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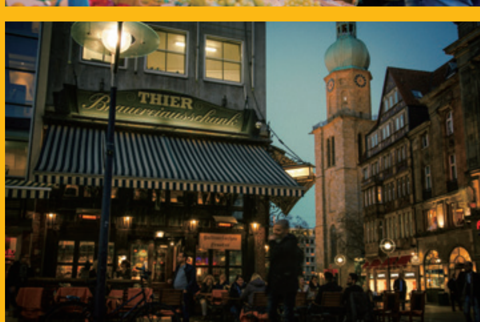
COVER

Dortmund

Germany

Dortmund is the town in the middle western part of Germany. In the old days as a free city of the Hanseatic League, and after the war "town of iron and coal" has supported the German steel industry. There are also many tourist attractions including historic churches, excellent art museums, etc. It is now widely known as the Bundes League's strong team "Borussia Dortmund", and the best beer factory in Germany.



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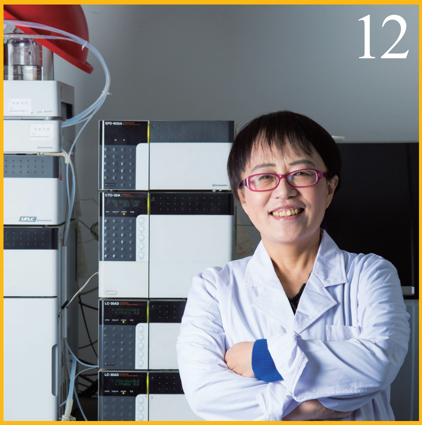

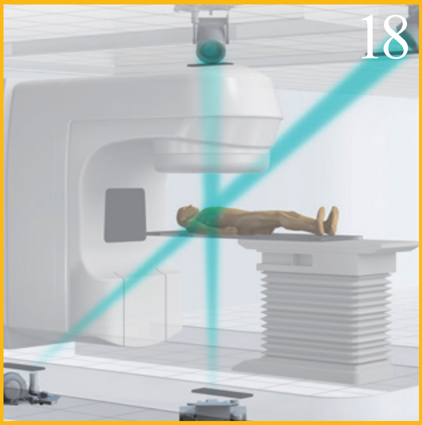

Frontiers in Materials Test Engineering

Spotlight on the work at TU Dortmund University, Germany

Shimadzu don’t just take on new customers, but long-lasting partnerships. The success of the collaboration owes also to the proximity of TU Dortmund University and European Shimadzu headquarter in Duisburg just 50 km away. Shimadzu has a longstanding reputation in materials testing products and celebrate their 100th anniversary in 2017.

Prof. Dr.-Ing. Frank Walther

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The research career of Prof. Dr. Frank Walther, Head of the Department of Materials Test Engineering (WPT) at TU Dortmund University in Germany, had begun studying the material properties of steels for applications in high-speed railway system during his PhD, and as his career progressed his focus expanded towards investigations of steels for other application areas as well as metal- and polymer-based lightweight materials and structures. "There is increasing interest in lightweight potential," adds Walther, referring to various strands of research and development aimed at producing materials with competitive strength properties at a fraction of the mass.

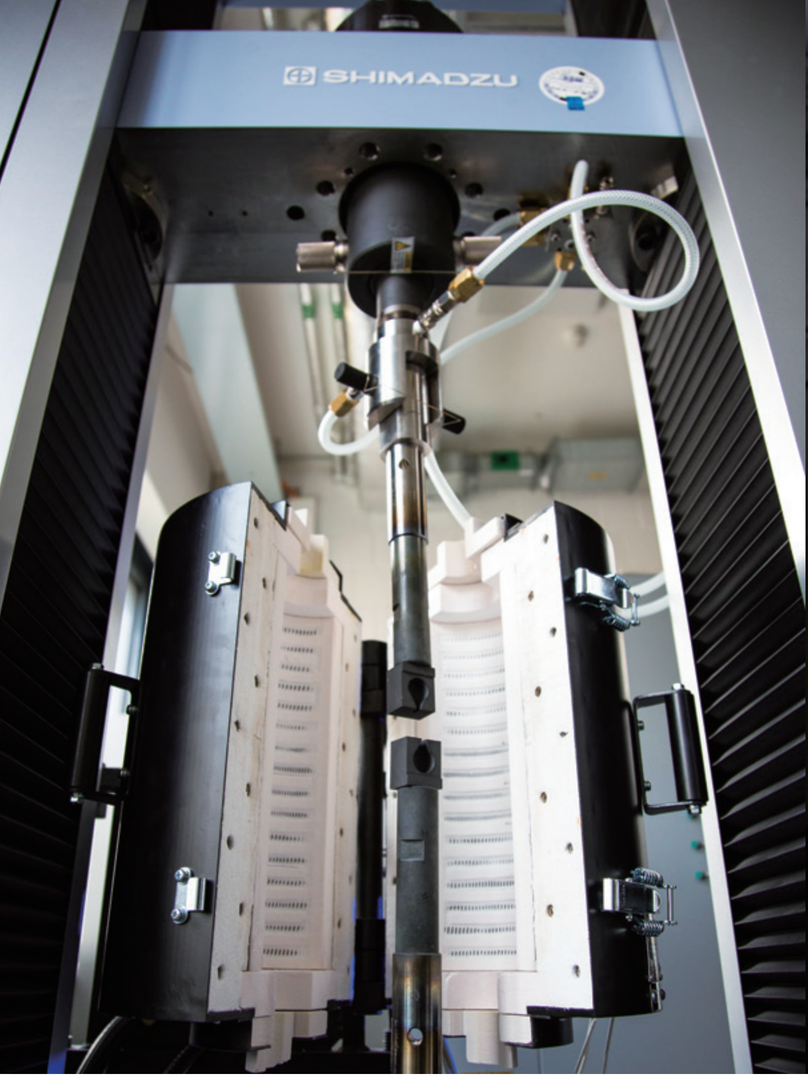
Moving to TU Dortmund University in Dec. 2010 he began to hunt around for companies who could provide the equipment he needed to kit out his labs, almost from scratch. "Shimadzu was an innovative partner with interests in academia and industry – and also interested and open for future developments," says Walther.

