The Japan Society for Precision Engineering

Introduction of JSPE Technology Awards 2021

This award is presented to researchers and engineers of companies who have had creative achievements in the field of precision engineering in recognition of their dedication and effort, as well as in the anticipation of their future development.

● *Development of ultra-precision grinding machines of ideal structure by utilizing topology and shape optimization methods*

Ryota SHINDO, Keiji UEMURA, Hisashi KATO, Tadashi TOKAI and Naoki TSUNEKAWA (Nagase Integrex Co., Ltd.)

We developed ultra-precision surface and profile grinding machines by pursuing the ideal structure based on innovative concepts and unconventional thinking. High-level analytical methods such as topology and shape optimization were utilized, and gravity center and robust optimization were incorporated. The proposed lean structural design increases resonance frequency by 2–3 times. Moreover, 40–50% space saving, 100–300% productivity improvement, and high precision mirror grinding (8 nm Ra) were achieved. Furthermore, revolutionary grinding machines less affected by temperature changes and vibration disturbances were also realized.

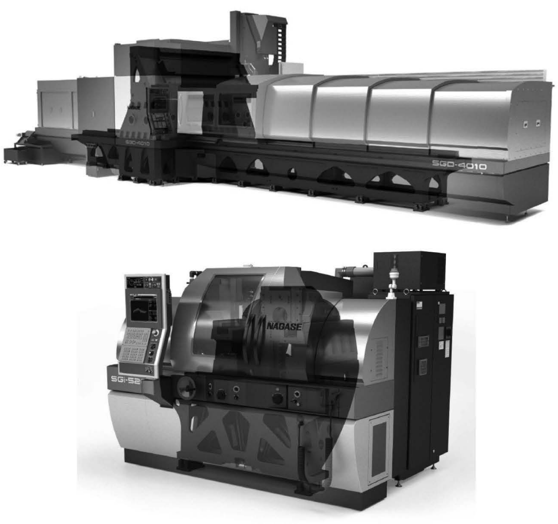

Fig. 1. Ultra-precision surface and profile grinding machines

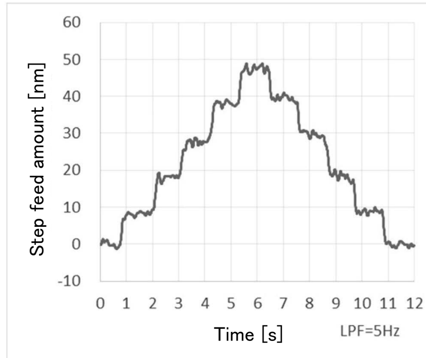

Fig. 2. 10 nm step feed followability at the machining point

● *Development of high-efficiency damage-free polishing technology for large-sized single crystal diamond substrates by plasma-assisted polishing*

Yuko AKABANE, Yukio SATO, Kohki SUGAWARA (TDC Corporation), Kazuya YAMAMURA (Osaka University) and Hideaki YAMADA (The National Institute of Advanced Industrial Science and Technology)

TDC Corporation, Osaka University, and National Institute of Advanced Industrial Science and Technology have jointly developed a high-efficiency, damage-free polishing technology for large-sized single crystal diamond substrates. Diamond is one of the most difficult to polish materials because of its hardness and chemical inertness. The large-sized diamond substrate can break, and a damaged layer be introduced when conventional scaife polishing using diamond abrasive is used, while the polishing rate is very low when CMP is used. The proposed technology offers highly efficient polishing of large-sized diamond substrates using

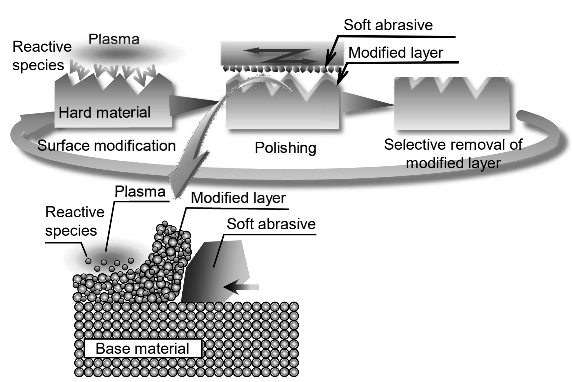

Fig. 3. Schematic of plasma-assisted polishing

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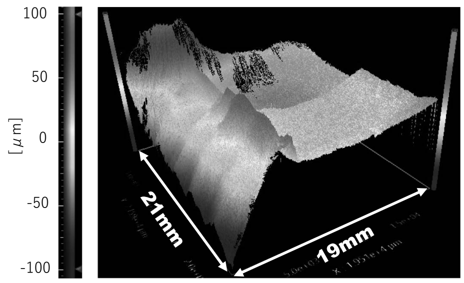
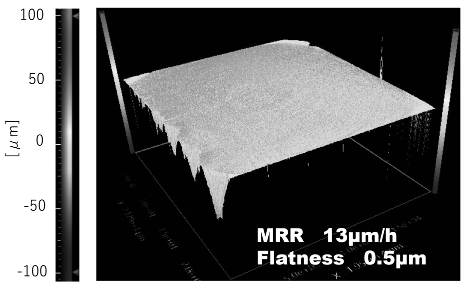


