

Support for Use of Tabletop Microscopes in Science Education

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OVERVIEW: The TM3000 tabletop microscope manufactured and marketed by Hitachi High-Technologies Corporation is designed to combine the resolution of an electron microscope with the ease-of-use of an optical microscope. Revolutionizing the conventional idea of an electron microscope, the TM3000 is used in a wide range of fields in Japan and other countries, ranging from the private sector to government agencies, hospitals, science museums, and educational institutions such as elementary or junior high schools. The TM3000 tabletop microscope is also being used to support education in Japan and elsewhere as part of Hitachi's CSR activities. By providing children with an opportunity to experience the micro-world first hand, potentially inspiring them to develop an interest in science, the aim is to help foster people able to work in the science and technology sector.

INTRODUCTION

BASED on the principles and strategies underpinning corporate social responsibility (CSR) activities at Hitachi, Hitachi High-Technologies Corporation and its group companies (the Hitachi High-Tech Group) have selected three specific areas on which they are focusing their own activities. These are: support for science education, protecting the global environment, and regional assistance. In particular, as a science and technology business, the Hitachi High-Tech Group is seeking to make the most of its scientific instruments and other products and technologies to provide support for science education, underpinned by a basic philosophy of creating value through high-tech solutions.

A waning of interest in science and technology has been noted in the youth of Japan in recent times. International comparison studies conducted by the Organisation for Economic Co-operation and Development (OECD) and the International Association for the Evaluation of Educational Achievement (IEA) found that, even among pupils who do well in science, the proportion who enjoy the subject has fallen to a low level. This drift away from science and technology was also corroborated by the analysis of results and survey of questions in the national academic achievement and learning situation survey (national achievement tests) conducted by the Ministry of Education, Culture, Sports, Science and Technology, Japan in elementary and junior high schools during April 2012. This waning

of interest in science and technology by young people has implications for the development of the future workforce for industry. It poses a major challenge not only for Japan but for all developed economies.

Given this reality, the Ministry of Education, Culture, Sports, Science and Technology has been instigating a variety of initiatives since FY2002 under a plan for encouraging interest in science and technology with the aim of making Japan into a nation that is creative in science and technology.

Through the development of the TM3000 tabletop microscope, Hitachi High-Technologies Corporation is helping prevent the waning of interest in science and technology by providing opportunities for the children who are the potential engineers of the future to develop an interest in science.

This article describes how the Hitachi High-Tech Group is using its tabletop microscopes to encourage and support science education.

TM3000 TABLETOP MICROSCOPE

Hitachi High-Technologies Corporation manufactures and markets electron microscopes that are used in applications such as quality control and for a variety of industrial research and development, including in fields such as nanotechnology and biotechnology. It designed the TM3000 tabletop microscope, which was first released in April 2005, to be a leading-edge electron microscope even easier to use and more accessible to people.



Fig. 1—TM3000 Tabletop Microscope.

Because the electron microscope is small enough for tabletop use, there are few restrictions on where it can be installed.

While conventional electron microscopes have demonstrated their effectiveness in fields such as materials analysis that involve high resolution and high definition⁽²⁾, factors such as their somewhat cumbersome specimen preparation requirements mean that, unlike optical microscopes, they are not an instrument that just anyone can use with ease. The TM3000 has a maximum magnification of $\times 30,000$ (more than is available on optical microscopes) and a startup time of only about three minutes (compared to around 20 minutes for previous models). It also features an energy-efficient design that does not require continuous electric supply, supports three observation modes [5-kV mode, 15-kV mode, and high-intensity energy-dispersive X-ray spectrometer (EDX) mode], and is equipped with a number of automatic adjustment functions including auto-start, auto-focus, and auto-brightness/contrast. Operation is also simplified by features such as the image shift function and control buttons.

Because the TM3000 can obtain realistic images with a good depth of focus and higher magnification than an optical microscope, it is used in a wide range of fields such as food, bioscience, semiconductors, and electronics. Also, because even first-time users can familiarize themselves with it quickly, it is also used for educational purposes in schools, science museums, and similar facilities.

The main features of the TM3000, released in 2010, are listed below.

(1) Compact tabletop design means simple installation

The small size of the microscope and the fact that it operates from a standard 100–240 V alternating current (AC) power supply using a three-pin plug mean that there are few restrictions on where it can be located (see Fig. 1).