The first piece of Shimadzu equipment Walther's group worked on was in tensile testing – establishing the maximum load a material can withstand before it fails. Yield and tensile strengths are important properties for evaluating reliability, providing a basis for calculations of components and constructions, particularly when the material is being used in a situation where it will be prone to extreme loading.

However in some applications the size of the load a material can bear quasi-statically is not as relevant as the number of cycles a material is subjected to with a specific load or resulting deformation. Fatigue testing measures the material's resilience to multiple cycles of loading and deformation before failing, and has long been a key aspect of research at WPT. Fatigue testing is also an important aspect of Shimadzu's product range.

There are four research groups at the Department of Materials Test Engineering focused on 1/ Steels led by senior engineer Dr. Marina Knyazeva, 2./ Light Metals led by Philipp Wittke, 3./ Additive Manufacturing led by Jochen Tenkamp and 4./ Composites led by senior engineer Daniel Hülsbusch. Research in all of these groups is geared towards understanding the process-structure-property relationships of materials and components.

"We know that the structure is like the fingerprint of the properties and we are interested in the prediction of local properties and lifetimes based on an enhanced understanding on process-chain influence," says Walther. "In running research and industry projects we investigate highly diverse low- and high-alloyed steel, aluminium, magnesium, titanium, as well as polymer-based and renewable material systems, also in form of coupled hybrid structures".



Case study:
Testing lightweight materials for energy efficiency

There are several applications in automobile and aerospace as well as in biomedical industries shaping the research conducted in the department. Examples include tensile and fatigue testing of the biomechanical properties of Cottonid – an innovative cellulose-based renewable material with temperature and moisture responses that make it useful as an adaptive element – to the development of a laser additive manufacturing process and fatigue lifetime testing technique for high-strength aluminium alloys for aerospace industry. Many projects rely on Shimadzu equipment.

In steels testing, the applications for automobile and railways, power plants and bridge constructions industries remain a key focus, and as Knyazeva points out, a main aspect of current projects in steels is energy. “Now we have a situation where new demands on energy and cost savings during operation exist, leading to higher requirements regarding material properties to accommodate social obligations, as well as light and safe constructions.” These energy considerations are also significant in alloyed metals and composites research.

The “low carbon economy” objective of the EU climate and energy package 2050 has been described as one of the biggest challenges for transportation and energy industries, so approaches that can reduce emissions have attracted a lot of interest. In recent work Walther, Hülsbusch and colleagues from academia and industry in Germany, Austria and Switzerland developed glass-fibre-reinforced polyurethane (GFR-PU) and compared their mechanical properties to glass-fibre-reinforced epoxy (GFR-EP). These composites have attracted interest for automobile and aerospace applications because of their lightweight potential, which can contribute towards reducing CO^2 emissions.

Mechanical failure in composites is dominated by gradual degradation as opposed to local crack initiation and propagation, which places additional emphasis on the importance of fatigue testing. GFR-EP has already been investigated for fatigue loading, whereas no studies are known for GFR-PU, despite some of polyurethane’s mechanical advantages in terms of tensile strength and fracture strain in comparisons of the pure resins.

The researchers developed together an energy-efficient aerospace industry-compatible high-pressure resin transfer moulding process for manufacturing the GFRs for mechanical investigation at operation-relevant temperatures from -30 °C to +70 °C. Much of the work comparing the mechanical properties of GFR-EP and GFR-PU, including tensile tests and evaluation of compression

after impact (CAI) tests was obtained using Shimadzu AG-X Plus testing systems which provide stress and strain control optimised for steel, plastics and ceramics industries. It also allows short test cycle times and ultrafast sampling to capture sudden changes, such as those found during brittle failure. Strain measurements were obtained optically using Shimadzu TRViewX system, a non-contact tool for avoiding damage to specimens during measurement, which is also compatible with testing under environmental conditions in thermostatic or humidity chambers.

The investigations confirmed the validity of the manufacturing process devised. GFR-PU showed outstanding damage tolerance and in addition comparative characteristics with GFR-EP although improvements to the manufacturing process to diminish the formation of voids in the composite and some chemical adjustments to increase the glass transition temperature are needed to improve mechanical performance at high temperatures.

Destructive testing with non-destructive and analytic extensions

"We know that destructive testing only – for example, conventional tensile testing for strength and fatigue testing for lifetime – is not expedient," says Walther. "We need to couple with advanced non-destructive testing and competences in analytical fields." The arsenal of characterization techniques includes process- and product-optimized strain, temperature, resistance, magnetic, optical and acoustic measurement techniques as well as correlated light and scanning electron microscopy (SEM) and computed tomography (CT) including modules for in-situ loading.

"The combination of destructive and non-destructive inspection methods provides important information about the physics of processing and operation loads and their effect on properties," says Knyazeva. "For understanding the basic mechanisms we also use analytic features that allow us to track the evolution of damage on different scales, tracking changes of microstructure, crack initiation and propagation."

Analytical tools has been another core strength of the Shimadzu product portfolio, and allow real-time characterization of systems under test. One example is energy-dispersive X-ray analysis (EDX), which probes the electromagnetic spectrum of different elements in a sample or component for chemical characterization. Another widely used analytical tool is Fourier transform infrared (FTIR) spectroscopy, which can identify changes in chemical composition of polymers to track aging. "For example, in polymer implants the oxidation index is important as an index of ag-

ing," says Walther.
"On the basis of environmental fatigue investigations we can predict the performance capability and lifetime of implants and assess how long things will last in the body." Studies of this kind at TU Dortmund University have highlighted the promise for biomimetic applications of nanostructured ultra-high-molecular-weight polyethylene (UHMWPE) which has a shape-memory effect. There is also an ongoing study, which will be carried out in synthetic human plasma.

Case study: Combined destructive and non-destructive inspection (DI/NDI)

Daniel Hülsbusch describes the focus on deformation and damage mechanisms and development in additively manufactured (AM) structures and composites. "We determine the complete damage process and separate the damage mechanisms in order to enable lifetime assessment and prediction in applications oriented for automobile and aerospace industries, and combine the knowledge of deformation behaviour with the influence of process chain parameters and service conditions, especially low and elevated temperatures and humidity."

