Technology Innovation:
Products

1 Genetic Test for Early and Minimally-invasive Detection of Cancer Recurrence

Liquid biopsies that use samples of blood or other bodily fluids have been getting attention recently as a minimally-invasive technique for detecting cancer. Unlike biopsies that use an endoscope or needle to obtain tumor-tissue samples, liquid biopsies detect a tumor-derived, tiny amount of genes present in blood. As tumor-derived genes have small mutations compared with normal genes, a highly-sensitive method is required for detecting these genetic mutations.

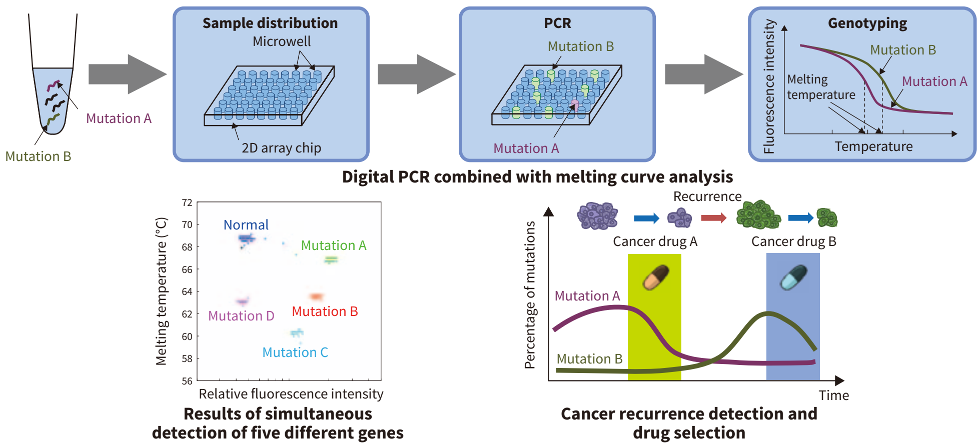
To satisfy the requirement, Hitachi has developed a technique that combines digital polymerase chain reaction (PCR) for quantifying particular genes with high sensitivity and melting curve analysis for identifying gene mutations. Sample are divided into a large number of microwells for gene amplification, and then the fluorescence intensity and melting temperature of each microwell are measured.

Hitachi has also demonstrated that the technique can be used to simultaneously detect multiple small genetic mutations of tumor-derived genes in blood with high sensitivity. The technique enables early and minimally-invasive detection of cancer recurrence, and is applicable to the identification of suitable drugs and the early assessment of treatment efficacy based on the type of mutation.

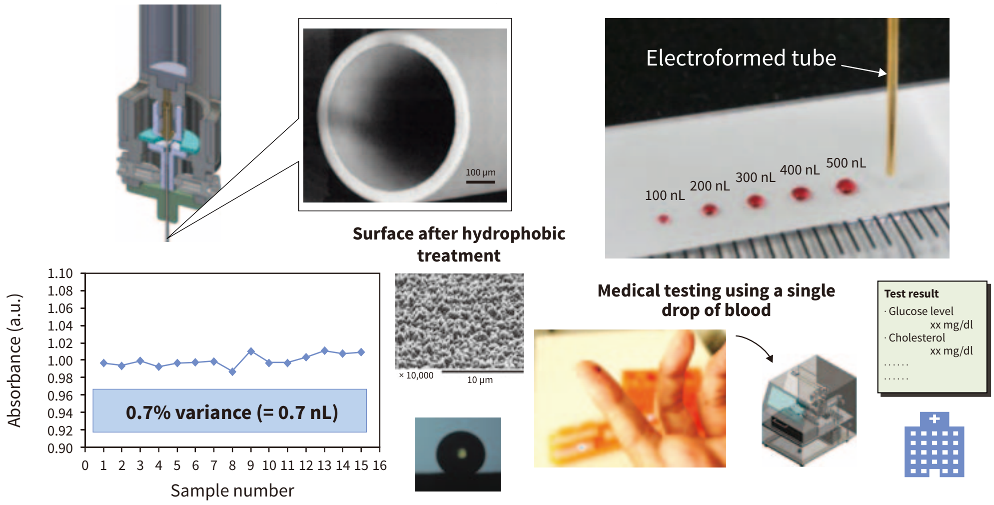
2 Liquid Handling Technique for Single Blood Drop Analysis

