

Materials Fabrication Laboratory
Chief Scientist: Hitoshi Ohmori (Dr. Eng.)



(0) Research field

CPR Subcommittee: Engineering, Physics

Keywords:

ELID grinding, Ultra/nano precision machining, Microfabrication, Surface modification, Pico-precision

(1) Long-term goal of laboratory and research background

The main objective of our research is the development of revolutionary and new material processing technologies in grinding, lapping, polishing, cutting and forming for an extensive range of materials. Through advanced research activities on ultraprecision, ultrafine, nanoprecision and ultra-smooth machining processes, required for the fabrication of advanced functional devices such as optical and electronic components, we launched the research of a new field of micro-mechanical fabrication technologies in addition to surface functional modification, transcription, process control and optimization techniques, aiming at a wide variety of materials, precision, mechanics and scale ranging from micrometer to nano/pico meter level, to meet practical and applied industrial needs.

(2) Current research activities (FY2023) and plan (until Mar. 2025)

<R&D on Electrolytic In-process Dressing technology>

Following our advanced research on the ultraprecision, nanoprecision and ultrasmooth machining processes required for fabricating advanced functional devices, we have undertaken research in new fields of micromechanical fabrication, in particular the electrolytic in-process dressing (ELID) grinding technique. In our study, a variety of parameters were studied to help achieve a fine surface finish in ductile-mode machining. We succeeded in realizing highly efficient, high-precision grinding of the following hard, brittle materials:

- Advanced ceramics: CVD SiC, ZrO₂, Fused silica, SiC wafer, TiN, Yb:YAG
- Sapphire as substrate for LED and a heat filter
- Metallic biomaterials (e.g. Co-Cr alloy, SUS304)
- Electrical device materials (e.g. Cr-N alloy)
- Hardened steel
- Plastic sheets for medical applications

Regarding simultaneous ELID-grinding for different two materials, specific hard alloys such as CuW and AgW have been selected to combine with another different material. Through the experiments, either of CuW or AgW could improve roughness of optical material (glass) when they have been ground simultaneously. Other combinations are expected to finish materials more smoothly by simultaneous ELID-grinding.

Collaborations with physical, optical, and manufacturing fields in scientific and industrial communities are also actively in progress.

<Research on combined process technology >

Based on the above knowledge, we attempted to grind silica substrates with ELID, and combined CMP in collaboration with Kurokawa Lab. in Kyushu Univ. A finished silica substrate can be used for X-ray mirror. Also for CVD SiC substrates, the combined process was tried to be applied. On the other hand, if ELID grinding and CMP are combined in certain conditions, finished surfaces can obtain features with magnified ground marks which are expected to provide new functions. Through cell culture on the ground surfaces, cells can remain and extended along with ground marks. This kind of surface features is expected to be applied to other purposes.

Applying an elastic polishing pad for CMP, periodically ELID-ground cylindrical structures of which pitches were designed from 2.5mm to 10mm could be polished smoothly along with their structures. For polished surfaces which have been polished with specific conditions, anti-fouling function has been proven. This result is expected to be applied to fabrication of solar cell covers.

<Development of critical components>

We have been developing critical components such as optics, sensors, and specific microdevices for advanced analyzers applying ultra/nanoprecision machining processes. As requirements for manufacturing are updated, the applied machining processes and their systems have been updated. In order to pursue ultimately precise machining process, we also have been focusing on optimisation of machining conditions to control machining phenomena.

As International Collaboration on the Extreme Universe Space Observatory (EUSO) mission, the advanced astronomical optical system comprising of Fresnel lenses has been developed. In August 2019, Soyuz launched the Mini-EUSO telescope applying two ultraprecision Fresnel lenses on the ISS. There are wide applications in observation such as bio-luminescence from plankton in the ocean, high-altitude atmospheric lighting, and meteoroids entering the atmosphere.

Based on such experience for lens fabrication, we have launched to create periodically arrayed lenses (lens array). Specifically, a new machining system creating spherical dimple-arrayed periodic structures has been devised. In order to increase productivity as number of the dimple increases, spherically profiled tools have been prepared and they could be plunged into the substrates to create periodic spherical dimples. It has been confirmed that each dimple can be created with enough transparency.

As a bio-application of machining process, a new process which can add functional properties on machined surface of Titanium has been investigated. By adjusting machining conditions, it has been proven that the machined surfaces can have anti-bacterial properties which are beneficial for use on implants.

<Research on micro fabrication processes>

Developed micro fabrication system provides multi-axis simultaneous control drive mechanisms with a resolution of 1 nm and is capable of fabricating micro optical, biological devices, their molds, and other complex shapes with free form surfaces to an ultrahigh precision and ultrafine dimensions using small diameter tools. The ELID-grinding has met practical applications and has been increasingly used to achieve mirror surfaces by electrolytic dressing of conductive grinding wheels with fine grains. Micro cutting using mono-crystalline diamond tools with micro tips is also applied to fabricate micro features creating new functions.

By using sharp edge of grinding wheel, a machining technique has been attempted to create continuous V-shaped grooves. This process is expected to be applied to special optical element molds. Not only V-groove creation, but also surface treatment such as hardening and coloring by surface oxidation during machining could be enabled by the proposed process. It suggested to find a new application adding information on the surface.