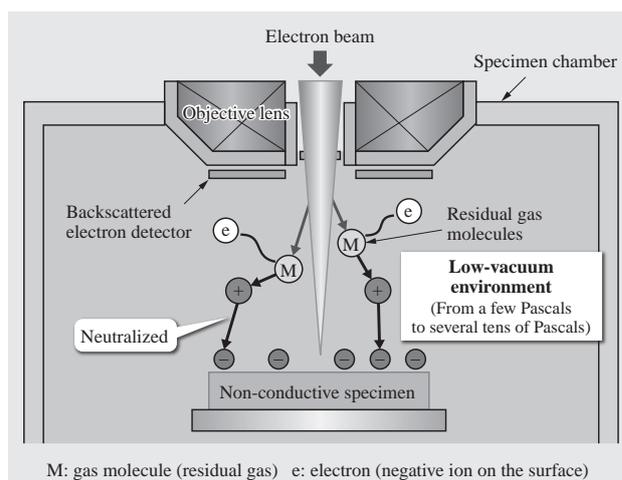


Fig. 2—Principle of Low-vacuum Observation.

A lower level of vacuum in the specimen chamber means more residual gas molecules. Collisions between the electrons and these gas molecules cause them to ionize into positive ions that neutralize the buildup of charge when they reach the specimen surface.

Conventional general-purpose scanning electron microscopes (SEMs) use a condenser lens with an exciting coil to produce a tightly focused electron beam. The TM3000, in contrast, uses a condenser lens with a permanent magnet to reduce weight and power consumption. Similarly, whereas the power supplies in conventional SEMs incorporate a large transformer, the weight of the TM3000 has also been reduced by using a newly developed, compact transformer-less power supply to supply direct current (DC) to the control circuits. This allows the microscope to be made small enough for tabletop installation. The design is also conscious of the environment, using a compact, dry (oil-free) vacuum pump.

(2) Non-conductive specimens do not require special preparation

SEMs obtain an image from the secondary electrons or backscattered electron signal that results from exposing a specimen to an electron beam in a hard vacuum. In the case of non-conductive specimens, however, some of the incident electrons remain in the specimen under the hard vacuum conditions, resulting in a buildup of electric charge (charge-up). This causes image noise and makes it impossible to obtain a crisp image. Normal practice for preventing this phenomenon is to use preparation techniques such as the deposition of metal on the specimen surface. The TM3000, in contrast, minimizes charge-up by using an observation technique that works in a low vacuum and therefore can be used without special specimen preparation (see Fig. 2).



Fig. 3—Screen Shot from TM3000 Tabletop Microscope. The screens are designed to be intuitive and easy to understand, and a full range of automatic functions that can perform adjustments at a single touch makes operation easy and magnification changes smooth.

(3) Simple operation

Hitachi High-Technologies Corporation has developed technology that allows the TM3000 to be used simply by connecting it to the USB port on a personal computer, with intuitive and simple operation screens designed to work in a similar way to a digital camera (see Fig. 3). To make the microscope even easier to use, Hitachi has also improved the speed and accuracy of the automatic functions that adjust the focus, brightness, and other settings at the press of a button. This means that even first-time users find it easy to produce images.

(4) Elemental analysis (option)

Because the TM3000 can be configured as an energy-dispersive X-ray system, it can be used not only to magnify the specimen, but also to determine its elemental composition.

As with conventional imaging, elemental analysis does not require any special specimen preparation (see Fig. 4).

USE OF TABLETOP MICROSCOPES

The Hitachi High-Tech Group has since the 1990s been providing children with the opportunity to experience the micro world using SEMs at its own facilities. Since the release of the TM3000, however, with its compact design, these events have been able to move outside the company.

Loan to Educational and Other Institutions

Since 2008, the Hitachi High-Tech Group has been supplying the TM3000 on loan to support the

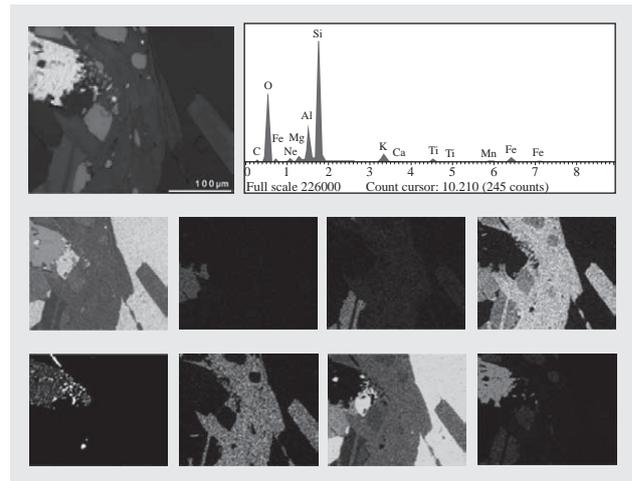


Fig. 4—Example Elemental Analysis of Rock Specimen (Elemental Spectrum and Elemental Distribution Mapping Data).

Analysis of the chemical elements contained in a specimen can also be performed without the need for pre-treatment.

activities of institutions that plan and operate their own educational programs aimed at getting children interested in science.

