Shibaura Machine
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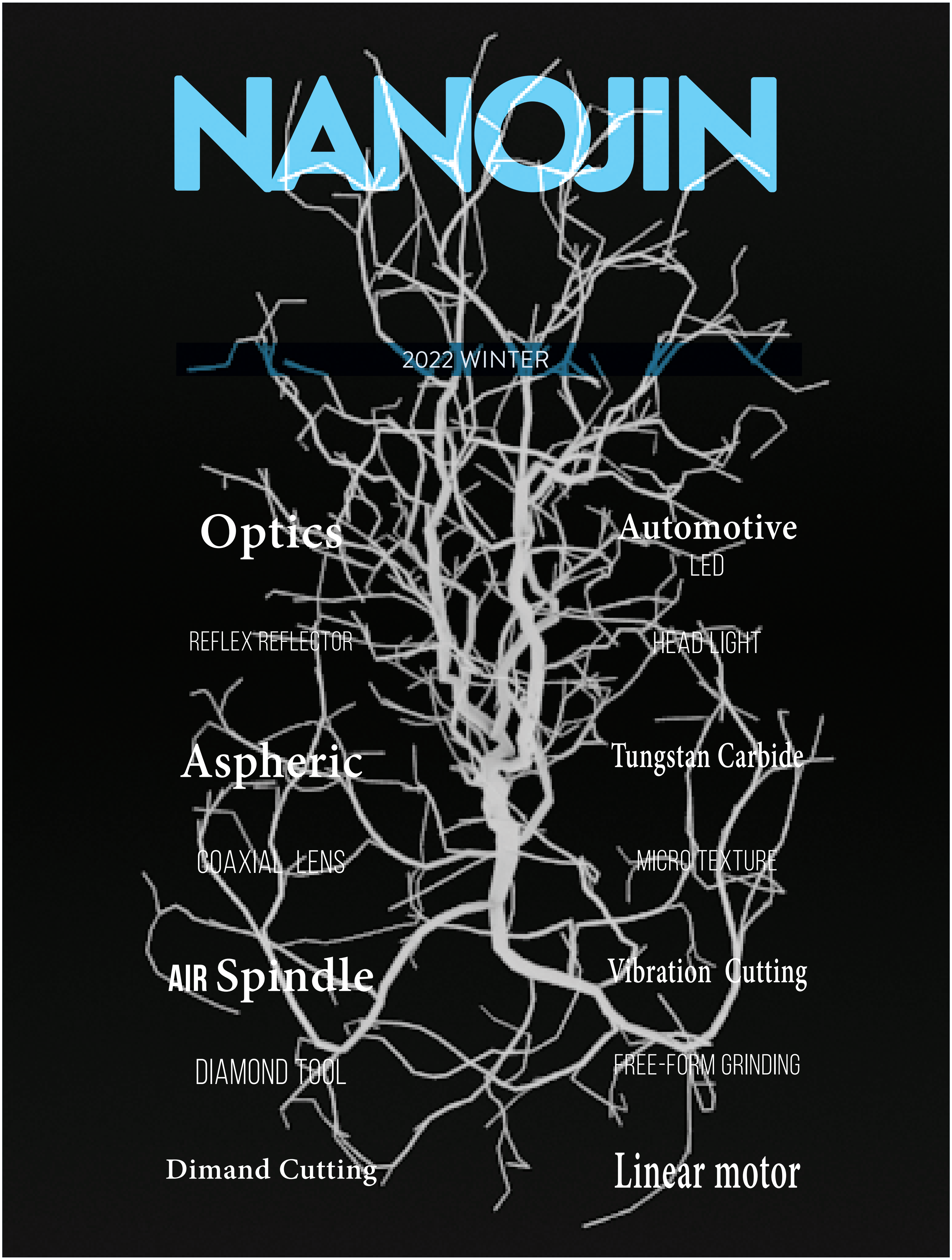
NANOJIN

2022 WINTER



EDITOR'S NOTE

We marked more than a year of the pandemic and had various experiences more than expected. While it's not perfect for stress-free communication on the internet, we have accepted different types of social media such as mobile, wireless and smart manufacturing. We are absolutely realizing a different lifestyle and business now. As well, we can notice some signs of recovery from several peaks of pandemics.

For us, one of the signs was to join EMO MILANO 2021. We could get many opportunities there with requirement of high value-added manufacturing, though we had to make many decisions about what and how to exhibit there. Hence, I would introduce two topics which show an opportunity for the target having hard problems and strong requirements by integrating good machine tool performance.

First issue is about lens array fabrication by ULG-100D. Lens array has strong optical benefit and is widely used for a variety of applications such as 5G communications. However, only a restricted mold manufacturing process can be selected because the mold would be required to have a high-quality surface despite needing complicated tooling strategy which is hardly achieved even by the skilled technician. ULG series, which is one of our lineup of precision machine tools, always propose the solutions of the productive improvement for aspheric optics fabrication by developing the machine tool performance. Particularly, full-digital control technology is one of significant developments in the last decade.

This enables the motion characteristic of the linear and rotary axis to improve markedly and achieve high level simultaneous control for all axes. Thus, it is shown in this leaflet as a case study regarding lens array mold machining by using above technology.

Second issue is machining a precise plate applied to the FC stack by UVM-450D. FC stack is well-known as key technology for ECO vehicles. It is surprisingly needed precision machining technology to get high efficiency. Particularly, quality of microstructure on plate weighs to create flow channels with small corner radius, pitch and high slope because separator plates are precision pressed components affected on the performance of FC stack.
Additionally, roughness for high hardness die is also important to eliminate errors in pressing. UVM series have strong benefits to achieve the above requirement due to the air spindle and linear-motor driven system. Here, this leaflet shows a case study regarding machining precise microstructure mold for hard materials with a new idea to compensate for tool contour error on machines.

We always search for an effective solution by development of machine tools, software, and peripheral devices and also hope a good opportunity for you to think about the next idea. Please let us know if you have a good interest.

Masahiko Fukuta
Expert / Ph.D. (Eng.)
SHIBAURA MACHINE CO.,LTD.

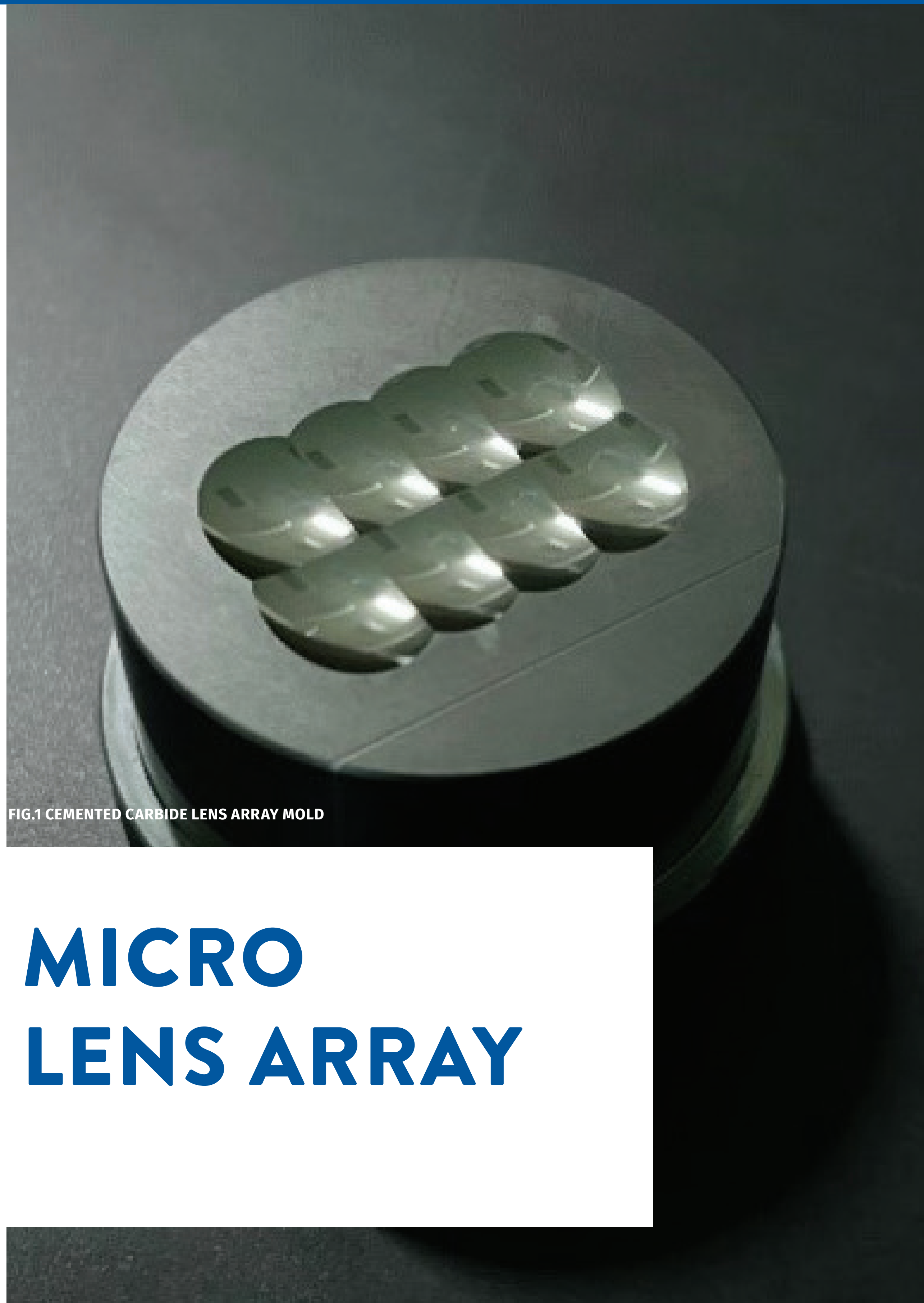


FIG.1 CEMENTED CARBIDE LENS ARRAY MOLD

MICRO LENS ARRAY

FIG.2 LENS ARRAY MOLDINGS

ABOUT LENS ARRAY

A Lens array is one of the important industrial products that are so pervasive in our daily lives. A lens array is an optical lens consisting of multiple lenses arranged on a surface, and it can have various functions such as focusing, diffusing, averaging, and homogenizing light depening on the design. The recent topic "5G" is the technology that cannot be realized without lens arrays. Lens arrays are used in a wide range of fields such as optical communication systems, IT, automobiles, measurement, solar modules, aircraft, and astronomy, etc. There are many applications for it, and more efficient productivity and high-precision are desired in recent years.

LENS ARRAY SHAPE & MOLD MATERIAL

Before we introduce the manufacturing method of lens array mold, we need to talk about mold materials and our machines.

Firstly, there are various mold materials for lens array such as cemented carbide, STAVAX, Ni-P plating, etc. depending on the material of the molded product.

There are also various form shapes of lenses such as simple R, aspheric, free-form and the number of lenses varies from a few to several thousand. Since the mold material, lens shape, and number of lenses vary from customer to customer, it is not hard to imagine if we use the same manufacturing method to every mold, it will not work very well. In other words, the optimum manufacturing method differs for each mold. Shibaura Machine offers variety of options to make lens array mold to meet customer needs, and customers can select the best choise from that options for their mold making process. Shibaura Machine, high precision machining center UVM and ultra-precision aspheric machine ULG are capable of making lens array molds.

