Facilities of TAMRON's Foshan factory

The lens manufacturing processes depicted on p.4-37 are from TAMRON's Foshan factory, located in Guangzhou Province, China. The facility covers a total of 30,287 square meters and the factory can consistently carry out all the steps required - from molding through painting, printing, lens polishing and metal processing - leading up to the final assembly. It also encompasses facilities other than the manufacturing lines. Below are some of the facilities.

Cafeteria

The menu includes noodles and rice dishes and employees can choose anything they desire.

Shop

The shop sells candies, cookies and cup noodles. The shop serves as a recreation room after working hours.

Dormitory

Fully equipped with a TV, air conditioner, PC, toilet and shower. A room is used by four or five employees.

Workshops

Classes are held on the subject of camera lenses, management know-how and PC training.

Library

Camera publications and fashion magazines are available for staff. On weekdays, the library is open until 23:00 - making it particularly popular.

Mr. Zhang Shenghai, the General Manager of the factory. Under his leadership, this factory is in operation.

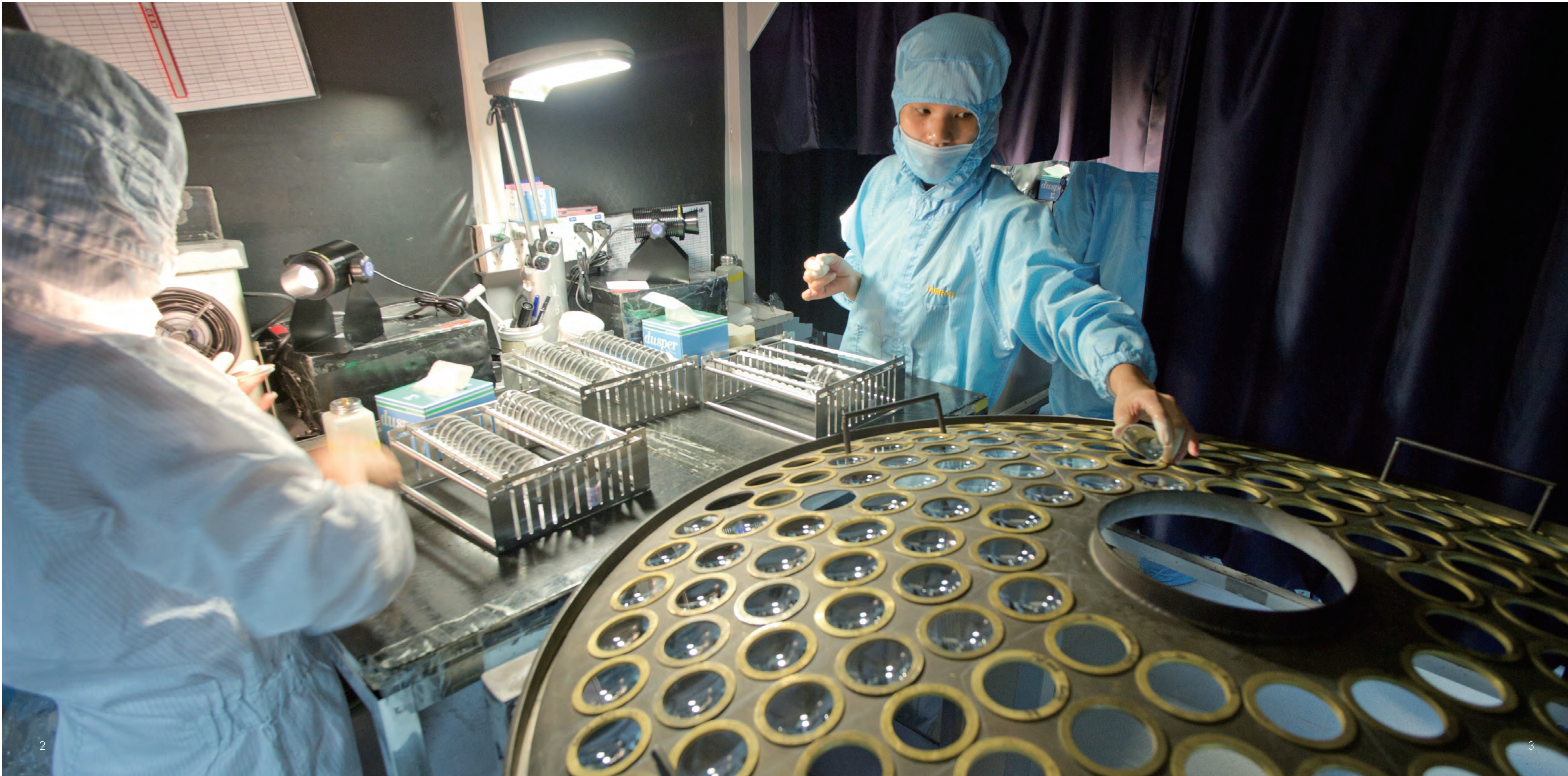
This is a translation of a section on single lens camera manufacturing processes taken from the book "Guidebook on Digital Single Lens Cameras, with Professional Solutions" published in Japan by Natsume Co., Ltd. in 2012.
Photographer: Michio Endo
Designed and Produced by: Ark Communications
Featuring TAMRON Optical (Foshan) Co., Ltd.