This coupled research approach is applicable across the groups in WPT department. For example, Walther and colleagues at TU Dortmund University have made extensive studies into how processing techniques affect the material microstructure and resulting mechanical behaviour and performance of aluminium alloys. Weight reduction in transportation industries can also help towards increasing maximum velocities as well as reducing fuel consumption. The low-density and good machining opportunities of aluminium alloys make them particularly attractive.
The researchers tested the fatigue behaviour of the aluminium wrought alloy EN AW-6060 using continuous load increase testing procedure and investigated the microstructure from various common manufacturing techniques. These include thread cutting, thread forming and thread milling in rolled flat specimens compared to extruded bulk materials. The researchers used Shimadzu EDX-720-P energy-dispersive X-ray fluorescence spectrometer to detect the chemical composition of processed alloys and determined the grain sizes by counting the number of grain boundary intercepts in micrographs. The fatigue resilience of the formed thread proved to be so outstanding that at the force amplitude of 3.5 kN endured the number of cycles before failure approached close to 10^7.
Once again key to tensile testing was Shimadzu AG-X plus test-

ing system and Shimadzu TRViewX integrated high-accuracy video extensometer for strain measurements. For fatigue testing Shimadzu servopulser systems of EHF-E and -U series with accessories are available. Additionally, chambers for superimposed temperature and humidity conditions to be integrated in the testing systems allow the researchers to validate their results with real operation conditions.

The study revealed that thread machining processes were both time- and cost-efficient, and highlights important process-structure-property relationships. The most favourable behaviour was found in formed threads, with cut threads fared worse due to uneven thread cuts. They were also able to present a short-time fatigue testing procedure despite the high cycle endurance of the materials, which results in significantly reduced time and cost efforts.

Milestones in tools enhanced: very high cycle fatigue testing

The ultrasonic fatigue testing system USF-2000 allows fatigue testing at ultrasonic frequencies of 20 kHz. This makes it possible to test the material's response until 10^7 cycles processing in just 10 minutes and up to 10^{10} cycles can be tested over 6 days. The WPT researchers were the first users of USF-2000 system in Germany.

If the cycle is from a stress in one direction to an equal stress in the opposite direction – such as equal tensile and compressive loads – that load ratio is -1. However, this does not always reflect the stress materials undergo during operation, which may go from low to high stresses in the same direction. "The USF-2000 in standard configuration is qualified for fully reversed loading, that means load ratio of -1," says Walther. "To accomplish requirements with superimposed mean loads, the new USF-2000A system in mean stress loading configuration was developed by Shimadzu." "We were impressed by the efforts of Shimadzu regarding this work, lots of innovative devices especially for composites were developed," says Hülsbusch.

Milestone achievements: high-speed camera

Another important issue is the HPV-X high-speed camera, which shed light on the deformation and abrupt fracture behaviour e.g. of wood, vulcanised fibre and carbon-fibre-reinforced plastics (CFRP). Although other mechanical properties of these materials have been well studied, their failure mechanisms had so far eluded investigation. In collaboration with Shimadzu the TU Dortmund researchers were able to correlate digital images of the process to capture the evolution of high-speed deformations and fractures in these materials.

The approach required a highly demanding image capture rate – 250,000 frames per second for wood and vulcanised fibre and as much as 2,000,000 frames per second for CFRP. Together they identified a signal processing bottle neck in the image capture speeds in the conversion of the light incident on the photodiode from an analogous electric charge to a digital signal. Triggering the image capture was also non trivial. An acoustical microphone was found to be the simplest and most reliable means of triggering image capture for wood and vulcanised fibre. However with the fast fracture rate of CFRP the finite speed of sound became a limiting factor for this approach. Instead the TU Dortmund researchers applied a conductive silver lacquer to the specimen surface as part of an electrical circuit. At the moment of fracture, the circuit opened triggering image capture.

The investigations showed that both wood and vulcanised fibre composite exhibit significant orientation dependence in tensile strength and deformation and fracture behaviour, respectively. Because of the excellent quality of research results they were published together in a peer-reviewed paper.

CFRP had far greater tensile strength than both – 20 times that of wood and 40 times that of vulcanised fibre – but it was highly brittle with almost no deformation before sudden fracture. With the data collected the researchers were able to explain this high brittle characteristic in terms of material's process-structure-property relationship. Under strain first a small bundle of fibres would succumb to damage leaving the full load to be carried on the remaining fibres, leading to sudden fracture.

Wider community and outlook

As well as the benefit to the materials testing community from the enhanced tools developed, TU Dortmund University also deliver a conference to bring the community together. "The Dortmunder Werkstoff-Forum is a conference and exhibition," says Hülsbusch, "where we and invited speakers present results derived from actual research in academia and industry, but the conference also underlines the outstanding appearance of Shimadzu since they are premium sponsor." He adds in praise of the company's great booth and staff presence. The event takes place every two years at TU Dortmund University and provides a valuable networking opportunity for the materials testing research community with around 120 participants and 10 exhibitors.

The field faces several challenges for future work. "The time between the releases of different car models is decreasing," points out Hülsbusch. "So for materials testing we need to improve standard procedures and develop new testing methods for time and

cost efficiency."

Walther also highlights how multi-material design and the development of heterogeneous materials with gradient structures introduce more complex loading histories, and the need to monitor an increasing number of parameters for process chain and local property optimization. Ultimately the WPT team aim to be able to predict local properties and lifetime of heterogeneous material complexes based on microstructure, deformation and failure mechanisms identified through destructive, non-destructive and analytical work.

"To summarise we have two main goals," says Walther. "The basic understanding of the deformation behaviour under service-relevant testing conditions in order to use in the context of lightweight construction and energy efficiency, and the development of new coupled destructive, non-destructive and analytical investigation strategies for reduction of testing time and costs, accelerated testing, and instrumented in-situ testing."

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A vigil eye on persistent organic pollutants

Analytical chemist Dr Yeru Huang and colleagues at one of China's premier research centers is collaborating with the United Nations, and Shimadzu Corporation to monitor and reduce environmental pollution.



In 2001 the Stockholm Convention on Persistent Organic Pollutants (POPs) was established with the aim of protecting human health as well as the environment by reducing or avoiding the release of dangerous substances into air, soil, water, and other media. The Convention initially identified twelve 'legacy' POPs that were used and produced in past decades and are now banned or restricted globally; a procedure was also put in place for new substances to be added to the existing list of POPs. As their name indicates, persistent organic pollutants are chemicals with toxic properties that do not degrade in the environment, and for this reason can accumulate in biological tissues and through food chains with the potential of long-range transport across national boundaries.