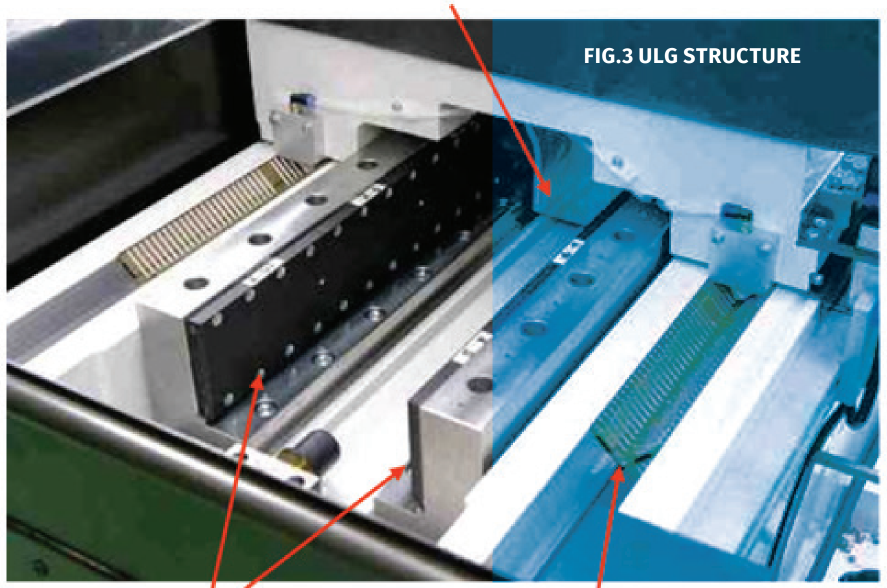


FIG.3 ULG STRUCTURE

FIG.4 ULG-100D(5A)

MICRO LENS ARRAY

ULTRA-PRECISION ASPHERIC MACHINE, ULG

Ultra-precision aspheric machine, ULG series is equipped with a V-V roller guide way and a linear motor drive for the linear axes. The V-V roller guide way realizes high rigidity and high positioning accuracy. It makes ULG possible to achieve a minimum setting unit of 0.1 nm and 1 nm step feed for each linear axis. Because of its high precision, the ULG is mainly used for the aspheric lens molds of smartphones or large-diameter lens molds for single-lens cameras which require ultimate machine precision.

V-V ROLLER GUIDE WAY REALIZES HIGH RIGIDITY AND HIGH POSITIONING ACCURACY. IT MAKES ULG POSSIBLE TO ACHIEVE A MINIMUM SETTING UNIT OF 0.1 NM AND 1 NM STEP FEED FOR EACH LINEAR AXIS.

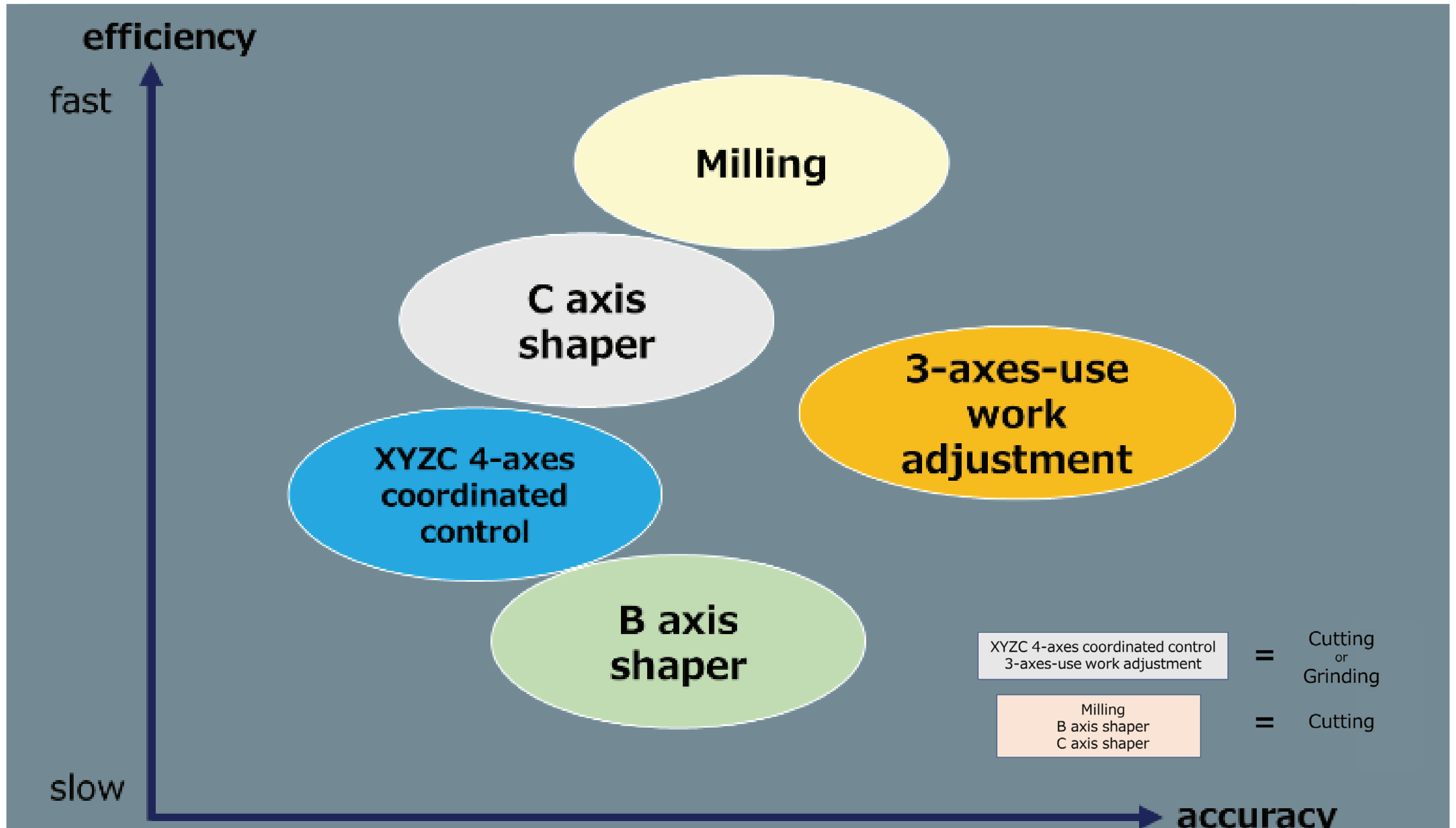


FIG.5 LENS ARRAY MANUFACTURING

GRINDING AND CUTTING LENS ARRAY MOLD BY ULG

Grinding or cutting is adapted depending on the mold material and multiple options are provided for each. In the case that mold material is very hard material such as cemented carbide, grinding is chosen and others are cutting. In particular when the mold material is electroless Ni-P plating,it is possible to use a single crystal diamond tool for cutting, which further increases the degrees of freedom in cutting arrangements. Electroless Ni-P plating is a material widely used for lens molds.It has high corrosion and wear resistance, and because of its amorphous structure, no grain boundary steps occur on the

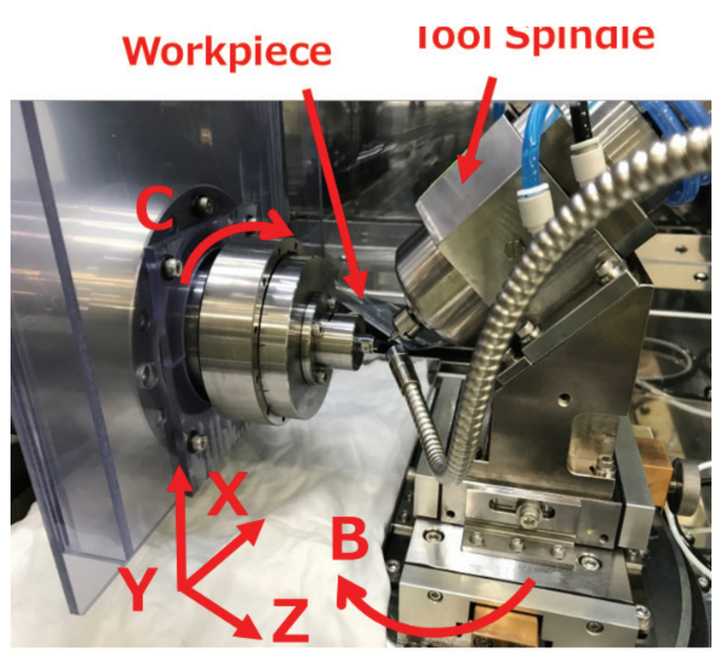
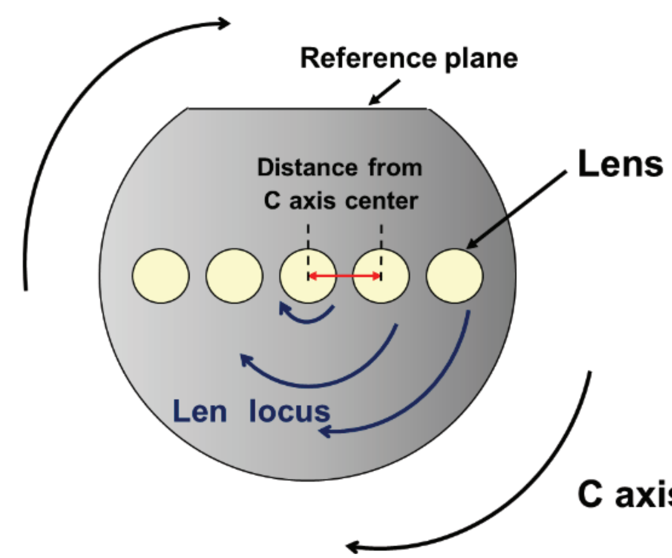


FIG.6 CUT 4-AXES COORDINATED CONTROL METHOD

MICRO LENS ARRAY



Cut surface, making it possible to get extremely high-quality mirror finished surface. In the case of turning, it is possible to achieve surface roughness less Ra"1nm"

TYPES OF LENS ARRAY MANUFACTURING METHOD

The following fig. is representing five typical methods of our lens array mold manufacturing. The horizontal axis indicates the accuracy of mold (form accuracy, roughness) and the vertical axis is efficiency. Since in this fig.5 the other factors except accuracy and efficiency are excluded, it does not mean that milling and 3-axes-use work adjustment are superior than other 3 methods. Every method has advantages and disadvantages, and we can propose proper one to meet the customers' needs.

XYZC 4-AXIS COORDINATED CONTROL METHOD

XYZC 4-axis coordinated control method is applicable to both grinding and cutting.

