

2. Climate Action (SDG 13)

Biomanufacturing based on microorganisms that can utilize carbon dioxide (CO_2) from the atmosphere is a popular field of study due to the beneficial impact that biomanufacturing can have in reducing CO_2 emissions, which is the main cause of global warming. This Special Issue presents the development of analytical and measuring technology in this field of biomanufacturing: specifically a rapid gas culture evaluation system and a multi-parametric evaluation system for fermenters. These new technologies can be used to develop bioreactors capable of large-scale, low-cost production and create sustainable systems of production.

In the field of Green Transformation (GX), there is ongoing development of a wide range of new technologies oriented towards achieving carbon neutrality. This Special Issue presents a compact catalytic reactor that can be used with general-purpose gas chromatography detectors to analyze CO_2 and other gas components with high sensitivity. This compact catalytic reactor can simplify complex gas chromatography systems and can be used for the simultaneous analysis of greenhouse gases, impurity analysis of hydrogen fuel, and other applications.

Cavity ring-down spectrometry (CRDS) is a technique that dramatically increases the detection sensitivity of laser absorption spectrometry and enables high-sensitivity analysis of ^{14}C, a radioactive isotope of carbon. The laser wavelength and cavity length were of a CRDS system stabilized and a low-temperature ring-down cavity was developed to enable the accurate identification of very low levels of non-fossil derived carbon in raw materials. The ability to easily and accurately determine how much of a material is derived from biomass resources will aid in the transition away from fossil resources and in reducing CO_2 emissions.

3. Affordable and Clean Energy (SDG 7)

Offshore wind power generation is increasingly being adopted as a renewable energy source though reducing costs associated with the operation and maintenance of offshore wind facilities is a major challenge. Underwater communication technology is used to transfer data to surface facilities from autonomous underwater vehicles (AUVs) that can help automate and reduce the labor and costs involved in inspecting offshore wind facilities. An optical-acoustic hybrid underwater communication modem could offer seamless communication across a wide range

of underwater distances by using optical wireless communication for high-capacity data transmission at near and medium distances and switching to acoustic communication for longer distances or when there is significant signal interference from water turbidity or other factors.

While the market for ceramics used in power modules for electric vehicles (EVs) and other applications is forecast to continue to grow, massive amounts of energy are consumed in producing these ceramics. This Special Issue presents Shimadzu's work on reducing power consumption and improving productivity during ceramics production by developing a dewaxing furnace that uses a gas monitoring system and superheated steam to improve heating rates. This technology improves the energy efficiency of ceramic production and also helps accelerate clean energy adoption through the use of EVs.

Blue direct diode lasers, which have an excellent light absorption rate for copper, are starting to be used in the processing of motor coils and battery electrodes for EVs. Shimadzu has developed a blue direct diode laser light source with the world's highest output power of 6 kW equipped with technology that adjusts the irradiating beam shape to match the processing target. This technology promises to enable energy-efficient welding and help improve efficiency and increase quality in EV production.

4. Responsible Consumption and Production (SDG 12)

Microplastics (MPs) have become a major source of environmental pollution and there is a growing need for qualitative and quantitative microplastic analysis. Shimadzu's microplastic automatic preparation device was developed to meet Japan's Ministry of the Environment guidelines and can isolate MPs from environmental samples with a high degree of reproducibility. This device will aid fact-finding surveys of pollution and help initiatives aimed at reducing the environmental impact of plastic products across their entire product life-cycle.

Mechanoluminescent materials are ceramic particles that repeatedly emit light in response to external mechanical stimuli. When combined with specific optical filters and image processing technology, these ceramic particles can be used to observe ongoing mechanoluminescent phenomena. This can be used to visualize signs of failure during fatigue failure testing of 3D-printed metal components, an application that can help improve quality control, predict the lifespan of products, and eliminate wastage from the manufacturing process.

Reducing the carbon footprint and energy consumption of products is becoming an increasingly important component of efforts aimed at mitigating climate change and achieving a circular economy. Since 2010, Shimadzu has awarded the "Eco-Products Plus" in-house accreditation to environmentally-friendly products. This Special Issue presents the history behind this accreditation, its significance, impact, and future prospects. The "Eco-Products Plus" initiative helps promote sustainable product development, efficient use of resources, and environmental conservation.

5. Industry, Innovation and Infrastructure (SDG 9)

Optical lattice clocks are highly accurate clocks 1000 times more accurate than cesium atomic clocks. Optical lattice clocks can be used to create time standards and as a master clock for high-speed communication in the next generation of industry infrastructure. Clocks with this degree of accuracy can also measure minute differences in height based on relativistic effects and could be used to measure deformation of the earth's crust among other applications. A prototype transportable strontium optical lattice clock was developed that is just one-third the size of a previous clock and offers substantial improvements in reliability and maintenance.

Finally, this Special Issue presents a compact, all-in-one mass spectrometry system. This system offers easy ionization of both liquid and solid samples and simple operation with a touchscreen interface and compound identification algorithms. The technology in this system will widen the applications for mass spectrometers to include organic synthesis monitoring, public safety inspections, and production process control, and promises to strengthen technological innovation and infrastructure in industry and education.

6. Conclusions

The social implementation and widespread adoption of the technologies presented in this Special Issue is an important step on the path to achieving a sustainable society. Nevertheless, a long journey awaits that requires the unceasing encouragement of even greater technological innovation. Pursuing these new technologies and their social adoption through open innovation also promises to be critical for building human society that thrives in harmony with the environment. We hope that Shimadzu's leading-edge technology will play an important role in this effort and pave the way for a more environmentally friendly future.