As of January 2013, regular events that use the TM3000 to provide a hands-on experience of using an electronic microscope are being held at four sites around Japan [the National Museum of Emerging Science and Innovation (Miraikan), Izumo Science Center, the Nagoya University Museum, and The Japan Society of Applied Physics] (see Fig. 5). The Izumo Science Center, for example, is sharing the TM3000 between schools with an interest in enriching and developing science and technology education, particularly those designated as Super Science High



Fig. 5—Tabletop Microscope at the Nagoya University Museum. The Hitachi High-Tech Group supports science and technology education by loaning out tabletop microscopes.

TABLE 1. Events Held during FY2012

Hands-on electron microscopy events using the tabletop microscope were held at the National Museum of Emerging Science and Innovation (Miraikan), Izumo Science Center, Nagoya University Museum, and The Japan Society of Applied Physics.

Institution	Event	Number of participants or visitors
National Museum of Emerging Science and Innovation (Miraikan)	High-Speed Cameras and Microscopes	353
Izumo Science Center	Temporary loan to SSHs and other schools	1,098
Nagoya University Museum	Micro Expedition*	195
The Japan Society of Applied Physics	Fascination of Science that can be Studied for Fun, etc.	1,087

SSH: Super Science High School

* Micro no Tankentai (Micro Expedition) is a registered trademark of Nagoya University.

Schools (SSH) by the Ministry of Education, Culture, Sports, Science and Technology, Japan.

As of February 2013, the total of more than 16,000 participants had been given a chance to experience the thrill of science at these hands-on electron microscopy events held across the different institutions.

Table 1 lists the main events held in FY2012, along with estimates of the number of participants or visitors.

Hands-on Learning Events Involving Radio Program

Another initiative by Hitachi High-Technologies Corporation in support of science education is Masaki Omura's Science Kids, a radio program that has been running since October 2006 (on Nippon Cultural Broadcasting Inc.). Each episode of this science program focuses on a different topic aimed at unlocking a sense of wonder in the children.

Each year during the summer holidays, the program stages a public recording event to allow direct communication with its elementary school children listeners. The events include a hands-on corner where visitors can try using the TM3000 for themselves (see Fig. 6).

Children bring objects from their daily lives, such as household goods, groceries, cloth, plastics, plant material, or insects, and are able to look at them using the TM3000 under guidance by staff from the Hitachi High-Tech Group. This is followed up in subsequent days by activities that make the microscopic world feel even more familiar to them, such as an electron microscope photography competition using the microscope images they obtained.

The questionnaires used to survey participants at each event are full of comments that express their delight at having access to an electron microscope for the first time and their surprise at the high-resolution images.

Participation in STEM Education Programs in USA

Hitachi High Technologies America, Inc. (HTA) is involved with science, technology, engineering, and mathematics (STEM) programs proposed by President Obama for encouraging education in these fields. STEM education is being pursued as a policy that seeks to boost national competitiveness of the USA by developing human resources in the fields of science and technology.

Hitachi, Ltd. is a member of Change the Equation (CTEq), a non-profit organization established to promote STEM education in 2011. As part of Hitachi, HTA provides demonstrations of the TM3000s or loans them out for use at school or science museum events run by CTEq. Currently, 17 TM3000s are available for loan, including units at HTA sales agents, with anywhere between five and 15 in use on any given day. Between September 2011 and January 2013, HTA was involved in education support activities at more than 110 different sites around the country (see Fig. 7 and Fig. 8).

Other educational activities by HTA include seminars and workshops for the teachers who instruct pupils at educational institutions. These provide advice on how to prepare future lessons and programs,



Fig. 6—Hands-on Corner at Event.

Hitachi High-Technologies Corporation sponsors the Science Kids radio program (Nippon Cultural Broadcasting, Inc.) for elementary school children that seeks to foster children's interest in science.



Fig. 7—Support for Education in the USA (from September 2011 to January 2013).

Education support activities by Hitachi High Technologies America, Inc. include loaning TM3000 tabletop microscopes and conducting demonstrations. Such activities have taken place at more than 110 sites to date.

and they cover subjects such as how to operate the TM3000, case studies of successful practical programs and the issues they face, and other data and topics relating to STEM education.

Also, a STEM education website went on-line in August 2012. In addition to posting information about STEM education, the aim is for the site to act as a valuable support tool by providing educational tools and learning modules that use the TM3000, and through the exchange of information and advice between teachers.

Other Activities

In Europe, Hitachi High-Technologies Europe GmbH (HTE) is supporting the nanoTruck project introduced by the German Federal Ministry of Education and Research in 2010 (see Fig. 9).