The photograph shows the setup for the grinding process. The lens array mold is attached to the C-axis by a vacuum chuck, and when the C-axis rotates, the lens rotates as well accompanied with the rotation of C-axis. In XYZC 4-axis

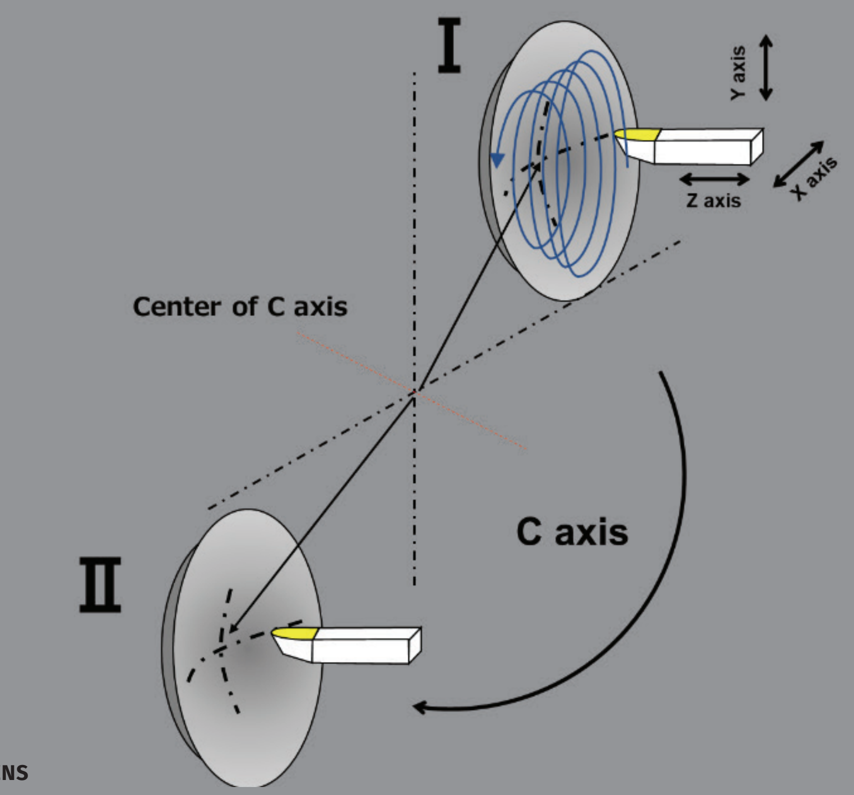


FIG.7 MOVEMENT OF LENS

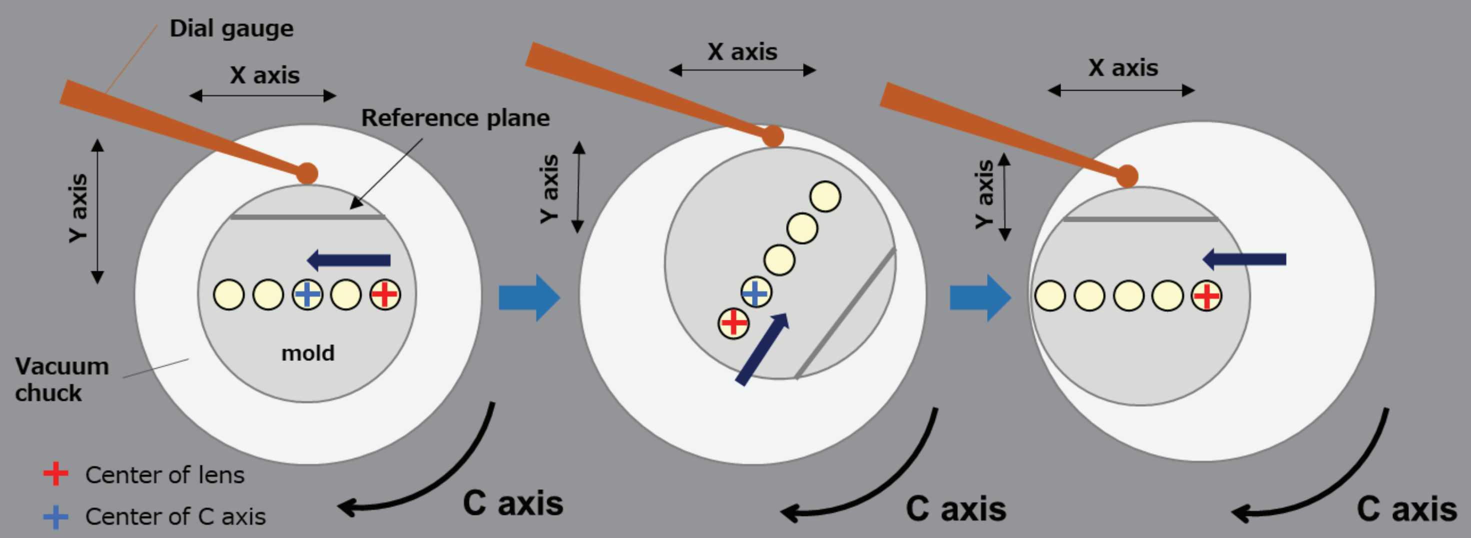


FIG.8 HOW TO ADJUST EACH LENS TO CENTER OF C AXIS.

MICRO LENS ARRAY

Coordinated Control method, XYZ is synchronized with C-axis is so that the tool follows the rotating lens. Once you set up the tool and workpiece you can just wait until all lens is finished.

3-AXES-USE WORK ADJUSTMENT

In XYZC 4-axis coordinated control method, the tool is following to the rotating lens surface and it requires machine the complexed 4-axis synchronized movement. Turning is the better way to get outstanding form accuracy and roughness, because it does not need the machine of the complexed movement comparing to XYZC 4-axis coordinated control method.

In 3-axes-use work adjustment, the center of each lens to be cut is moved to the center of the C-axis to realize the turning process. By using this method, it is possible to obtain form accuracy comparable to a normal turning.

MILLING

Milling is generally used in machining centers though, the ULG is able to do milling by installing a tool spindle. Milling by the ULG can accommodate from a few to thousands of lens arrays. A typical cutting example of milling is a wafer level lens array. Easy to setup, shape stability, and good pitch-to-pitch accuracy are the features of the ULG milling.

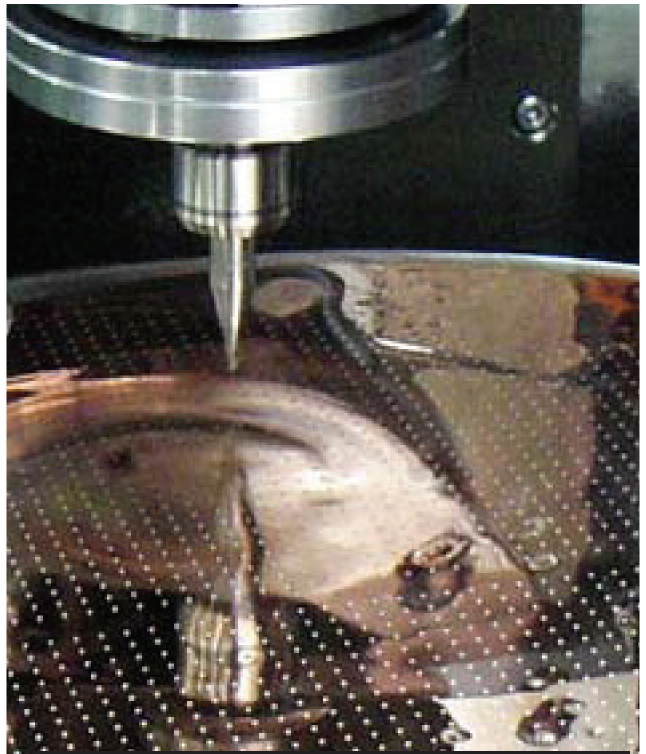


FIG.9 MILLING WAFER LEVEL LENS ARRAY BY ULG

MICRO LENS ARRAY

B-AXIS SHAPER

In this cutting method, B-axis rotate in order to face the tool in the same direction as cut surface normal direction. By this method, it is easy to get strain less surface compared to other method, but since this method is shaper cutting, efficiency is not high.

C-AXIS SHAPER

This cutting method is similar to milling, however, the tool is mounted on the C-axis instead of the tool spindle. Since C-axis is rotated at low speed compared to tool spindle, this cutting method can avoid the characteristics of the cut surface caused by the high speed rotation of the tool spindle in milling.

CUTTING EXAMPLES

Here we introduce an example of milling of lens array for LEDs.

The workpiece material is copper, the lens shape is an aspheric surface of Φ0.5, and the number of lenses is 300. The tool is a single crystal diamond of R0.1 mm. The machining conditions were tool rotation

