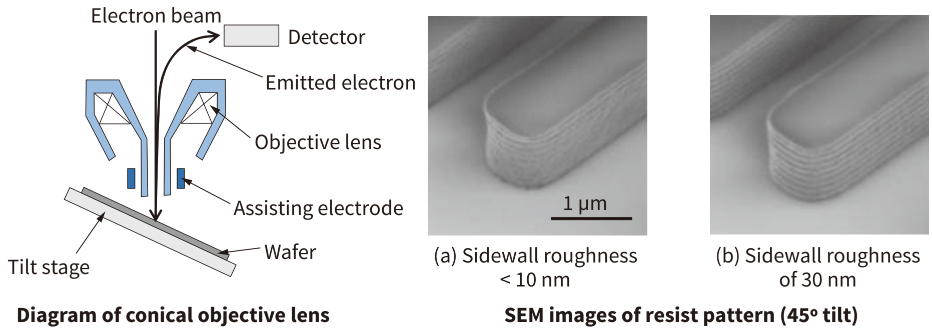
Technology Innovation:
Products



1 Novel objective lens structure and SEM images of resist patterns

1 Tilt-SEM for Observing 3D Shape of Semiconductor Devices

With the advancement of information society, the demand for high-performance and reliability of the Internet of Things (IoT) and automotive devices is rapidly increasing. To ensure the quality of the devices during their fabrication processes, a scanning electron microscope (SEM) capable of in-line three-dimensional (3D) metrology and inspection of fine device structures is important.

Observation of structures from various directions is a good way to visualize their 3D features. To observe an in-line wafer with high resolution and at a large stage tilt angle, an objective lens that has a short focal length and can avoid colliding with the wafer is required. Moreover, shifting in the field-of-view (FOV) when the stage is tilted needs to be kept to a minimum because the operator needs to look for the target pattern again after tilting the stage.

To fulfill these requirements, Hitachi has developed a novel conical objective lens equipped an assisting electrode to achieve high-resolution, large stage tilt of up to 55 degrees, and a small shift in the FOV. Equipped with the novel objective lens, Tilt-SEM, the CT1000 enables observation of fine roughness with an amplitude of a standing wave less than 10 nm formed on the sidewall of resist patterns. It also reduces the shift in FOV caused in optics by tilting the stage to less than 1 μm, which prevents the operator from missing the target pattern.

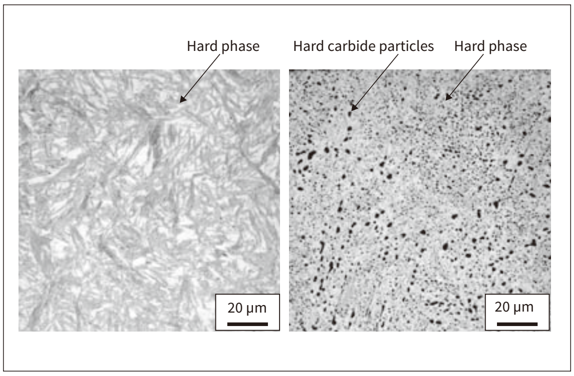
In the future, Hitachi will establish a 3D monitoring method of various semiconductor devices using the Tilt-SEM, thereby contributing to improve the device performances, shorten the turn-around time, and enhance the production yields.

2 Development of High-concentration Carburizing with Benefits for Cost Reduction of Production Process and Lower Load on Environment

Gears are a crucial component of drive mechanisms in construction and other machinery and typically undergo gas carburizing as a means of improving their durability. Unfortunately, productivity is an issue with current carburizing practices, which not only take a number of days to treat large gears, but also require post-treatment. In response, Hitachi has developed a high-concentration vacuum carburizing technique.

By encouraging the infusion of carbon into the surface of the gear and its internal diffusion, the new technique shortens the time taken for carburizing by 35% compared to past practice. It also increases durability five-fold through the precipitation of fine particles of hard carbide near the surface of the gear, thereby avoiding the need for post-treatment.

Another issue with past practice was its use of carbon monoxide (CO) in the carburizing process, making it difficult to reduce emissions of carbon dioxide (CO_2) in production. The new technique, in contrast, avoids this problem and reduces the load on the environment by using a method in which no CO_2 is generated in the reaction.