Thanks to the development of highly sensitive test reagents and measurement techniques in recent years, it has become possible to make accurate measurements of the concentration of substances present in even very small quantities of blood. While liquid handling techniques capable of precisely dividing a small quantity of blood into separate samples are required when conducting more than one type of test, precise quantity control is difficult when dealing with samples such as blood that have highly variable viscosity.

In response, Hitachi has developed a technique for the precise handling of liquid samples in small quantities using a precision-manufactured electroformed tube. This is able to dispense the entire quantity of a sample, regardless of its viscosity and without dead volume, simply by sliding the plunger inside the tube. The accuracy has been improved by hydrophobically treating the surface, being able to control the quantity to within 0.7 nL when dispensing 100 nL* of liquid. The technique has demonstrated its ability to handle quite small blood samples (approximately 1,000 nL), roughly equivalent to a mosquito bite, and to measure the concentration of biochemical panels like glucose or cholesterol with high precision.



1 Overview of new genetic test



2 Precise handling of liquid in small quantities using electroformed tube

In the future, Hitachi aims to reduce stress and cost for patients by utilizing the technique in its medical testing systems to enable blood testing to be done using just "a single drop of blood."

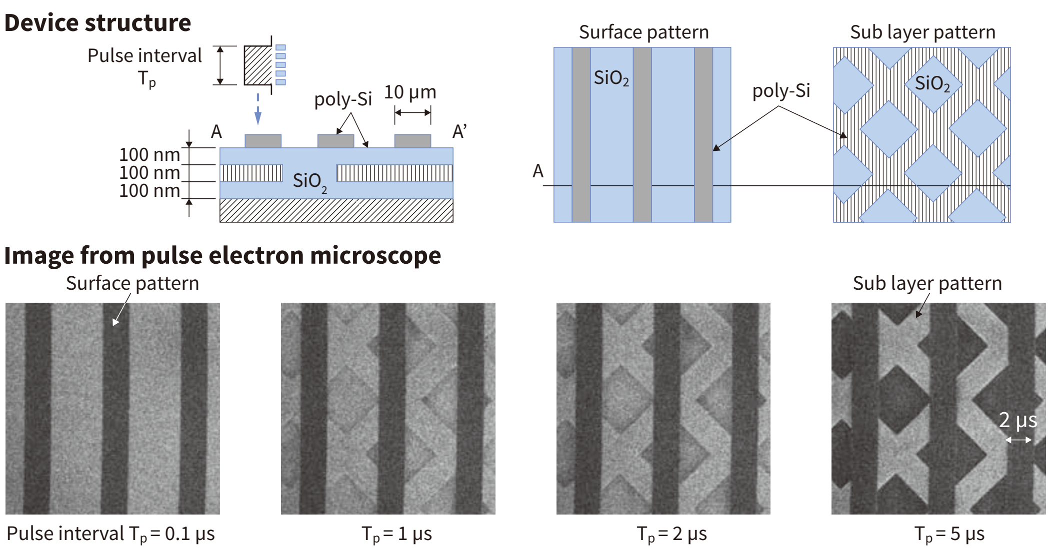
* 1 nL is one billionth of a liter.

3 Pulse Electron Microscope for Observing Internal Structure of Three-dimensional Semiconductor Devices

As semiconductor devices approach the limits of miniaturization, more complex and three-dimensional designs are being adopted as a means of improving their performance. For this reason, leading-edge process development requires methods for measuring the electrical characteristics of three-dimensional structures and their interiors.