In general POPs can be grouped into three main categories: pesticides for agricultural activities, industrial chemicals, and substances generated unintentionally as a result of chemical reactions or incomplete combustion. Examples of 'legacy' pollutants are aldrin, chlordane, dichlorodiphenyltrichloroethane (commonly known as DDT), hexachlorobenzene and toxaphene. In order to evaluate the effectiveness of the Stockholm Convention as a tool for reducing the negative effects of POPs on human health, wildlife and the environment, a global monitoring plan that supports the collection of comparable and consistent data on the presence and distribution of POPs is of paramount importance. This monitoring plan involves of all five United Nations Regions, with the Asia-Pacific Region including Japan and China.

Scientifically monitoring the environment requires reliable methodology and instrumentation. Now, chromatography is an analytic technique that allows for the identification of a large number of chemical compounds in a given sample. Combined with suitable detector technology, a chromatograph can isolate very small amounts of a toxic substance in the context of environmental monitoring of persistent pollutants. The fundamental components of a chromatograph consist of a column housing the so-called stationary phase, a mobile phase that carries the sample to the column, and a detector. If the mobile phase is a gas (and the stationary phase is a high-boiling-point liquid adsorbed onto a solid, for example), the technique is known as gas chromatography (GC). Alternatively, both stationary and mobile phases can be in liquid form. For GC, the column is contained in an oven where the sample in injected, and because of the high temperature inside the oven, the sample boils and is carried into the column by the mobile phase. A molecule injected into the column can condense on the stationary phase, dissolve on the surface of the stationary phase or remain in gaseous form. Importantly, either way, GC makes it possible to identify various chemical compounds by recording the retention times of substances present in a sample, that is, the time taken by the compounds to travel through the column and reach the detector. The output from the detector is a series of time-resolved peaks, each corresponding to a substance found in the studied sample. Chromatography can be successfully interfaced with mass spectrometry (MS), which is a technique used to detect gives mass and charge ratio of molecular fragmentation, to provide a valuable analysis tool.

International collaborative effort against persistent pollutants

Dr Yeru Huang applies her background in analytical chemistry to the study of environmental pollutants. As a graduate student at the Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences in China, she specialized in techniques such as GC hyphenated with microwave induced plasma atomic emission spectrometry (GC-MIP-AES). When she moved to Japan to work as a researcher at the National Institute of Environmental Studies, she turned to toxic chemicals and gained extensive experience with laser-ablation inductively coupled plasma mass spectrometry and ion chromatography. Dr Huang later returned to China to take a position as a research scientist at the National Research Center for Environmental Analysis and Measurement (NRCEAM). She has worked at the Center for 21 years now, and her activities – supported by Shimadzu Corporation– are at the forefront of research on POPs.

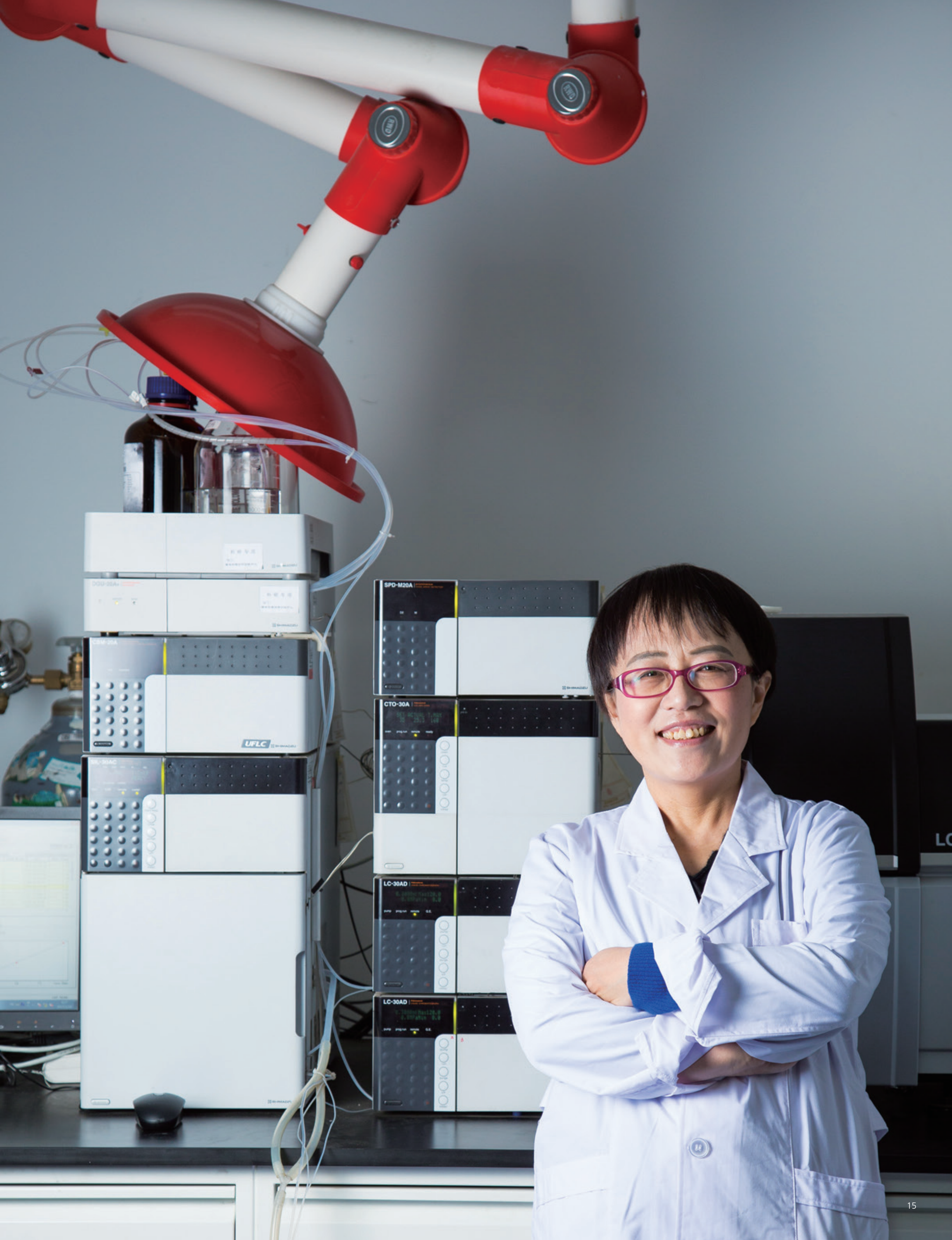
"NRCEAM was established in 1984 under the Ministry of Environmental Protection," explains Dr Huang. "Currently 45 people are employed by the Center, and our work can be split into three categories. One responds to a direct mandate from the Ministry of Environmental Protection for monitoring national environmental pollutants such as POPs, mercury, dioxin and heavy metals. A second category encompasses our research projects, mainly on POPs and dioxin. POPs have been our focus since 2002." A third activity requires the Center to offer its services to the public, companies, research institutes or local environmental agencies. For example, Dr Huang and co-workers have been monitoring emission of municipal waste incineration. "It is our duty to educate the general public about environmental protection," she adds.