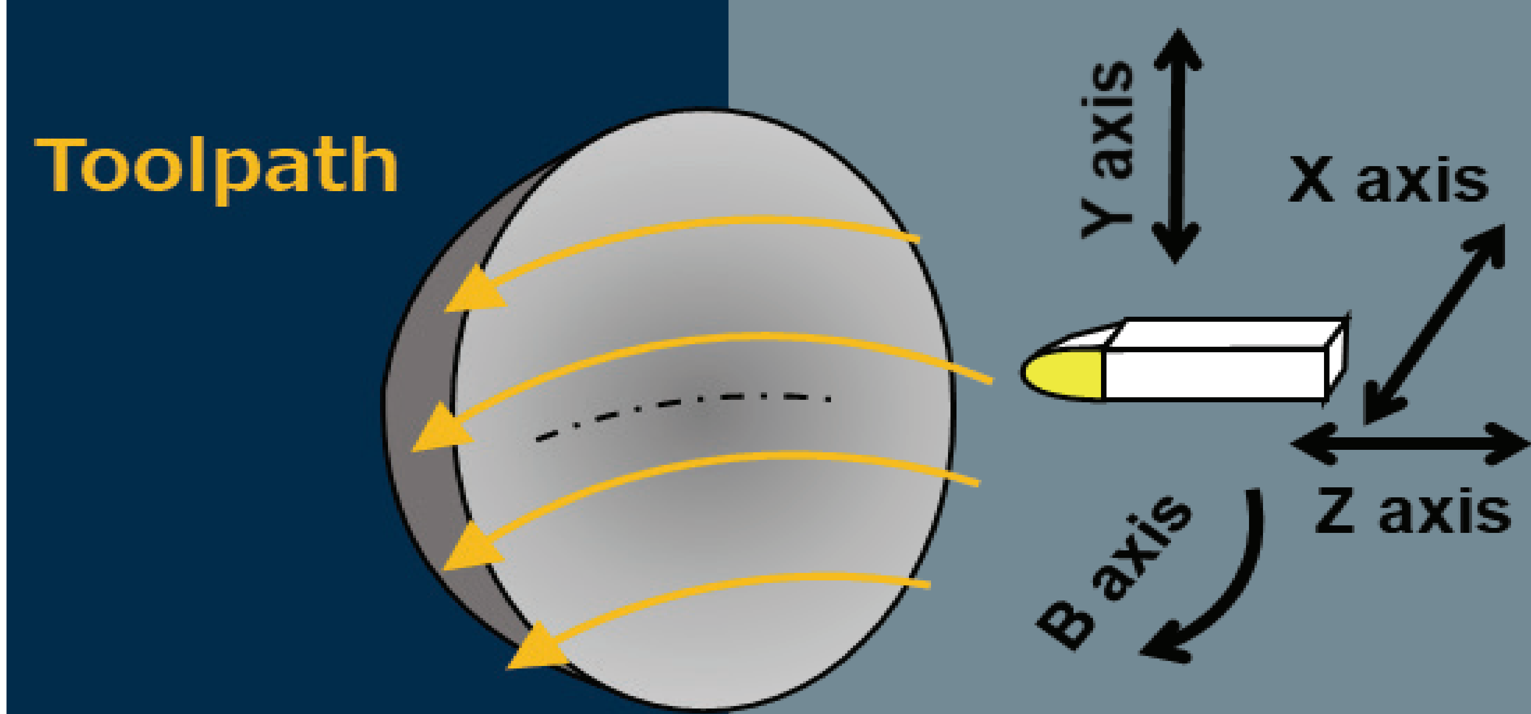


FIG.10 B-AXIS SHAPER

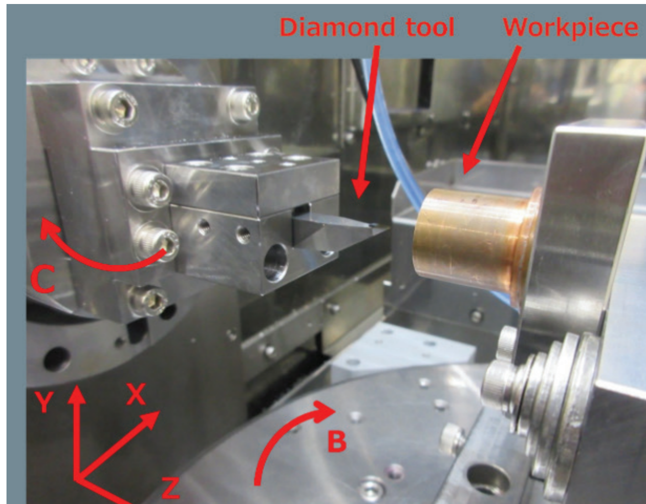
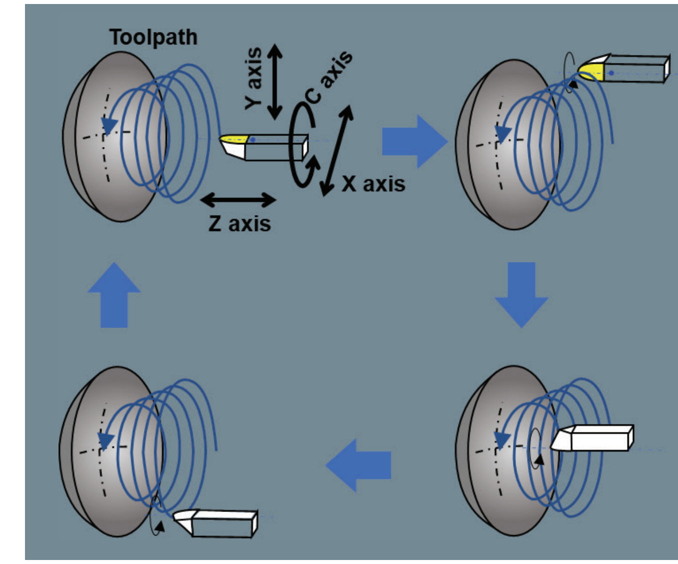
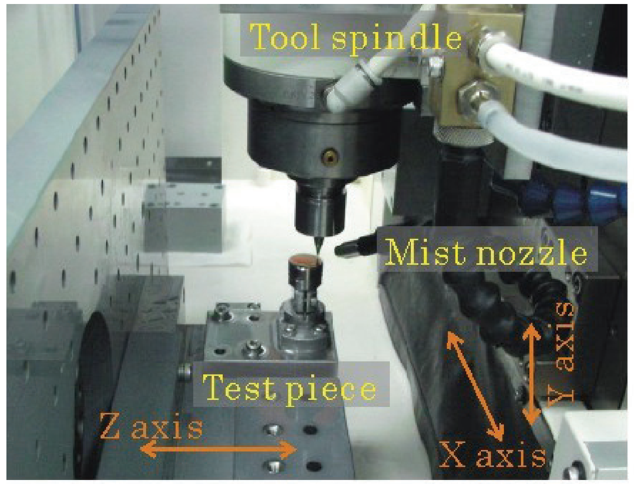


FIG11.C AXIS SHAPER

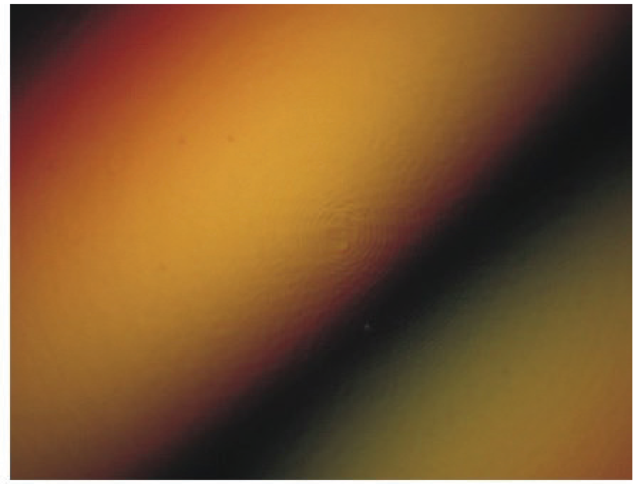


Speed of 20000min-1, feed rate of 40mm/min, and finishing depth of cut of 2um.

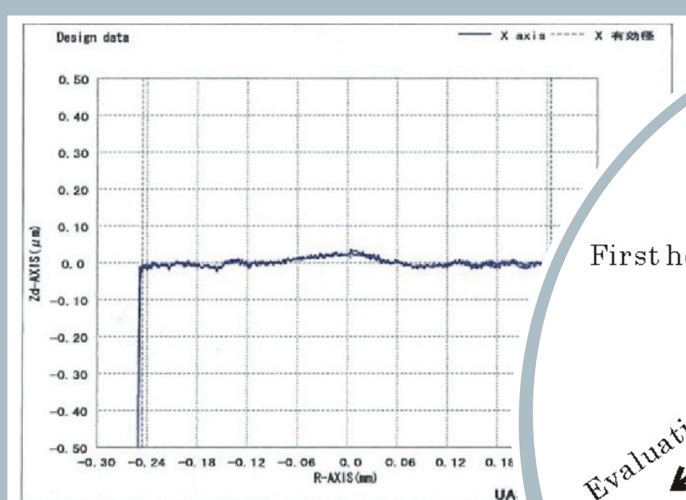
The evaluation was performed on the last 50 lenses out of 300 lenses. As a result, the variation of SAG depth was under 1um, the form accuracy was about 0.1um, and the surface roughness was around 5nm.