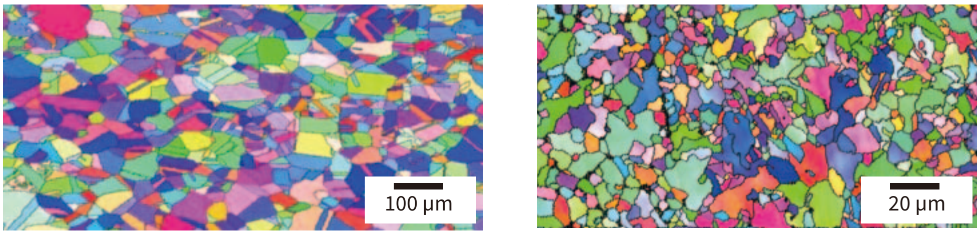
To meet this need, Hitachi has developed a way of using a pulse electron microscope to observe the interior of three-dimensional structures. Because the characteristics of leak currents from the surface of a sample change depending on its internal structure, the use of an electron beam to produce a surface voltage on a sample contains information about its internal structure. By utilizing this principle, the surface voltage of a sample can be modified, and its internal structure visualized by using a pulse electron microscope to generate electron beam pulses and control the interval between them.

It is possible, for example, to image the pattern of a dielectric material formed in a sub-layer of the device to confirm how accurately it is aligned with the surface pattern. As pulsing the electron beam can also be used to observe small differences in capacitance, the technique has another potential application in checking for transistor junction defects.



Si: silicon SiO_2: silicon dioxide

3 Use of pulse electron microscope to observe internal structure of three-dimensional semiconductor device



Microstructure of previous material

Microstructure of new material

4 Microstructure of new material resulting from oxide phase

4 Innovative Materials and Metals Additive Manufacturing Technique

Hitachi has developed a new material and manufacturing technique for use in additive manufacturing (3D printing), a process that is seeing increasing use in a wide range of sectors such as industrial equipment and medical devices. Work by Hitachi on the development of high-performance materials has been prompted by the near-net-shape capabilities of metal 3D printers and their rapid cooling and solidification characteristics. The new material is an alloy intended for harsh environments such as nuclear reactors that uses an oxide phase to achieve a fine microstructure. Strength testing of the alloy and evaluation of its performance under exposure to radiation in the simulated interior of a reactor demonstrated that it has 1.8 times the strength and four times the radiation tolerance of the material used previously.

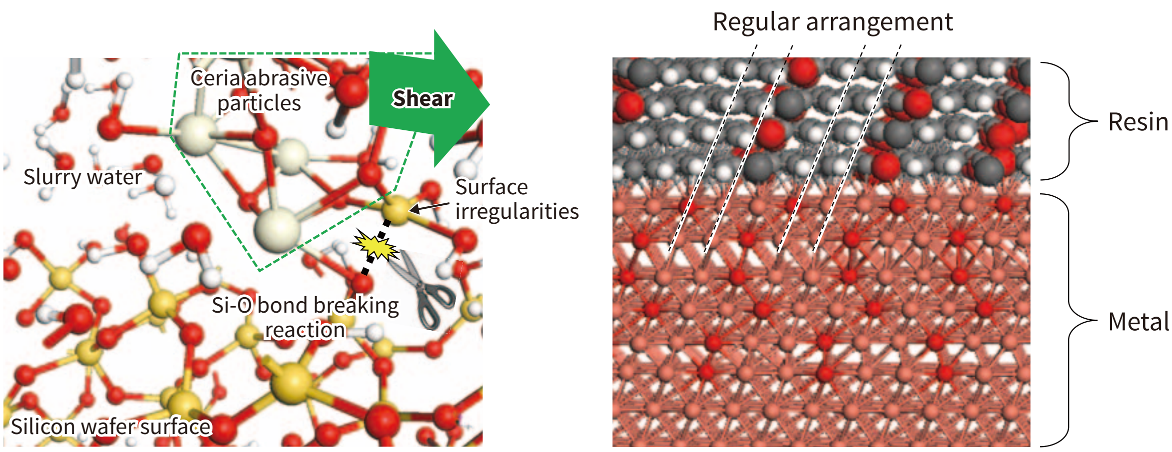
For manufacturing, Hitachi has developed a design system and 3D printer for the precise and high-quality fabrication of components with complex shapes. The design system enables optimal manufacturing based on the printing material and model of 3D printer being used and has improved the dimensional accuracy of manufactured parts by a factor of two compared to manual design. Hitachi has also developed a 3D printer that uses a vacuum and preheating mechanism to reduce impurities by 30% compared to previous printers.