The work of Dr Huang illustrates how collaborations with other institutes and universities as well as with dynamic companies such as Shimadzu Corporation can advance and support the environmental monitoring of POPs on both a national and international scale. Indeed, Dr Huang and her colleagues have been working with the United Nations University (UNU) , now United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS) in Japan since 1996, and both NRCEAM and the UNU rely on Shimadzu's equipment and technical expertise.

With the project 'Environmental Monitoring and Governance in the Asian Coastal Hydrosphere', now in its 21st year, the UNU-IAS aims at providing ten Asian countries with the scientific knowledge and technology to monitor new POPs in the environment. Notably, the project has recently focused on rivers and coastal areas to estimate the levels of perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) in water samples as well as in aquatic biota in that environment.

The objective of the study, in which NRCEAM participates, is to establish whether or not bioaccumulation is present in these areas. The project addresses a pressing issue in China, as the country still counts many products containing PFOA and PFOS. In Dr Huang's view, all research carried out at NRCEAM is the backbone for technical operations on site. "We must be able to apply our results to environmental management nationwide," she observes, and a similar reasoning holds at the global scale. In the context of POPs, the research of Dr Huang aims at developing technical methodologies to sample and analyze toxic chemical compounds, looking at regional pollution characteristics and changes over time. Based on these findings, it is then possible to build standard monitoring protocols to be relayed to local environmental agencies.

Since its conception, the project of the UNU has also evolved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to contribute to the implementation of multilateral environmental agreements such as the Stockholm Convention. In this context, Shimadzu provides all participating countries with laboratory equipment and technical training on several aspects of the chemical analysis that can be carried out with their instrumentation. Dr Huang and her co-workers have been using Shimadzu's equipment since the beginning of their collaboration with the UNU: they have several devices for GC-MS and LC-MS/MS analysis. Now, Shimadzu's state-of-the-art triple quadrupole gas chromatograph mass spectrometer brings in an additional capability, thanks to its high sensitivity which makes non-target screening possible. "Not only does Shimadzu provide high-quality equipment, they also offer comprehensive training courses," says Dr Huang. "For example, an important aspect in organic analysis for environmental samples is sample pre-treatment, which can be a delicate task. To achieve consistent results in the UNU-IAS project, Shimadzu's professionals taught us how to correctly prepare the collected samples for subsequent chemical analysis."

Future of POPs monitoring

The second POPs Monitoring Report for the Asia-Pacific region under the Stockholm Convention was published in March 2015, and it clearly identifies the aspects that must be taken into account in the future for the global monitoring of persistent pollutants to be effective and reliable. While countries such as Japan and China have already provided comprehensive spatial and temporal data on original POPs as well as on newly added ones, it is crucial for as many countries as possible to take the necessary steps to collect analogous data. The first crucial element is to build and strengthen the infrastructure for POPs analysis, ensuring that laboratories can operate in a self-sustainable manner over the long term. Equally important is the need for scientific equipment, analytical methods and calibration tests that meet international scientific standards and existing requirements in terms of quality assurance and quality control. The training programs offered by Shimadzu Corporation in the UNU-IAS project play a pivotal role in addressing the latter aspect, which is fundamental for comparison studies and for mapping long-range transport of POPs.

Dr Huang emphasizes the importance of standardized methodologies and protocols for environmental monitoring of pollutants at the Changzhou Foreign Languages School last year, in the Jiangsu Province in China, which received wide media coverage. "Around December 2015 many students began to feel unwell, showing signs of dermatitis and bronchitis. Parents strongly suspected that these symptoms had something to do with the restoration project of land adjacent the school. We were called on site to investigate the degree of pollution and identify the contaminants. It turned out that the neighboring premises were pre-chemical plants, and some toxic materials for pesticide manufacturing were still buried underground. When the soil was dug up for restoration project, volatile chemicals were released into the air. It was a challenge for us to conduct contaminated soil analysis. We encountered many peculiar organic compounds that needed to be determined, and research is still required to develop a methodology for analyzing these chemical substances. This incident made me realize that there is an urgent need for standard monitoring techniques for environmental management."

In the future, Dr Huang is committed to continuing her studies on POPs, especially the new substances that are added every year to the list of toxic chemicals under the Stockholm Convention. "We need to find out if those substances are present in China, and if so what the effect on the environment might be," she explains. Thinking of the episode that took place at the Changzhou Foreign Language School, Dr Huang plans to work on the development of soil examination techniques while keeping a strong focus on monitoring air pollution. It is important for Shimadzu to maintain its working relationships with researchers such as Dr Huang. The expert technical support and training provided by Shimadzu extend beyond individual research groups and centers, reaching an international scale at which pollution monitoring can truly make a difference and improve the health of the planet and of its inhabitants.