2 Hardened microstructure of gear

It is anticipated that the technique will be adopted by manufacturing plants in Hitachi's product-related businesses that encompass automotive and industrial equipment as well as construction machinery.

3 Optical Technique for High-resolution Measurement of Particle Size Distribution of Sub-micron Particles

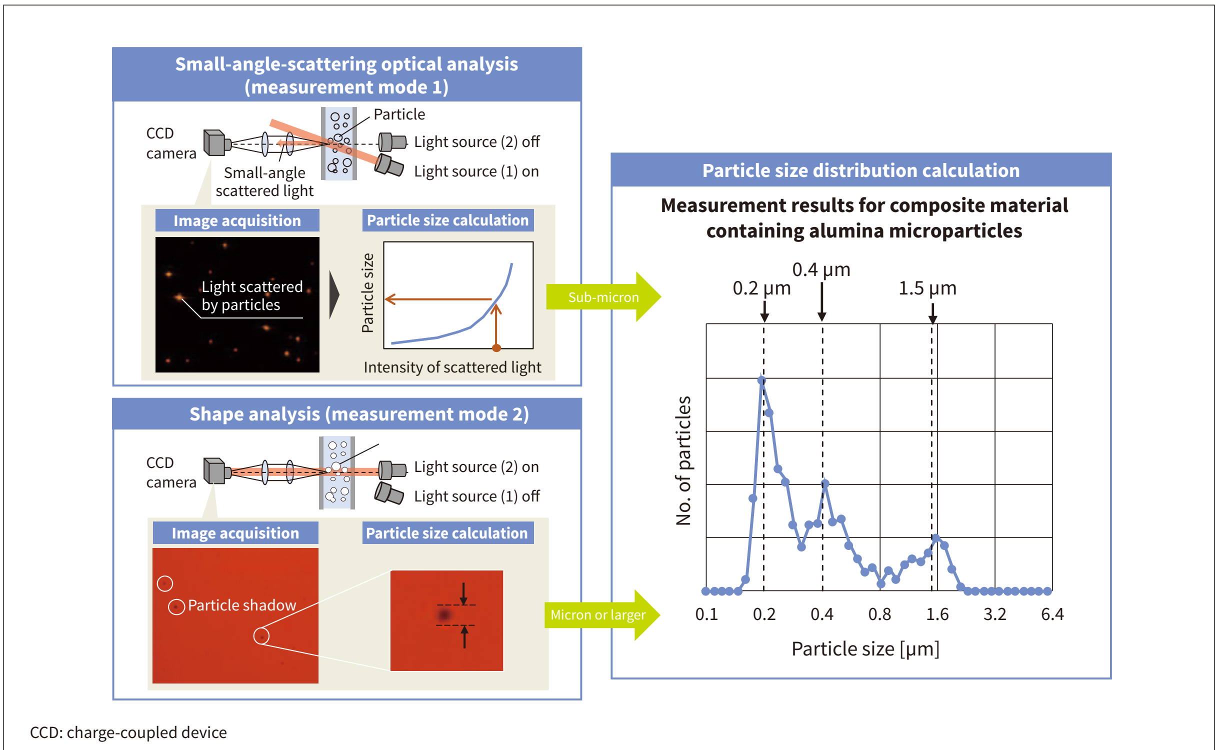
There is a need for reforms to manufacturing that maximize productivity without relying on the experience of expert personnel. Hitachi has been working on the use of technologies such as the IoT and artificial intelligence (AI) to perform automatic control based on measurement data in production processes that involve powdered materials such as ceramics or pharmaceuticals. This has included the development of a high-resolution technique for measuring sub-micron particles that is needed for managing and controlling particle size distribution, an important factor in product quality.

High-resolution measurement of particle size distribution with the ability to identify individual particles in a material was made possible by the development of an optical analysis technique using small-angle scattering capable of measuring the size of individual particles of 1 µm or less, and by combining this with a shape analysis method that can measure the size of particles at the micron order. When used to measure a composite material containing alumina microparticles with mode diameters of 0.2 µm, 0.4 µm, and 1.5 µm, the technique obtained a particle size distribution that correctly resolved the peaks at each diameter mode.