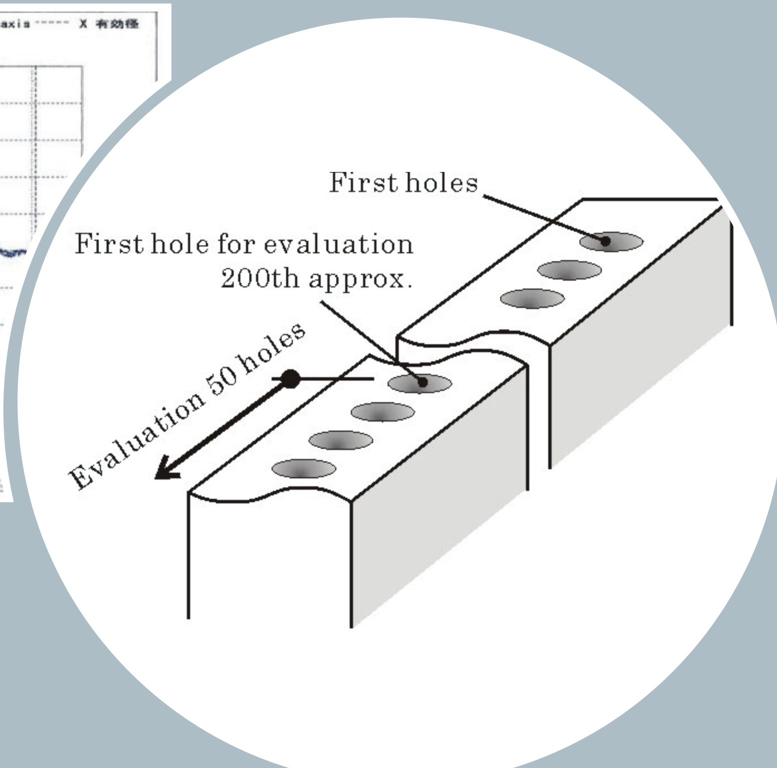
Cut setup for test piece

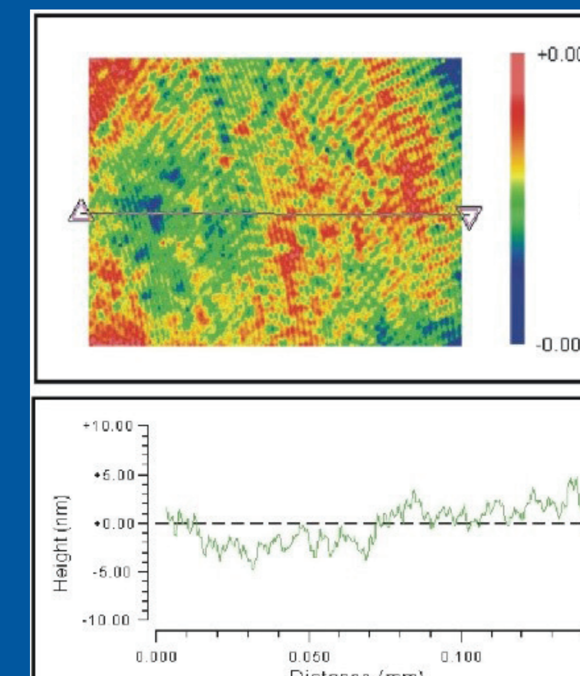

Cut surface of lens array

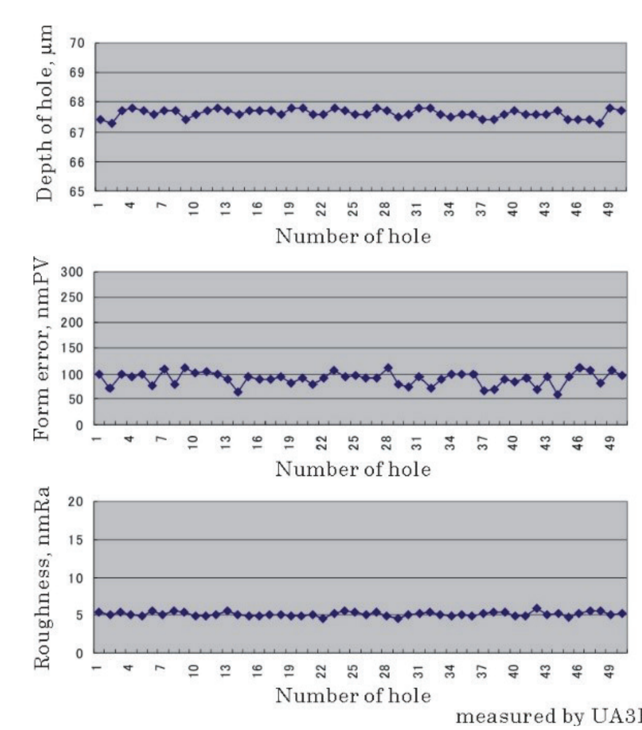
MICRO LENS ARRAY



FORM ACCUARACY







FROM INSIDER #1

ULTRA-PRECISION MACHINING TECHNOLOGY FOR CONTRIBUTING TO HIGHER POWER DENSITY OF FUEL CELL (FC) STACKS

TEXT
KUNITAKA KURIYAMA

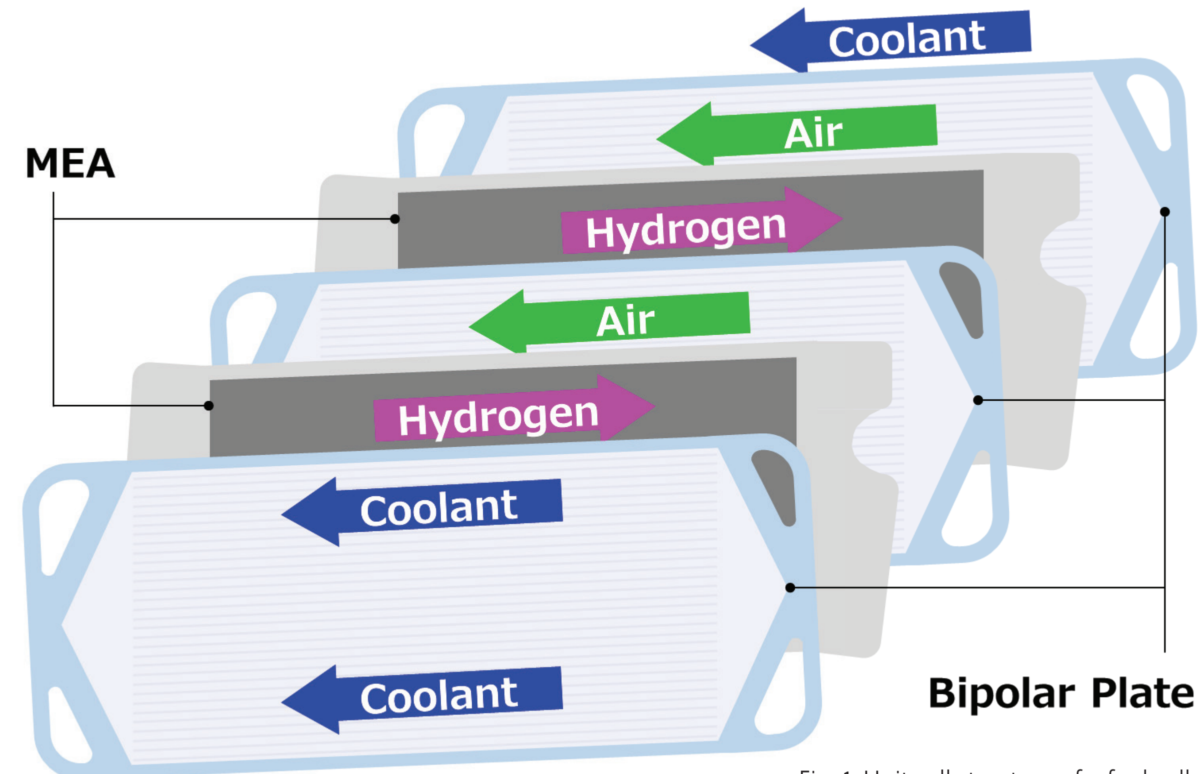


Fig. 1. Unit cell structure of a fuel cell stack5)

With the challenge of decarbonizing mobility being set forth as a green growth strategy in conjunction with attaining carbon neutrality by 2050, there are particularly high expectations for fuel cell vehicles. Fuel cell stacks, which act as the power supply unit, are being rapidly developed with higher power densities for practical use, and one reason for these dramatic technological innovations is the high precision of the flow channels of the thin metal sheets called bipolar plates, of which several hundred are mounted in the power supply unit. This paper will present an application example where ultra-precision machining technology was developed for enabling ultra-precision machining of this micro-bipolar plate shape.

1.INTRODUCTION

At the end of 2020, the Japanese government declared its policy goal of achieving a carbon-neutral, decarbonized society by 2050, in which the amount of carbon dioxide and other greenhouse gases emitted and absorbed will be net zero. According to 2018 results, about 20% of the country's 1.1 billion tons of carbon dioxide emissions came from automobiles,1) and so major changes are needed to adapt to a decarbonized society in the future. In response, recent years have seen the rapid development of technologies in fields such as electric vehicles (EVs) and fuel cell vehicles (FCVs). Fuel cell vehicles are fueled by hydrogen and emit only water, and since they are not fueled by fossil fuels and hydrogen can be generated indefinitely, there are high expectations for them as the ultimate in clean mobility for solving many environmental problems.2)

The fuel cell used in FCVs is actually a small generator that generates electricity through an electrochemical reaction between hydrogen and the oxygen in the air. A fuel cell consists of a membrane electrode assembly (MEA) with electrocatalysts coated on both sides of a polymer electrolyte membrane sandwiched between thin plates called bipolar plates, which are composed of separate air and hydrogen flow channels. Fig. 1 shows an overview of the set of structures called a cell. Hundreds of these cells are stacked on top of each other to form the actual fuel cell stack unit.3)

The initial fuel cell stack developed in 2008 had a maximum output/volume of 1.4 kW/L (maximum output 90 kW/volume 64 L (108 kg)), but the latest model has a maximum output/volume of 3.1 kW/L (maximum output 114 kW/volume 37 L (56 kg)), which is a 2.2-fold increase in volumetric output density, and demonstrates the rapid pace of miniaturization and performance improvements.4)

Higher performance of elements, such as the MEA and bipolar plate, is a factor in the improved output density, but the bipolar plate must have three main features: (1) Complete separation of hydrogen and air flowing on the front and back surfaces, (2) Fine and complex channel shapes to increase the contact area with hydrogen and air, and (3) Thin cells to increase the overall unit density. However, in the conventional press, the thickness of the plate is not uniform due to insufficient machining accuracy of the mold, resulting in extremely thin parts. This can lead to holes in the plate and the mixing of hydrogen and air. Therefore, the bipolar plate requires a high-precision mold that can press the fine channel shape and plate thickness uniformly. This paper presents examples of using an ultra-precision channel machining and compensation method that was developed to improve the performance of fuel cell stacks.

2. ULTRA-PRECISION MACHINING CENTER UVM

This paper examines the use of ultra-precision machining center UVM to achieve highprecision in fuel cell bipolar plates. The UVM series is an ultra-precision machining center that incorporates the nanometer-order elemental technology6) developed for the ULG series, which is used in the field of optical lenses, into the realm of general-purpose machining. Fig. 2 shows the four models in the UVM series lineup. The UVM-450C series standard model has a table size of 450 mm x 450 mm. To handle large workpieces, the UVM-700C's table work surface size has been increased to 700 mm x 700 mm, and the maximum loading weight has been increased to 400 kg. The UVM-450D is equipped with a thermostatic system for strengthening the structure against environmental fluctuations and an enhanced internal structure for vibration control andhigh-precision positioning. The UVM-700E (5AD) is a 5-axis model that provides a high degree of freedom for large workpieces such as automobile headlights. All UVM series models are equipped with Shibaura Machine's aerostatic bearing spindle featuring a maximum speed of 60,000 min-1, and linear motor control with a minimum setting unit of 10 nm is used for all linear axes.

> " LINEAR AXIS DRIVES OF THE UVM SERIES ARE EQUIPPED WITH CORED LINEAR MOTORS"

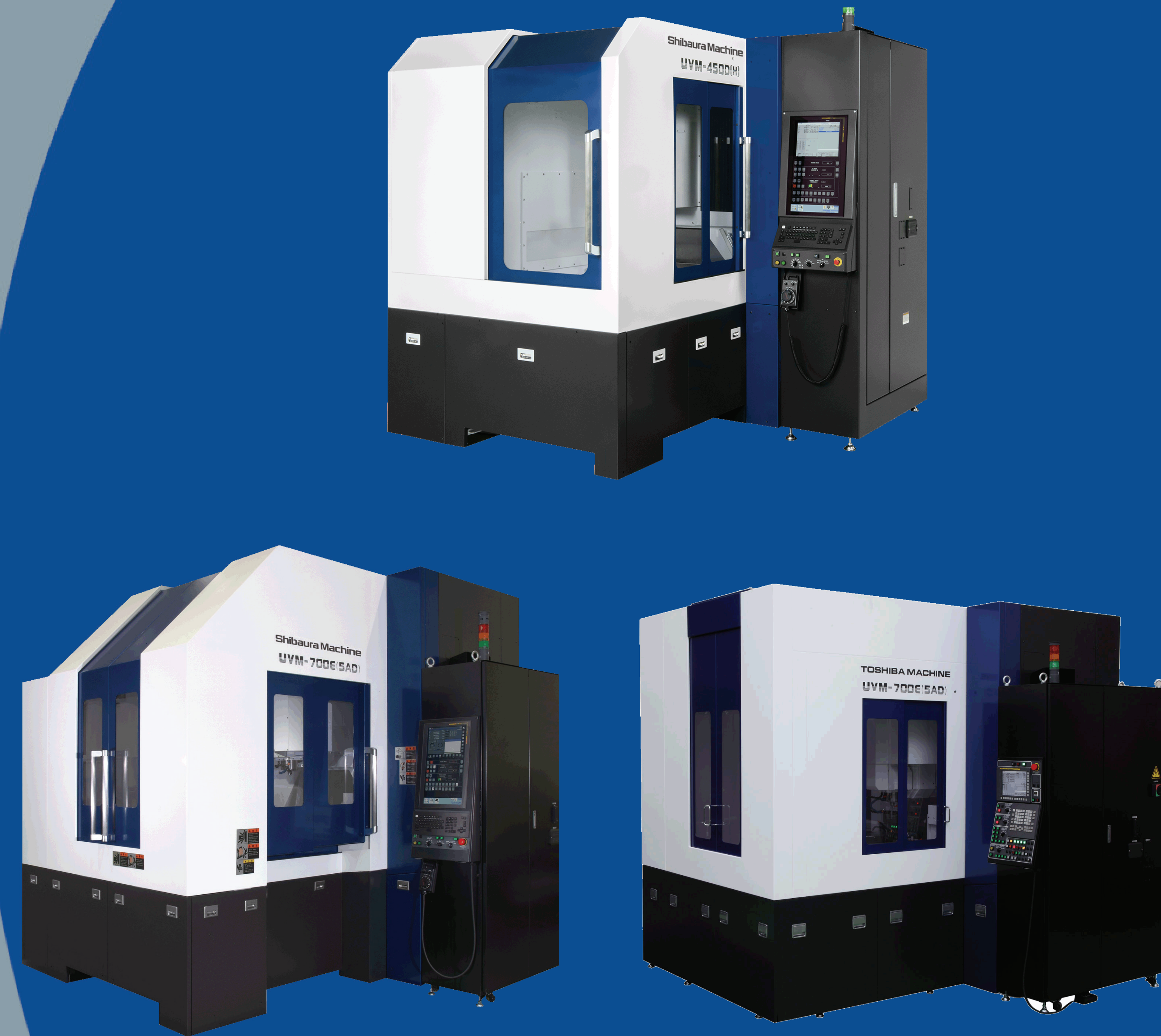


FIG. 2. UVM SERIES LINEUP

3. COMPONENT TECHNOLOGIES

3.1 AEROSTATIC BEARING SPINDLE

Shibaura Machine has been developing aerostatic bearing spindles for their high-precision machine tools since the 1970s. However, general machining centers use ball bearing spindles, and even most machining centers that claim to be high precision use ball bearings. While it is true that for high-precision applications, the bearings are designed to be ultra-lightly pressurized, the rolling elements of the bearing are in constant contact with the inner and outer rings, and so vibration, heat generation, and wear are inevitable when the bearing rotates. Therefore, compared to aerostatic bearings, ball bearing spindles have the following undesirable characteristics: (1) Inferior rotational accuracy, (2) Heat generation during high-speed rotation, and (3) Inevitable deterioration over time.