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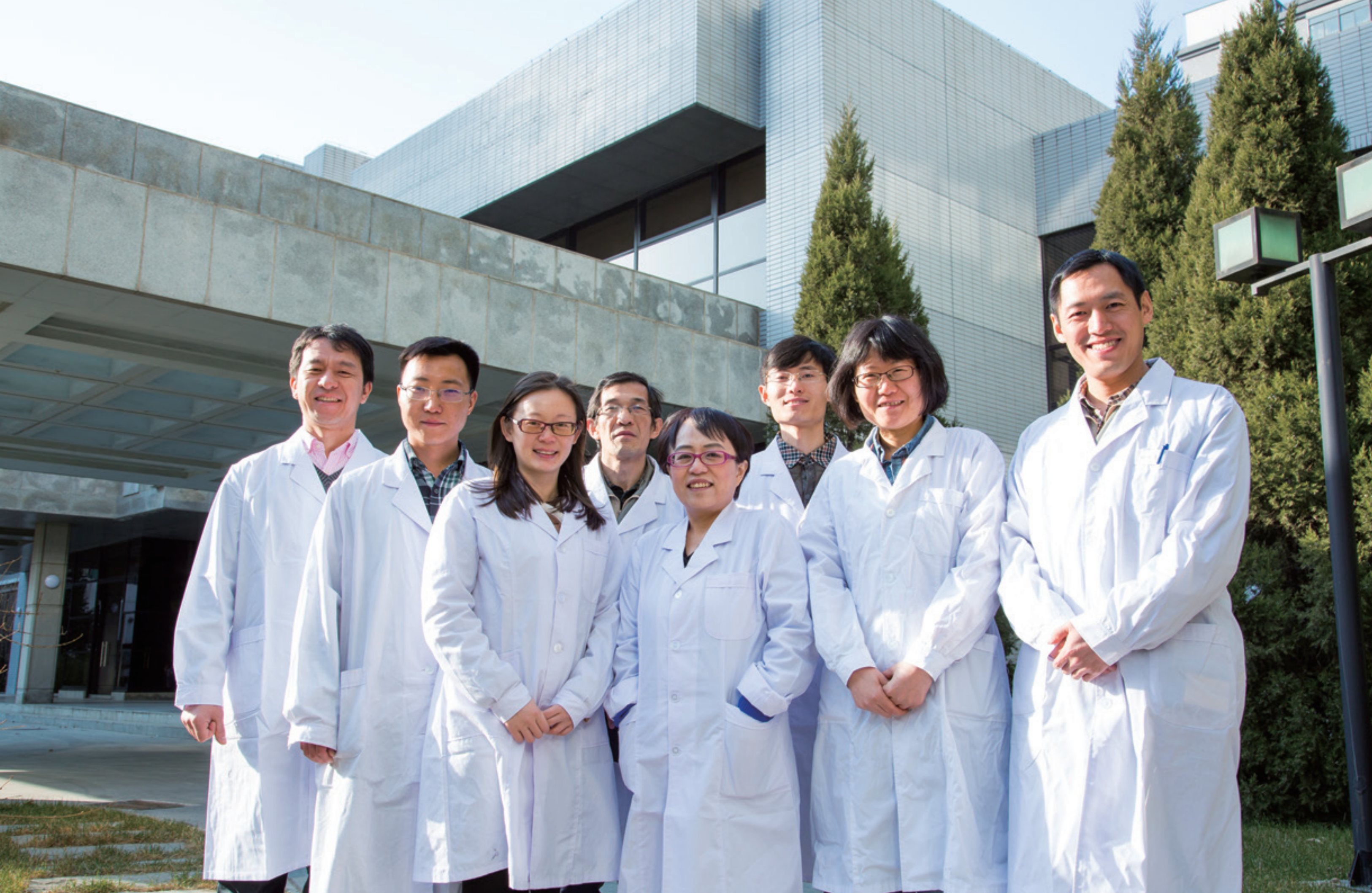


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Shimadzu Analytical & Medical Solutions for Advanced Cancer Research & Treatment

For over 30 years, cancer has been the leading cause of death for Japanese. In addition to measures by the Japanese government to fight cancer, Shimadzu Corporation is also using its various technologies to fight cancer, based on the Shimadzu's corporate philosophy "Contributing to Society through Science and Technology."

Increase in Number of Cancer Patients Due to the Aging Population

According to a recent study, approximately half of current Japanese will experience some sort of cancer (malignant neoplasm) during their lifetime and one third will die of cancer. Cancer has remained the leading cause of death since 1981. Consequently, cancer can truly be called a national disease.

The primary causes include a shift to a Western, meat-centered diet and the low percentage of Japanese who have medical examinations, but it is also caused by the increase in the elderly population. Cancer occurs when genes are copied incorrectly. In healthy young people with a strong immune system, any incorrectly copied genes are eliminated by the body as a foreign substance, but cancerous cells tend to grow more readily in elderly people with a compromised immune system. In 1981, the average life expectancy was 73.79 years for men and 79.13 years for women. In 2015, a little more than 30 years later, the life expectancy increased by about seven years, to 80.79 years for men and 87.05 years for women. Though not conclusive, there seems little doubt that the increase in the elderly population is one factor that is pushing up the relative number of cancer patients.

It also means that cancer is more difficult to prevent and treat than other diseases. Cerebrovascular disease, which was the leading cause of death until the early 1980s, and heart disease, which is consistently among the top three causes, are both lifestyle related diseases that increase with age, but due to the introduction of superior drugs able to dissolve blood clots, catheterization procedures able to expand blocked blood vessels from inside the vessel, and improved diagnostic imaging systems and other technologies that facilitate such procedures, an increasing number of cases are being cured. Of course, cancer treatments are constantly advancing as well, but the increasing number of patients is outpacing such advances.

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Given these circumstances, the Japanese government has frequently implemented measures to address the cancer problem. In 2015, they held a cancer summit, where they formed a plan to accelerate measures to combat cancer in three areas, prevention, treatment/research, and symbiosis, based on a variety of survey results and other considerations. Then, they promoted the implementation of corresponding measures widely throughout society.

Consequently, as an instrument manufacturer that is also involved in healthcare, Shimadzu Corporation has been investing considerable effort in measures to fight cancer. As a pioneer of radiography and other medical X-ray systems and the first in Japan to commercialize such a system over 100 years ago, Shimadzu has steadfastly remained committed to contributing to society through its Medical Systems Division. Furthermore, as Japan's largest analytical and measuring instruments manufacturer, Shimadzu has been involved in advancements in a wide variety of fields, such as environmental testing, foods, and energy. In particular, many of our analytical instruments are used in healthcare fields involving the development of diagnostic or therapeutic drugs, and the scope of applications is expanding.

Shimadzu's activities are not limited to developing technologies, either. In an effort to develop additional ways to contribute to society, Shimadzu has been strengthening its collaborations with academic and research institutions throughout the world in joint research and development projects.