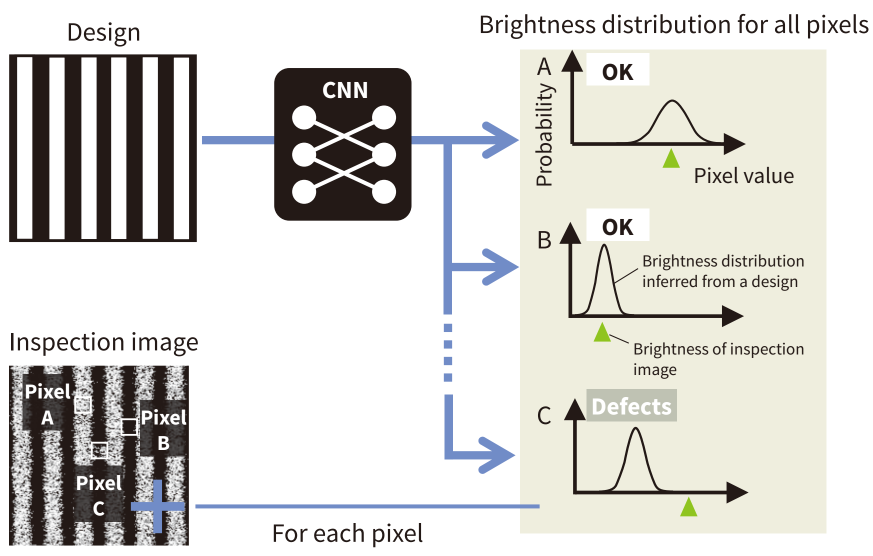
In the future, Hitachi intends to implement automatic process control based on measurement data obtained using this new technique.

4 Deep-learning-based Semiconductor Inspection Technique for Whole-wafer Inspection

The advances in IT devices over recent years and rising data processing throughputs call for further



3 Overview of new high-resolution measurement technique and measurement results for composite material containing alumina microparticles



CNN: convolutional neural network
* Scan image courtesy of imec

4 Image processing using deep learning

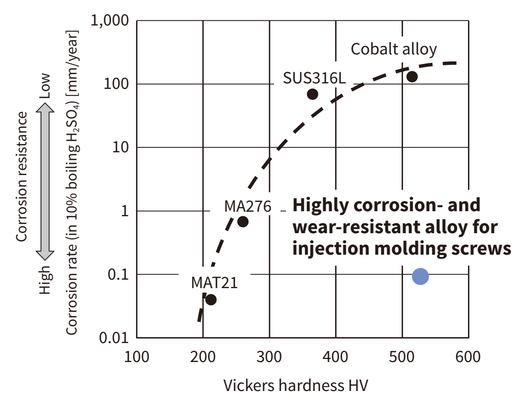
improvements in semiconductor integration density. While the microfabrication of semiconductor manufacturing processes continues to progress, problems have arisen with the random occurrence of very small defects that cannot be detected by conventional optical inspection systems. This has created a need for whole-wafer inspection by SEM. A key challenge for whole-wafer inspection is how to maintain accuracy while increasing inspection speed. To satisfy this requirement, Hitachi has developed a method for highly accurate inspection using low-resolution and wide-angle images that applies deep learning to image processing and scans the whole-wafer at high speed.

Past inspection methods detect defects by determining the differences in shape between the design and the circuit pattern determined from the acquired image. Unfortunately, reducing image resolution to accelerate inspection speed makes it difficult to identify the circuit pattern. This results in frequent misdetection of defects. To solve this issue, Hitachi has developed a new method that compares the acquired image against the brightness distribution obtained from the corresponding design at the same resolution by means of deep learning. This is able to minimize misdetections even at low resolution and achieve accuracy equivalent to past methods using images with a field of view 16 times larger, thereby speeding up inspection time by a factor of 16.

5 Development of Corrosion- and Wear-resistant Alloy for Injection Molding Screws

Because they are exposed to the corrosive gases released by molten plastic and subject to wear due to glass fiber or inorganic filler, the screws used in the injection molding of plastic products need to withstand harsh environments, with high levels of resistance to both corrosion and wear.