The aerostatic bearings used in the UVM series have a structure where compressed air is supplied between the rotating shaft and housing to lift the spindle out of the bearing and hold it in place by aerostatic pressure. The air layer smooths out the accuracy error components, making it possible to rotate smoothly like exceeding the machining accuracy of each component adversely affecting the rotational accuracy, such as the roundness and roughness of the rotating shaft and bearings, for reducing the effect of vibrations. Fig. 3 shows a comparison of the actual rotational accuracy measured by a displacement sensor. The ball bearing spindle in the figure on the left shows abnormal vibration errors due to the rolling elements' turning motion as they rotate, while the aerostatic bearing in the figure on the right shows no abnormal vibration errors and rotates with a smooth path.

“SHIBAURA MACHINE HAS BEEN DEVELOPING AEROSTATIC BEARING SPINDLES FOR THEIR HIGH-PRECISION MACHINE TOOLS SINCE THE 1970S”

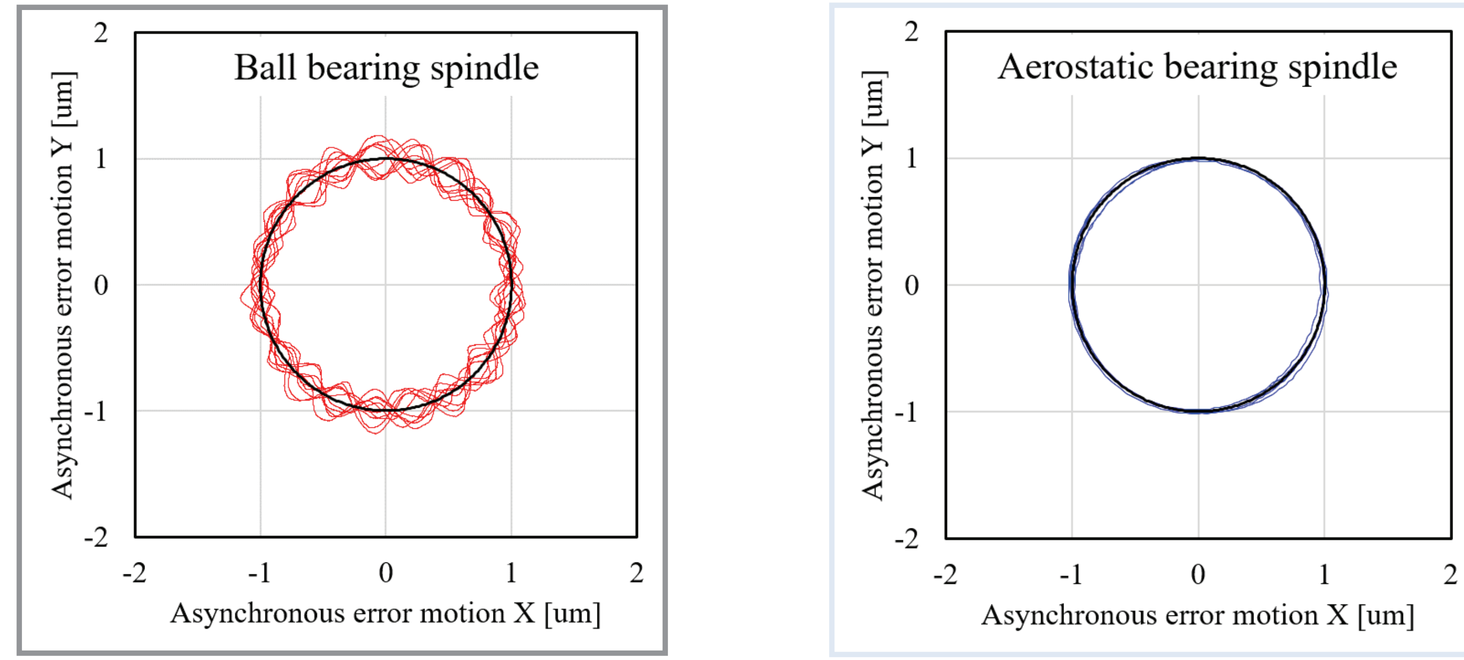


FIG. 3. COMPARISON OF ROTATIONAL ACCURACY

3.2 LINEAR MOTOR DRIVE CONTROL

All linear axis drives of the UVM series are equipped with cored linear motors. The high-rigidity guiding mechanism has a structure that minimizes the degradation of motion accuracy due to magnetic attractive force, which is a concern with cored linear motors, and has the advantage of allowing the setting of high position loop gain and a control resolution of 0.5-nm scale feedback. As a result, the performance of the feed system has been improved to a level where steps of 10 nm can be accurately controlled.

Fig. 4 shows the response waveform for a 10-nm step feed measured at the same actual machining point as the tool tip. The waveform shows that positioning error at the cutting edge was reduced, and accurate and smooth reversing motion characteristics were obtained with high response, which improves the machined surface quality and

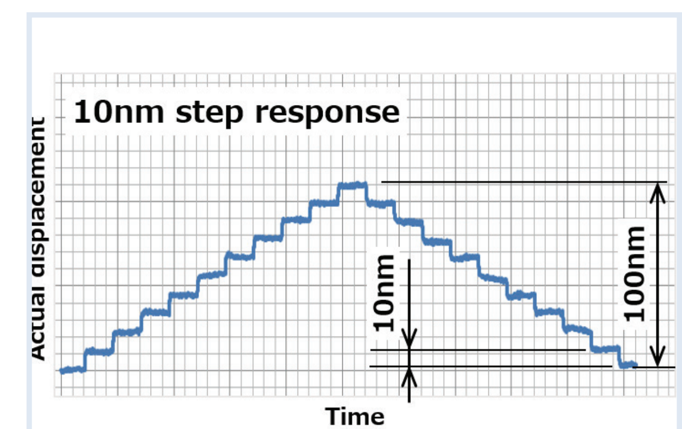


FIG. 4. 10-NM STEP RESPONSE AT MACHINING POINT

minimizes manual finishing such as polishing and deburring in mold fabrication.7)

4. MACHINING TECHNOLOGY

Two main evaluation criteria are used for accuracy in ultra-precision machining. These are form accuracy, which indicates the correctness of the form, and surface quality (roughness), which indicates the specularity of the surface. In the field of ultra-precision milling, in addition to high-precision positioning of the machine itself, high form accuracy has been achieved by calculating the correct tool path using 3D CAD/CAM with high calculation accuracy, and high surface quality has been achieved by using a high-speed rotating spindle to minimize chip formation and to reduce workpiece deformation. However, current machining technology is not adequate for bipolar plate molds requiring high form accuracy, and so we developed a machining technology that corrects the accuracy error component of ball end mills to achieve even higher accuracy.

4.1 HIGH-PRECISION TOOL SHAPE DETECTOR FORMEYE

Tool measuring devices are installed in conventional machining centers to measure the position and diameter of rotating tools for machining. The UVM series also uses a line sensor type tool measuring instrument, which has the capability to measure the contour of the tool itself. However, in the conventional methods for measuring the tool contour, there is a large interior error on the measuring instrument side when the line sensor is switched between horizontal and vertical, resulting in a large step near the 45° angle of the tool, which is a major barrier to achieving high-precision correction machining. Since the sensor structure makes this error unavoidable, we studied replacement of the sensor with a method capable of measuring the tool contour more accurately and found the imaging method to be the most suitable. However, the imaging method tends to result in more expensive units and longer measurement times. There are two reasons why imaging-type measurement takes a long time: (1) Image processing of the entire screen takes time, and (2) Because the phase of the high-speed rotating tool cannot be known when shooting, shooting must be performed repeatedly until the photo with a required phase is taken. For (2), because the aerostatic bearing is manufactured in-house, a rotation sensor for phase recognition can be built into the spindle to identify the phase during high-speed rotation, making it possible to complete the measurement with a minimum number of images. Furthermore, minimizing the number of shots enables shorter times required for image processing, allowing for faster processing. Fig. 5 shows the appearance of FormEye during measurement. FormEye can be installed and maneuvered in the same way as existing tool length measuring instruments, and no special treatment is required. Fig. 6 shows the measurement results for the tool contour. The measurement results show that even a brand new tool has an error of about 4 μm from the ideal round shape, which directly leads to an machining error. Also, this measurement function enables step-by-step monitoring of the detailed progression of damage to the tool edge due to wear or other factors after machining, enabling accurate tool life management.8)

“THE MEASUREMENT RESULTS SHOW THAT EVEN A BRAND NEW TOOL HAS AN ERROR OF ABOUT 4 MICRON FROM THE IDEAL ROUND SHAPE, WHICH DIRECTLY LEADS TO AN MACHINING ERROR.”