One of the most promising of such efforts to contribute to society is through the ultra early diagnosis of cancer. Cancer originates in epithelial cells of the mucous membrane (stage 0). As it grows, it arrives at the muscle layer (stage 1) and eventually reaches the lymph nodes,

Diagnosis

Positron emission mammography (PEM)

Fluoroscopy

where it becomes more difficult to cure if it metastasizes. On the other hand, if it can be discovered at an early stage, it can often be completely cured.

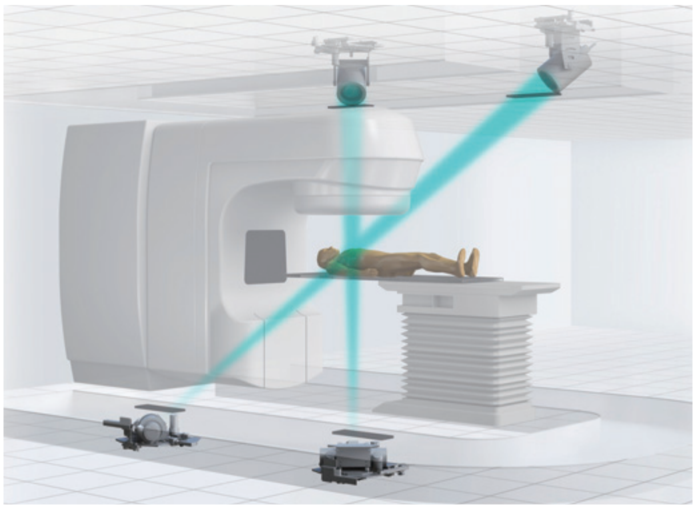
The methods used for ultra early diagnosis are not limited to using medical diagnostic imaging systems and can also involve other analytical instruments as well. One of the techniques involves trying to find indications of cancer by testing the blood or urine for lipids, amino acids, or other metabolites with characteristics that are unique to cancer patients, as compared to healthy individuals. We are already close to the practical use stage for using mass spectrometers, which is capable of more precise analysis than most other analytical instruments, to screen for certain types of colon cancer. In addition, as we have often featured in this publication, we are constantly improving the accuracy of our analytical instruments used by many researchers around the world to research various other techniques as well.

Meanwhile, for cancer treatment applications, in recent years we have been investing in the development of instruments for supporting surgical procedures, such as by commercializing a SyncTraX tumor-tracking radiotherapy system to support procedures involving pinpoint radiation of tumors in organs that move involuntarily.

Similarly, the LIGHTVISION near-infrared light camera system can be used to visualize the lymph ducts and blood vessels below the surface of tissue in real time during surgical procedures. Consequently, it can help improve the success rate and minimize the scope of surgery.

For Shimadzu, whose stated management principle is “Realizing Our Wishes for the Well-being of Both Mankind and the Earth,” contributing to measures for fighting and treating cancer is considered one of our missions. Therefore, Shimadzu remains committed to providing technologies to the world, so that researchers, physicians, technologists, and others throughout the world that are diligently engaged in research aimed at saving as many people from cancer as possible can achieve their goals as soon and in as concrete terms as possible. Today, more than 140 years after Shimadzu Corporation was founded, we still have many missions that we need to fulfill.

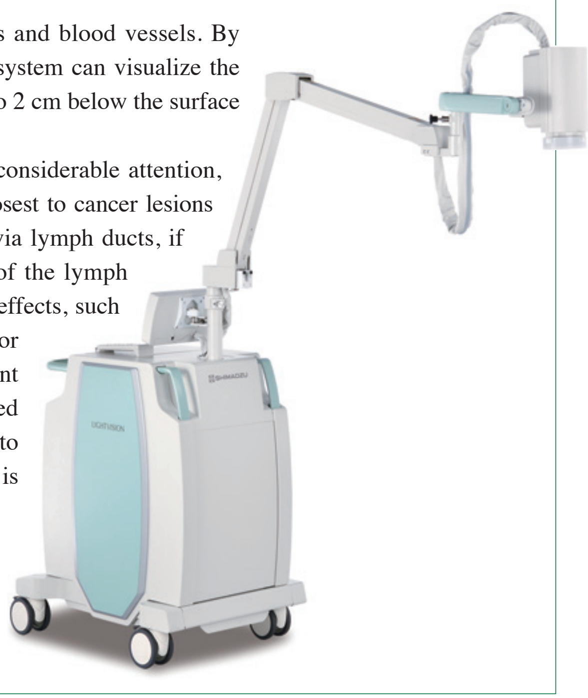
Treatment



X-ray Motion Analysis

Angiography

LIGHTVISION Near-Infrared Camera System Provides Powerful Support for Surgical Procedures



LIGHTVISION is a system that uses near infrared light to visualize lymph ducts and blood vessels. By administering a special drug that emits light in reaction to near infrared light, the system can visualize the drug flowing through lymph ducts and blood vessels located at a depth of roughly 1 to 2 cm below the surface and display the corresponding image on a monitor during surgery.

In recent years, a testing method called sentinel lymph node biopsy has attracted considerable attention, especially for breast cancer surgery. The sentinel lymph node is the lymph node closest to cancer lesions and therefore is often considered a sentinel for cancer. Since cancer metastasizes via lymph ducts, if the biopsy results show no metastasis in the sentinel lymph node, then excision of the lymph node in the armpit (axillary lymph node) can be avoided, which can minimize aftereffects, such as motor impairment or abnormal sensation of the upper arm, edema in the armpit, or swelling of the arm (lymphedema), and which can provide major benefits equivalent to preservation of the breast. Because the sentinel lymph node cannot be identified with the naked eye, dyeing or radioisotope methods have been conventionally used to identify the node, but using the LIGHTVISION system to visualize the lymph duct is expected to enable more reliable identification.

This system is based on Shimadzu analytical instrument technology that was originally used widely in drug discovery research. As needs of the world grow and evolve, Shimadzu's analytical and measuring instrument technology, such as the LIGHTVISION system, has been fully applied in healthcare fields.