In response, Hitachi has developed a highly corrosion- and wear-resistant alloy (carbide-dispersed Ni-Cr-Mo-Ta alloy) that is based on the MAT21 corrosion-resistant alloy of Hitachi Metals, Ltd. Although adding carbon on its own to MAT21 improves wear performance, it



5 Performance of new alloy

also upsets the balance of elements and impairs corrosion performance, causing clumping of the molybdenum carbides that play an important role in corrosion resistance. Along with the addition of carbon, the new material is also alloyed with suitable quantities of other elements that have a stronger tendency to form carbides than molybdenum (including Ti, V, Nb, and Ta). The preferential crystallization of these carbides minimizes the clumping of molybdenum and successfully improves hardness and wear performance without compromising the high corrosion resistance of MAT21.

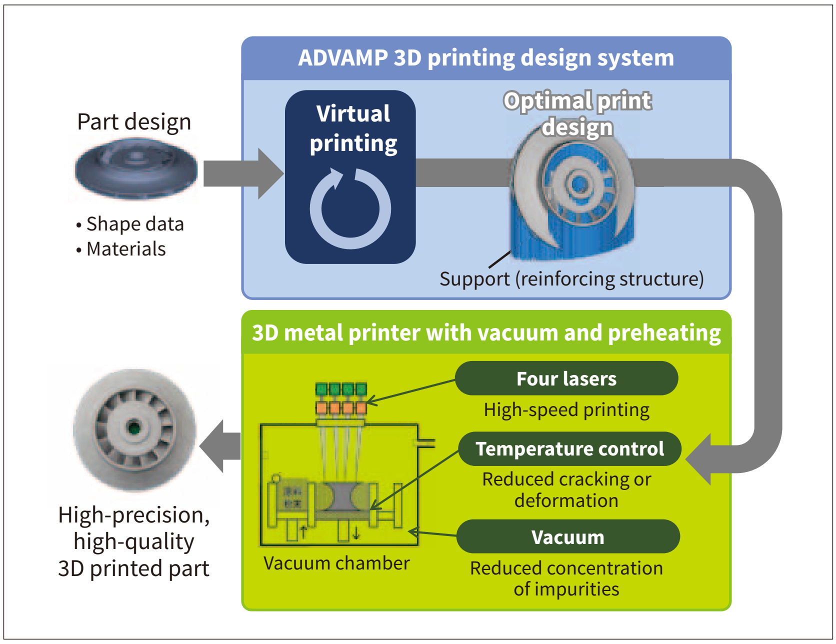
With a view to future commercialization, Hitachi plans to conduct trials to assess how easy the new alloy is to manufacture and how well it performs in use.
(Hitachi, Ltd., Hitachi Metals, Ltd.)

6 Metal Additive Manufacturing Process for Precise, High-quality Fabrication of Complex Part Shapes

Use of metal additive manufacturing has grown rapidly over recent years. This has created a demand for printing process design techniques that utilize 3D printer mechanisms for enhanced part quality together with digital techniques that enable greater precision in part production while also simplifying the work of the designer. In response, Hitachi has developed a metal additive manufacturing process for the precise and high-quality fabrication of parts with complex shapes.

To improve the quality of manufactured parts, Hitachi has developed a 3D printer equipped with a vacuum and preheating mechanism that minimizes contamination and the risk of parts fracturing. Use of the printer enables the fabrication of nickel alloy parts with around 30% less oxide than previous models and the production of tool steel parts without risk of fracture. Hitachi has also developed an additive manufacturing design system (ADVAMP) that can run repeated virtual print runs to deliver an optimal design. When ADVAMP was used to design and manufacture test specimens for deformation testing, it delivered a two-fold improvement in the dimensional accuracy of the parts compared to past manual design, with a 40% reduction in the volume of supporting material.

In the future, Hitachi intends to contribute to innovative manufacturing using additive manufacturing techniques by working with a variety of partners to trial the new techniques in actual practice.



6 Example of metal additive manufacturing using new technique

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