In the future, Hitachi intends to incorporate materials informatics into its manufacturing technologies to accelerate the development of materials for 3D printing.

5 Material Design Technique for Electronic Components

The miniaturization and performance improvements in electronic components over recent years have created a greater need for precise atomic-level control over boundaries between different materials. Accordingly, Hitachi has developed a technique for studying friction, wear, and adhesion at such boundaries at the atomic scale that involves a molecular simulation calculated using a mix of quantum and Newtonian mechanics.

The technique has been put to use simulating the chemical machine polishing used to achieve wafer flatness in the manufacture of semiconductor devices. This



(1) Dynamic process for eliminating surface irregularities in chemical machine polishing

(2) Strong bond achieved by boundary having a regular arrangement of atoms belonging to both resin and metal

5 Molecular simulation of boundary between different materials was done as part of the package design of a polish slurry that speeds up the semiconductor process where the technique was used to elucidate the complex polishing mechanism that involves a mix of chemical reactions and shear force.

Another application is simulation of the adhesion between the resin (encapsulant) used to hold electronic components in place and the filler particles it contains, and between the resin and other materials such as metals, using this to help design the composition of encapsulants that will provide higher adhesion strength.

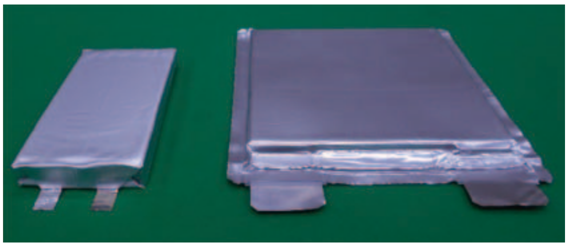
Hitachi also has plans to utilize the technique in the design of electronic materials suitable for 5th-generation (5G) telecommunications.

6 High-energy-density LIB Using Semi-solid Electrolyte with Low Volatility

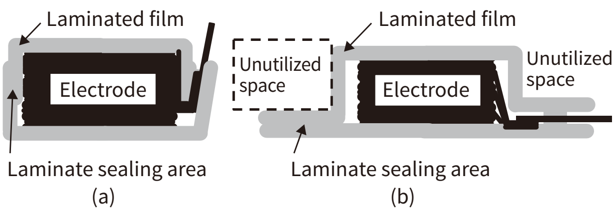
The energy storage systems for electrification of society demand compact lithium-ion batteries (LIBs) with large capacity and high safety. An issue with conventional LIBs containing organic liquid electrolyte, however, is that its volatilization temperature and flash point are as low as close to room temperature, which lowers the safety of the LIBs. And the reinforcing material and cooling systems that they require to ensure safety only make the LIB system larger.

By developing an electrolyte with low volatility with a high level of safety, a compact battery design without unutilized space, and an electrode design that realizes both suffcient safety and high energy density, Hitachi has achieved an energy density of 600 Wh/L without compromising safety, successfully developing a battery with a capacity of 130 Wh, which consequently has reduced the battery size to two-fifths of the previous size. In addition, the newly developed battery was revealed to meet the relevant safety standard (IEC 62660 standard), including crushing and overcharging tests.

This technology will enable vehicles equipped with the LIBs to make better use of internal space and allow for more space-efficient installation of electrical storage capacity for renewable energy.



High-energy-density LIB (left) and conventional LIB (right)



Structures of newly developed (a) and conventional (b) batteries

6 Semi-solid battery with high levels of safety and energy density