100TH ANNIVERSARY
Materials Testing & Inspection

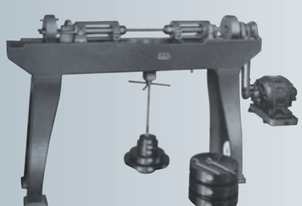
A 100 year History of Shimadzu
Testing machines

Innovation and Collaboration

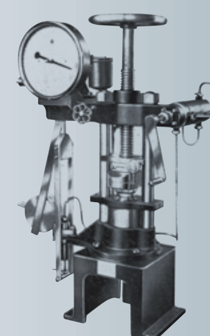
Supporting manufacturing in the future, utilizing 100 years of experience and knowledge

Shimadzu began manufacturing testing equipment in 1917.
Throughout this 100-year history, we have been at the forefront of providing precision, quality solutions for the most challenging R&D and QA/QC requirements.
Our steadfast customer-focused commitment and unwavering dedication to technical excellence are both hallmarks of our history and the principles that guide us into the future.

1917 Started manufacturing material testing machines (fiber and cement testing machines)



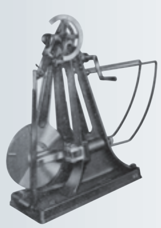
1921 Ono rotary bending fatigue testing machines from about this time



1931 Brinell and Rockwell hardness testers at about this time

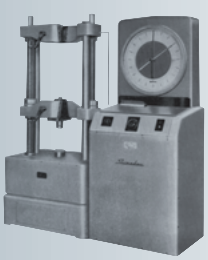
1936 Delivered a 1-t creep testing machine to a steel mill

1947 Developed rubber hardness testers, later adopted in the JIS standards



1950 Charpy impact testing machine

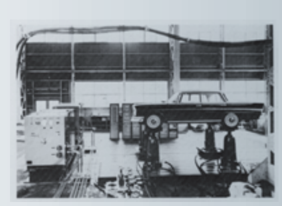
1954 Commercialized the micro Vickers hardness tester



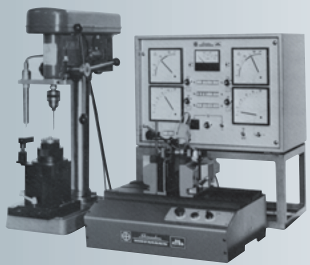
1955 the first hydraulic universal testing machine (RH-10)

1959 the first AUTOGRAPH IS precision universal testing machine

1965 a 500-t structural member testing machine



1967 the first fatigue testing machine (EVH)



Delivered a fully automatic
Charpy testing machine
to a steel manufacturer

1968

1975

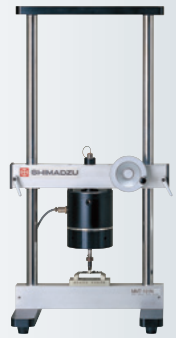
UMH and UEH universal testing machine

the SALD-1000 particle size analyzer

1987

1996

the MMT
microservo

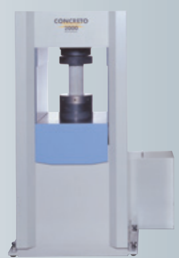


the EZ Test
compact
table-top tester

1997

2001

CONCRETO2000
fully automatic concrete compression
testing machine



MST-I micro AUTOGRAPH
micro strain tester

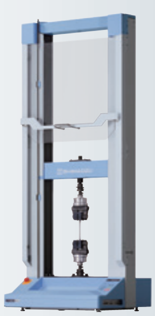
2003

2004

USF-2000
ultrasonic fatigue testing system

AG-X series
AUTOGRAPH

2007



2009

AGS-X series
AUTOGRAPH

UH-X and UH-FX universal testing machine

2011

2012

EZ-X compact table-top tester

HMV-G
micro Vickers
hardness tester

2013

2015

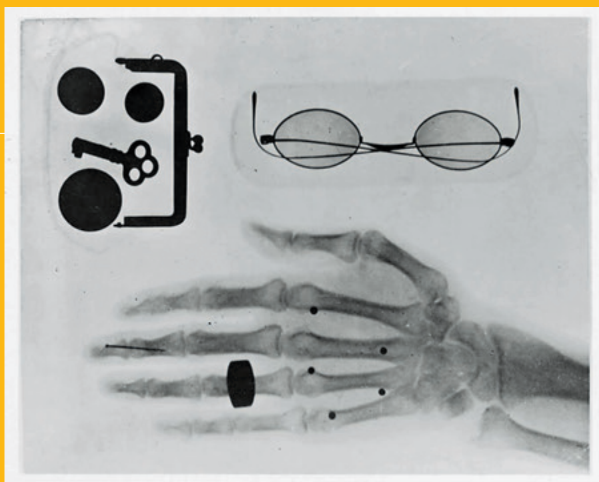
HyperVision
HPV-X2 high-speed video camera

NJ-SERVO series
electric motor-driven actuator

2016

2017

Celebrated 100 years of
testing machine manufacture



Joint Industry-Academia Collaboration Succeeds in Producing an X-Ray Photograph

X-rays were discovered by the German physicist Wilhelm Conrad Roentgen in November 1895. In October of the next year, less than one year later, in a distant island country in the Far East, Professor Hanichi Muraoka of the Daisan Senior High School (predecessor to the current Kyoto University) helped his assistant Sosuke Kasuya, collaborator Genzo Shimadzu Jr., and his brother Genkichi successfully produce an X-ray photograph in the laboratory at Shimadzu Corporation, a company located in Kyoto Japan.

Their initial attempts were a series of failures. Due to low performance capabilities of the battery and induction coil equipment, they could not achieve the necessary voltage levels. Therefore, Professor Muraoka suggested using the Wimshurst electrostatic generator that Genzo Jr. had created previously, which was capable of generating instantaneous voltages up to 200,000 volts. By hanging the vacuum tube from the ceiling with silk thread and turning the generator with an electric motor, they were able to generate a continuous discharge of 200,000 volts for several tens of minutes, which resulted in a faint image of a silver one-yen coin inside a wooden box that was placed on the photographic dry plate. This was the first X-ray image obtained by Shimadzu Corporation.

Later, after improvements to the induction coil and vacuum tube and creating their own fluorescent screen, they were able to produce sharp images. Consequently, Shimadzu started manufacturing and selling educational X-ray apparatuses in 1897. Therefore, Shimadzu was the first to pave the way for the practical use of X-ray systems in Japan. In 1909, Shimadzu developed the first Japanese medical X-ray system, which contributed significantly to the advancement of medical care in Japan.

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