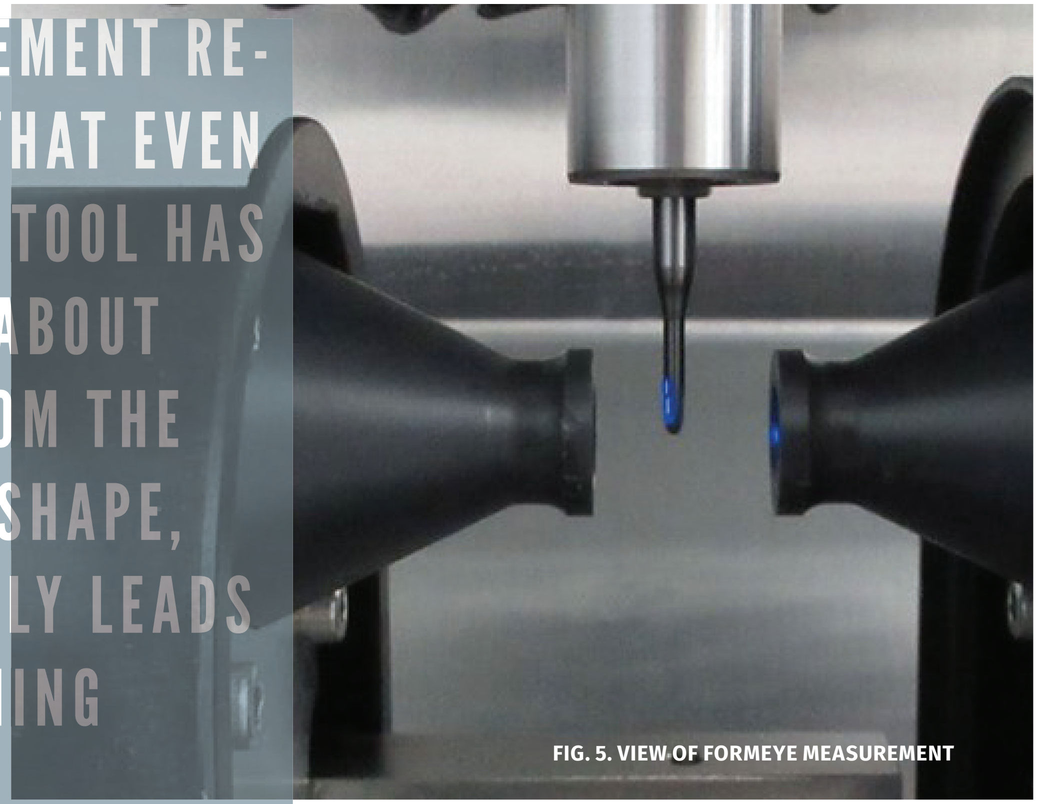


FIG. 5. VIEW OF FORMEYE MEASUREMENT

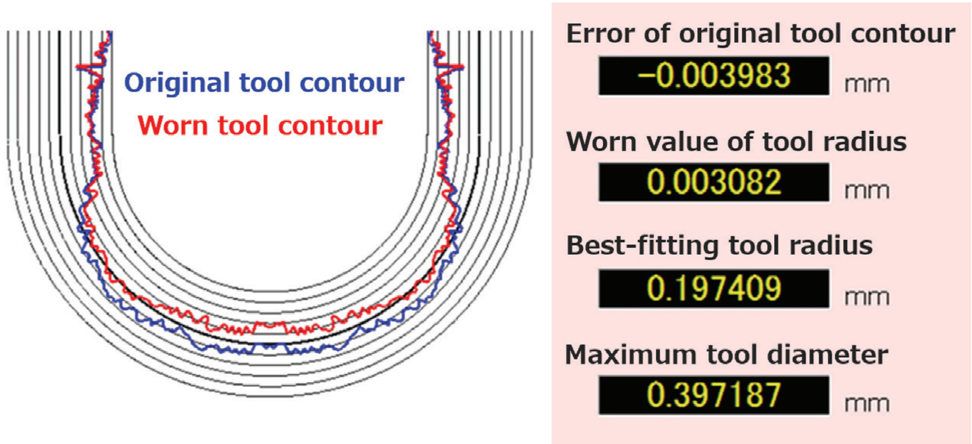


FIG.6 TOOL CONTOUR MEASUREMENT BY FORMEYE

4.2 TOOL PATH VECTOR CORRECTION

Even in ultra-precision milling, the machining process consists of (1) Model creation in 3D-CAD, (2) Machining path generation in CAM, (3) Actual machining, and (4) Measurement analysis. FormEye has made it possible to obtain accurate tool contour data, but currently, no matter how high the computational accuracy of 3D CAD/CAM, only an ideal shape of a perfect circle can be defined for tools. Therefore, if an error of 4 µm is found in the actual tool contour, as shown in Fig. 6, the error is directly transferred to the machined workpiece as a form error component. If the tool protrudes from the perfect circle, which is the ideal shape, the machined workpiece will be over-cut. However, if the tool is receded from the perfect circle, the machined workpiece will have uncut sections. In order to correct this error, information is needed on which direction and how far to retract or advance. Since FormEye provides information on the unevenness of the tool contour, it is only necessary to identify which position of the tool is acting at each selected machining point on the workpiece surface.

To solve this problem, we developed software that provides an error correction function called "tool path vector correction." In tool path vector correction, 3D CAD data is used to identify each contact point of the tool and provide information on which direction to move the tool. Fig. 7 shows a schematic diagram of tool path vector correction. In the conventional process, a tool radius value is input to the 3D model to calculate the NC data for machining. If the result does not pass the subsequent analysis, it can take nearly 100 hours to modify the 3D model and recalculate the NC data by inputting an optimum tool radius value. Furthermore, if the machining results are not satisfactory, this corrective machining routine must be repeated several times, resulting in a tremendous loss of production time. In contrast, the process using tool path vector correction automatically corrects the NC data coordinate values on the machine side based on the values measured by FormEye, making it a "method of error correction not returning to CAM" where 3D model correction and NC data re-creation are unnecessary. This enables significant reductions in loss of production time from non-machining processes.

> "WE DEVELOPED SOFTWARE THAT PROVIDES AN ERROR CORRECTION FUNCTION CALLED "TOOL PATH VECTOR CORRECTION.""

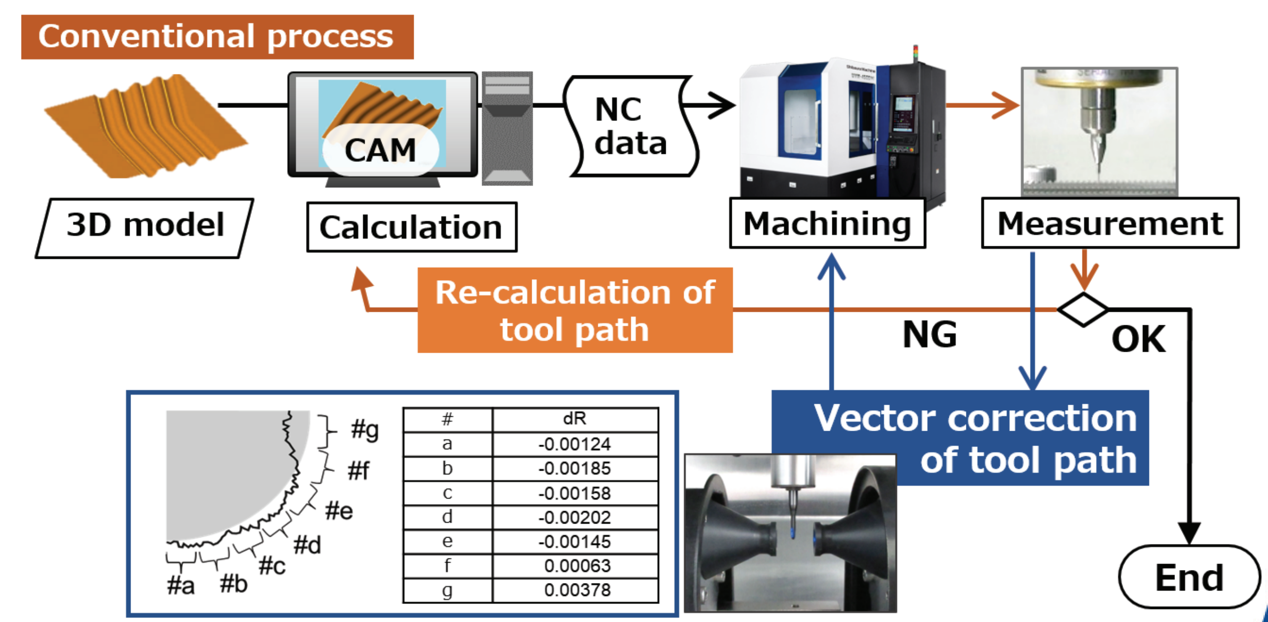


FIG.7 BENEFITS FOR VECTOR CORRECTION OF TOOL PATH

5. MACHINING VERIFICATION

Machining verification of the bipolar plate form was conducted with the aim of improving the form accuracy using FormEye and tool path vector correction. The 3D model and cross-sectional view of the bipolar plate form for machining verification are shown in Fig. 8. The workpiece material was stainless steel for molds (HRC52), and the tool was a cBN ball end mill (R 0.5 mm). Fig. 9 shows the contour accuracy of the ball end mill and the tool correction amount obtained by FormEye's tool shape measurement. The correction amount calculated from the tool contour is minimal around 0° at the tool rotation center, and increases toward the periphery, reaching a maximum of 2.5 µm around 90°. Therefore, when machining without correction, the form accuracy will be 2.5 + α (effect of wear or disturbance) µm, and as the angle of the workpiece approaches the 90° vertical wall, over-cutting due to tool contour error is expected to occur. Using this tool, a machining test was conducted to compare the correction effects with and without tool path vector correction. The form accuracy of a cross section of the machined surface was measured by a FormTalysurf PGI850A (made by Taylor Hobson). Fig. 10 shows the machining results without vector correction. The form accuracy is -3.2 to +0.2 µm (PV: 3.4 µm), which is a large error from the design value and does not meet the required accuracy. While the workpiece surface is cut without error near the 0° angle, excessive cutting is observed as the angle of the workpiece surface approaches 90°. Fig. 11 shows the machining results with vector correction. The results of machining with vector correction show that the phenomenon of over-cutting that was seen without vector correction has been improved, and a form with almost no error relative to the design form was obtained. The form accuracy was -0.6 to +0.7 µm (PV: 1.3 µm), which is less than ±1 µm, which is required for bipolar plate molds.

6. CONCLUSION

This paper describes one example of the development of machining technology for high-precision forming of bipolar plates for fuel cell stacks. In addition to this case, many other industrial products are improving their performance at a remarkable pace, and the component parts are becoming significantly more precise and miniaturized. Consequently, while more and more markets will be requiring nanofabrication technology, there will also be more areas where conventional manufacturing processes cannot be adapted, and so the production process itself needs to be examined beyond the existing framework. We will continue to identify needs from new perspectives and strive to expand the application scope of nanofabrication technology for manufacturing.

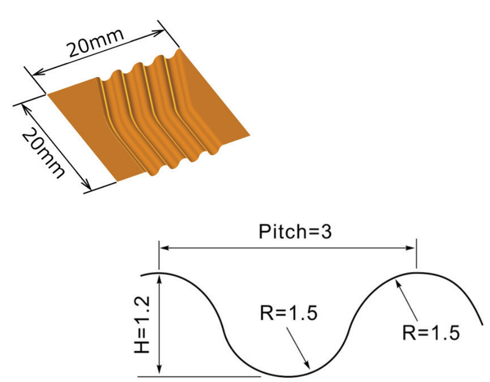


FIG. 8. MACHINING 3D MODEL

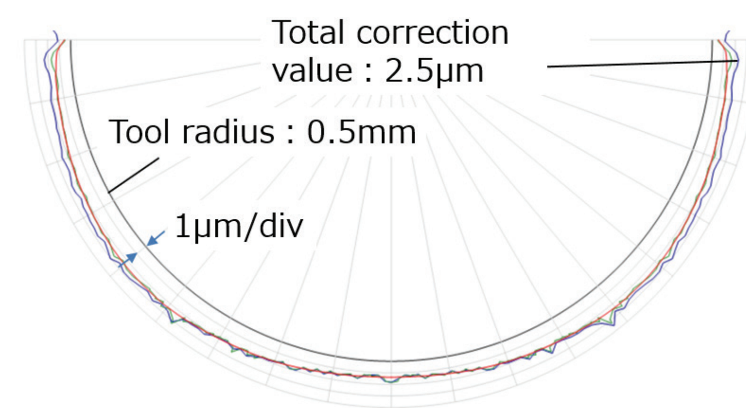


FIG.9 TOOL CORRECTION AMOUNT

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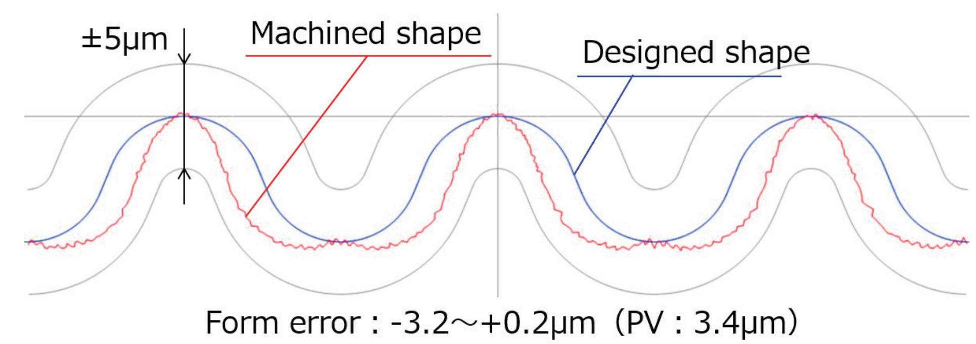