High-quality machining of cemented carbide was conducted using a PCD ball end mill. A collaborative research on micro-grooving of Co-Cr alloy by polycrystalline diamond ultra-fine end mill for development of metallic cell culture vessels" was performed continuously. We successfully created continuous microgrooves on Co-Cr alloy surfaces using an ultrafine ball end mill with a tool tip radius of 25 μm . These 30 μm in width microgrooves displayed a surface roughness (Ra) of less than 20 nm. Our findings indicate that plastic deformation predominantly governs the removal mechanism during the micromilling process applied to Co-Cr alloy, employing this ultrafine polycrystalline ball end mill. Furthermore, cell culture experiments revealed a notable orientation of cells within the grooves, particularly those machined with the 25 μm tool tip radius. Microgrooving of aluminum nitride was conducted using the smallest commercially available PCD square end mill. It was confirmed that high-quality and highly efficient ductile mode machining of aluminum nitride can be achieved through creep feed machining with a large cutting depth.

We have been studying microfluidic chips for bioanalysis. This year, we continued to develop a microfluidic chip which enables facile digital PCR. Digital PCR is an analysis method for nucleic acids with high sensitivity and high precision. However, the commercialized digital PCR instruments are expensive and not yet in widespread use. We have been developing a digital PCR method using only standard laboratory equipment. This year, we applied this method to one-step reverse transcription PCR for direct detection of RNA. With a model RNA sequence (SARS-CoV-2 gene), we observed an excellent performance in the concentration range of 1.0 ~ 10,000 copies/microliter. These results proved the practical usefulness of the developed method.

<Research on tribo-fabrication technology>

Tribology is the science and technology of friction, wear, and lubrication. It is concerned with phenomena that occur at the machine contact surfaces; thus it supports fundamental technologies and production of mechanical systems. Phenomena that occur at the contact point between the

tool and the workpiece in various lubrication states during the removal machining process can be expressed as tribological problems. We propose the new term “tribo-fabrication” to describe technologies that involve both tribology and machining/manufacturing interactions.

In measurement of friction coefficient for machined surfaces, not only surface integrity, but also uniformity of machined marks influences the result strongly. Especially for a standard specimen for calibration, we are focusing on precise combination of machining and finishing to obtain its necessary surface properties stably.

Furthermore, a novel surface modification system, integrating a femtosecond pulsed laser with a dielectric barrier discharge-type atmospheric pressure plasma unit, has been developed. A highly functional CrN film is being efficiently fabricated on the surface of a Co-Cr alloy, which is utilized as a metallic biomaterial. Additionally, a dedicated system is currently being constructed to establish a new "laser-assisted peening method." In this method, a nanosecond laser is irradiated with an offset focus to heat the material to a temperature approaching its melting point, and the desired components are subsequently fixed through fine peening.

(3) Members

as of March, 2025

(Chief Scientist)

Hitoshi Ohmori

(Senior research scientist)

Kazutoshi Katahira, Kazuo Hosokawa

(Research Consultant)

Takahito Kobayashi, Hirorou Nomura,
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Naohiro Nishikawa, Taku Sugawara, Toshiro Doi,
Nobuhide Itoh, Takashi Matsuzawa, Weimin Lin,
Atsushi Ezura, Alan Hase, Mitsuyoshi Nomura,
Keita Shimada

(Visiting Technician)

Masayuki Takahashi, Koso Nagao, Ryosuke Imura,
Teiji Anzai

(Senior Visiting Scientist)

Syuhei Kurokawa

(Student Trainee)

Ayumu Sekiguchi, Kento Shinagawa,
Fumiya Tabata, Eri Tsunoi

(Part-time Worker)

Taisei Kametaka, Mayumi Sahashi

(4) Representative research achievements

1. Kazuo Hosokawa and Hitoshi Ohmori, Digital reverse transcription PCR using a simple poly(dimethylsiloxane) microwell array chip for detection of SARS-CoV-2, *Biochemical and Biophysical Research Communications*, 741, 151070, 2024 DOI: 10.1016/j.bbrc.2024.151070
2. Kazuo Hosokawa, and Hitoshi Ohmori, Digital PCR using a simple PDMS microfluidic chip and standard laboratory equipment, *Analytical Sciences*, 39, 2067-2074, 2023 DOI: 10.1007/s44211-023-00425-2
3. Satsuki Ito, Shiori Ishitsuka, Nobuhide Itoh, Hitoshi Ohmori, and Katsufumi Inazawa, Fabrication technology of fiber-bonded grinding wheel containing composite abrasive grains, 2022, *Advanced Micro-Fabrication and Green Technology-Transactions of MIRAI*, Vol.10, p46-56.
4. Katsufumi Inazawa, Hitoshi Ohmori, and Nobuhide Itoh, Effects of O₂ fine bubbles on ELID grinding using conductive rubber bond grinding wheel, 2022, *International State-of-the-art in Surface and Interface Fabrication Technologies IV*, p10-19.
5. Min Li, Bernhard Karpuschewski, Hitoshi Ohmori, Oltmann Riemer, Ying Wang, Ting Dong, Adaptive shearing-gradient thickening polishing (AS-GTP) and subsurface damage inhibition, 2021, *International Journal of Machine Tools and Manufacture*, 160, 103651.

Laboratory Homepage

https://www.riken.jp/en/research/labs/chief/mater_fab/index.html