The nanoTruck project is a trailer containing a variety of small experimental apparatuses and science-related exhibits that visits schools, universities, and other organizations around Germany to demonstrate to the public how nanotechnology relates to their daily lives. Its aims are to boost interest in advanced technology, increase the number of people interested in studying the natural sciences, and eliminate distrust and misunderstanding of nanotechnology.

HTE has endorsed this project, including loaning a TM3000 free of charge, and has collaborated with the project managers to devise a way of installing the TM3000 that retains its performance as the trailer travels around the country. This ensures that it continues to provide people with a chance to experience the nano world for themselves, even inside a vehicle. In doing so, the TM3000 has proved to be



Fig. 8—Science Education Event in Dallas, Texas.

HTA has participated in events run by the US non-profit organization, Change the Equation (CTEq), at schools, science museums, and other venues. Its involvement has included the loan of TM3000s and the conducting of demonstrations.



Fig. 9—nanoTruck with TM3000 Tabletop Microscope.

Hitachi High-Technologies Europe GmbH supplied a TM3000 tabletop microscope to support the nanoTruck project run by the German Federal Ministry of Education and Research.

particularly popular among the nanoTruck's exhibits, with many visitors being moved by the nano-world experience it provides. HTE has also loaned out microscopes in the UK, including to the British Museum and the Natural History Museum.

In the Naka district of Ibaraki Prefecture in Japan where the TM3000 is manufactured, the Hitachi High-Tech Group has complemented its promotion of science education by also running science classes for elementary school children as part of its regional outreach activities (see Fig. 10). At science classes held in December 2012, design staff from the Hitachi High-Tech Group taught children about the differences between optical and electron microscopes, and gave them the opportunity to use these instruments to look at objects such as hair or the eyes and feelers of ants.



Fig. 10—Science Class at Elementary School. The Hitachi High-Tech Group runs science classes for elementary school children as part of its regional outreach activities in the Naka district of Ibaraki Prefecture, Japan where the TM3000 is manufactured.

Experiencing for themselves the expressions of surprise with which the children attending the science classes greeted the electron microscope images reminded the designers afresh of the fascination of microscopy.

Elsewhere, the Hitachi High-Tech Group also accepts invitations to collaborate on external events. In September 2011, the Group cooperated with the British Council, a public international cultural exchange organization from the UK, on the Royal Institution Christmas Lectures. This included the loan of a TM3000 and handling operation on the day at The University of Tokyo (see Fig. 11). The program brought a science experiment program run by The Royal Institution of Great Britain to Japan with the aim of helping provide a rounded education to the young people who are destined to take up the challenges of the 21st century, while also demonstrating why science is fun and interesting. During his presentation, Professor Mark Miodownik, Professor of Materials and Society at the Department of Mechanical Engineering of University College London, utilized the TM3000 in demonstrations and audience-participation experiments, displaying detailed electron microscope images on a screen.

In September 2012, a TM3000 hands-on corner and the public recording of a radio program were included in “Tohoku Miraizukuri Day with Hitachi in Kesenuma,” a traveling event in support of the Tohoku recovery that was organized by Tohoku Hitachi. The event provided an opportunity to mingle with children from the disaster-affected region hit by the Great East Japan Earthquake in 2011.

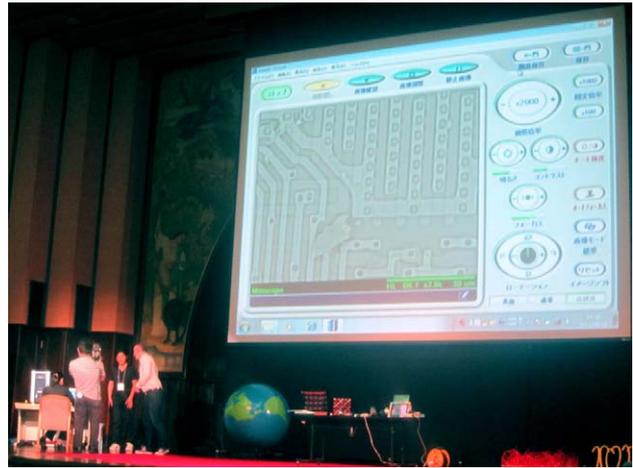


Fig. 11—The Royal Institution Christmas Lectures. The Hitachi High-Tech Group assisted with the Royal Institution Christmas Lectures (organized by the British Council and others) held at The University of Tokyo in September 2011, including the loan of a TM3000 tabletop microscope and handling operation on the day.

CONCLUSIONS

This article has described how the Hitachi High-Tech Group is using its tabletop microscopes to encourage and support science education.

Giving children a chance to view the microscopic world for themselves provides an opportunity to make them feel more comfortable with science, and this has the potential to help foster the people who will advance and develop the high technology of the future. By drawing on these features of its business to make an ongoing contribution, the Hitachi High-Tech Group can fulfill its social responsibilities as a corporate citizen.

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