FIG. 10. CRFIG. 10. CROSS-SECTIONAL FORM ACCURACY WITHOUT VECTOR CORRECTION

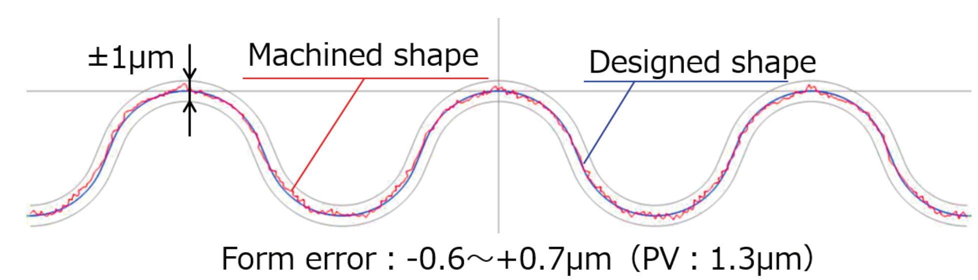
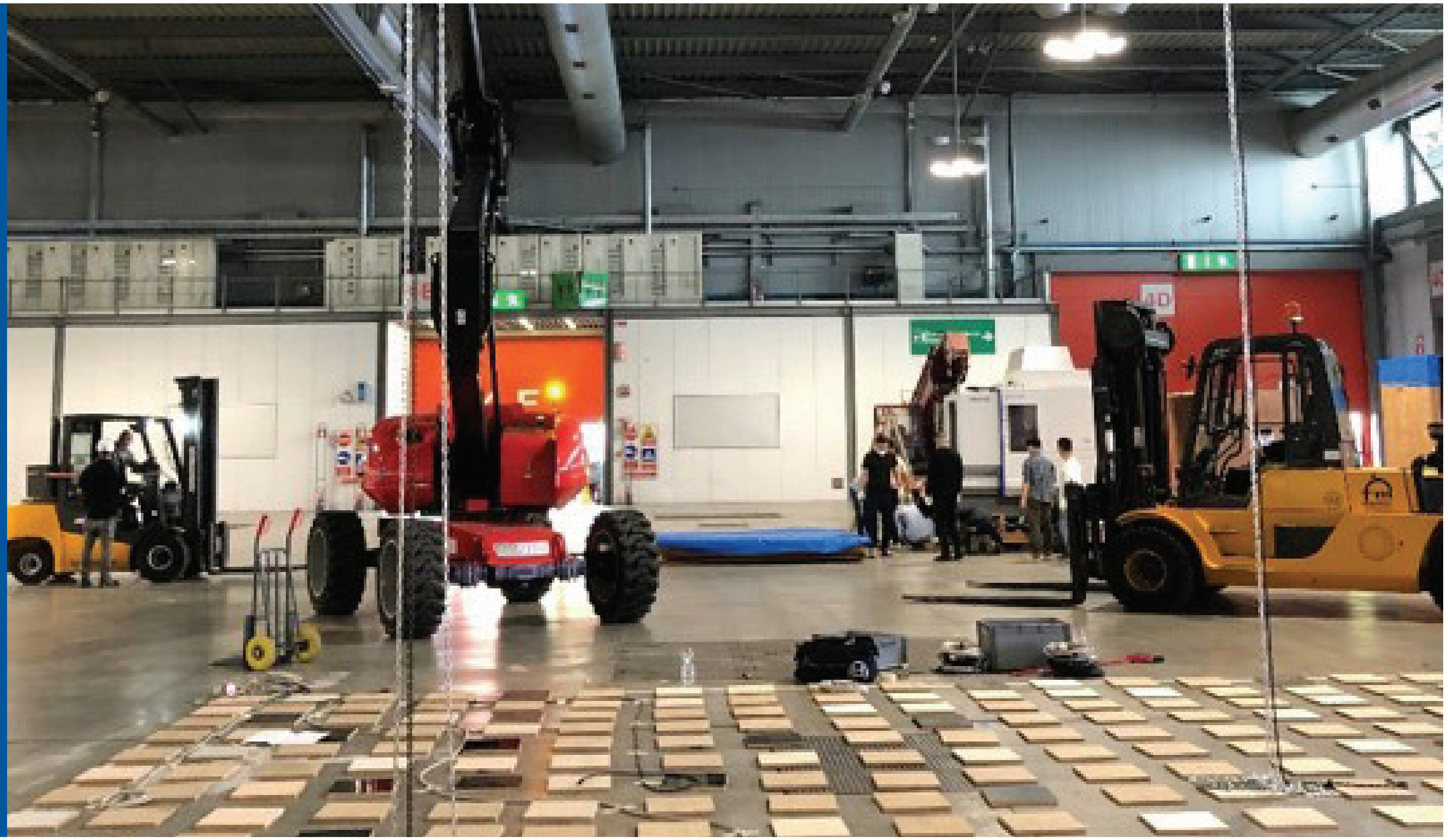


FIG. 11. CROSS-SECTIONAL FORM ACCURACY WITH VECTOR CORRECTION

EMO MILLAN REVIEW

Changing from Summer to Autumn early October, Shibaura Machine had a great opportunities to let the customer in Europe know about who we are, what we do, how our products work at EMO 2021 in Milano. Since we changed our company name from Toshiba Machine to Shibaura Machine, it was the first time to present our company and products in Europe. In our booth, we displayed ultra-precision that integrates our excellent technology, samples machined by UVM series. You may also check our presented samples in detail at EMO from the previous edition of the digital leaflet, named NANOJIN_Autumn.



EMO MILLAN REVIEW

Creating something from nothing, it was so impressed that the booth had been completed rapidly. A lot of exhibitors and visitors from many other countries came by Shibaura Machine's booth and were surprised by cutting hard mold with high form accuracy and fine surface roughness. There were also technical school students who have their fulfilled background in the certain field were interested in our samples like headlight.

SURUGA BAY

WHEN THEY SKY IN THE SURUGA BAY TURNS ORANGE AT SUNSET.
MANY ANGLERS LINE THE COAST OF SURUGA BAY.
FISHES' STARVING TIME IS A GREAT CHANCE TIME FOR ANGLERS.

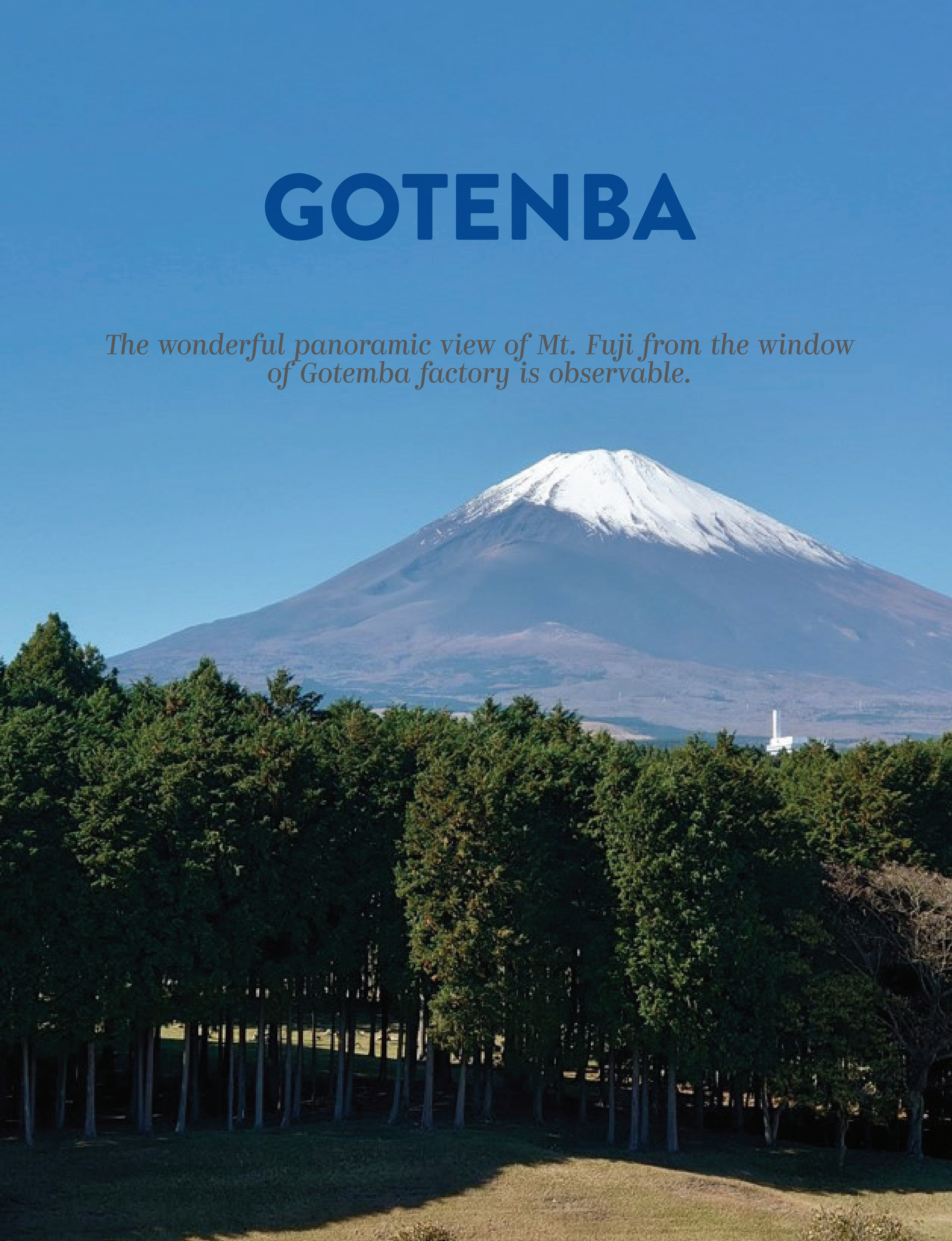
AND OFF THE COAST, A NIGHT FISHING BOAT THAT LIT LIGHTS FLUTTERS THE FLAG OF A BIG CATCH PRAYER AND WORKING ON FISHING.

NUMAZU CITY, SHIZUOKA-KEN, IS A CITY ON THE COAST OF SURUGA BAY, WHICH IS THE DEEPEST BAY IN JAPAN (2,500 M AT THE DEEPEST PART). SURUGA BAY IS KNOWN AS A GOOD FISHING AREA AND IS BLESSED WITH ABUNDANT FISH SPECIES.

THE PHOTO SHOWS A FISH NAMED MAHI-MAHI, A LARGE CARNIVOROUS FISH THAT IS DISTRIBUTED IN THE WARM WATERS OF THE WORLD AND IS CAUGHT FOR FOOD.
IN HAWAII, IT IS KNOWN AS A SUPER-CLASS SPIECES UNDER THE NAME OF MAHI-MAHI.

GOTENBA

The wonderful panoramic view of Mt. Fuji from the window of Gotemba factory is observable.



GRINDING HUB

17.-20.05.2022 • Stuttgart, Germany