Surface morphology of the 20-mm square mosaic SCD (100) substrate before PAP



Surface morphology of the 20-mm square mosaic SCD (100) substrate after PAP

Fig. 4. PAP realized high material removal rate (MRR)

plasma-assisted polishing developed at the Osaka University. When polishing a 20 mm square large-sized mosaic single-crystal diamond substrate grown by microwave plasma CVD, a flatness of 0.5 μm and surface roughness of *S*q 0.3 nm order were obtained. The polishing rate was 13 μm/h or more, which was 10 to 100 times faster than other chemical polishing techniques. Band-A emission derived from the damaged layer was not observed in the cathode luminescence measurement of the diamond substrate. Moreover, no lattice strain was observed in the cross-sectional TEM. The application of this technology enables polishing large-sized diamond substrates, promotes the spread of high-performance heat sinks and power devices, and realizes a sustainable low-carbon society.

- ***Development of high-speed varifocal lens TAGLENS and pulsed light source PLS, which offer high observation functionality exceeding the depth of focus limitation***

Koji KUBO, Aimin SHA, Yuki KURAHASHI, Yutaka WATANABE and Satoru YOSHIDA (Mitutoyo Corporation)

When observing an object with a height greater than the depth of focus using optical instruments, such as microscopes, it is necessary to refocus the lens to each position of the object. This is one of the problems limiting the throughput of inspection and measurement.

TAGLENS is a high-speed varifocal lens using the resonance frequencies of a liquid in a cavity to achieve the lensing effect. By mounting it in an optical system, high-speed scanning of the focus position becomes possible without using a mechanical drive mechanism. TAGLENS keeps the focus position moving at a period of 14 μs or smaller, depending on the liquid resonance. This is shorter than the typical exposure time of a camera used in many applications. Two methods can be utilized, which take advantage of the properties of the TAGLENS.

The first method is performing image processing on a single blurred image obtained by mixing focus and defocus, obtained using continuous illumination. It is possible to get an extended depth of focus image in real time by deconvolution, using an optical transfer function of the optical system which incorporates TAGLENS. The second method is based upon acquiring a stack of images through focus using a pulsed illumination source synchronized with the TAGLENS. We have developed both methods and successfully implemented in microscopes and imaging systems. Additionally, we have developed image acquisition and analysis algorithms, optimized for TAGLENS, and various observation functions, such as autofocus, focus stack, 3D form data, and more.

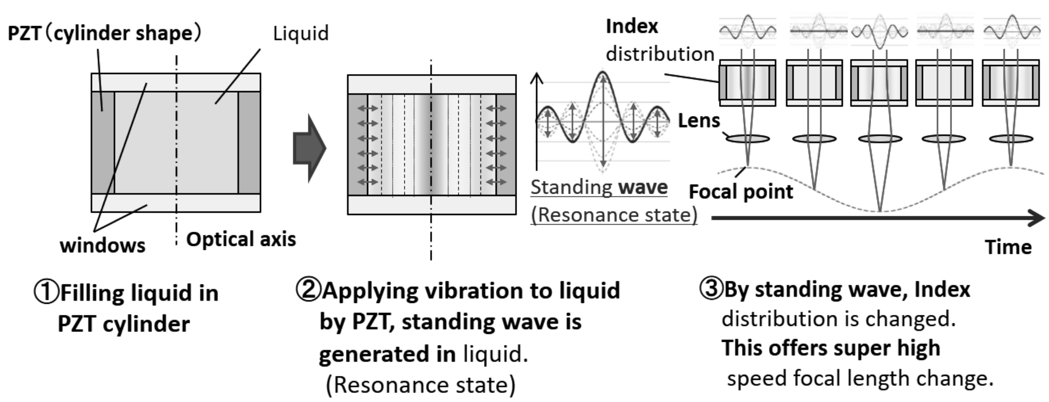


Fig. 5. TAGLENS principle