TAMRON®

Production Process of a Tamron Lens

Production Process of a Tamron Lens

Tamron's Foshan Factory in China



Flow chart for processing of lenses

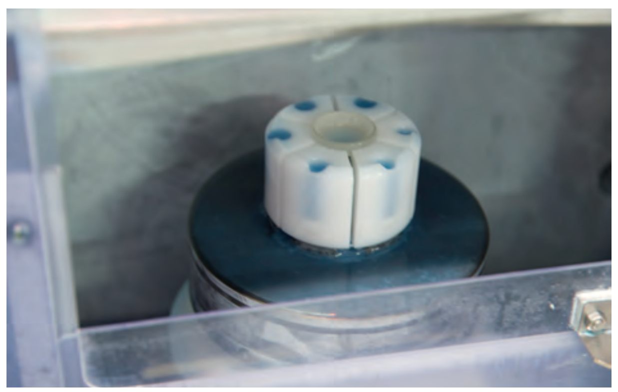
Lens processing is the manufacturing of the lens itself, separate from the exterior components and the metal components. This is the core of a digital single-lens camera and its performance will greatly affect the photographic results. The surface of each lens is initially opaque, but gradual polishing of each side will eventually increase its transparency. The surface is coated and some lenses will be pasted together before becoming camera lenses in their final form to be assembled. This manufacturing process can be seen at Tamron's Foshan factory in Guangzhou Province, China.

1. Melting and pressing glass

To create the predetermined refractive index, raw materials that have been blended, stirred and undergone an annealing treatment (a thermal process that makes the optical capacity as homogenous as possible) are purchased from outside manufacturers.

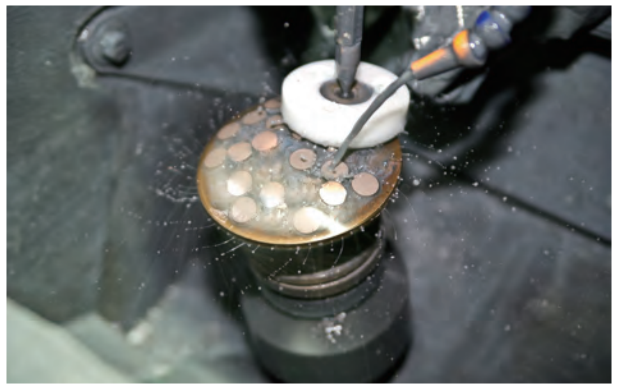
2. Rough grinding of glass

To bring out the thickness of the lens core.→p.6



3. Precision grinding

To smooth the roughly polished surface of the lens and give the curvature radius (R) and the rough surface their final forms.→p.8



4. Polishing

This completes the appearance and performance.→p.10

5. Cleaning

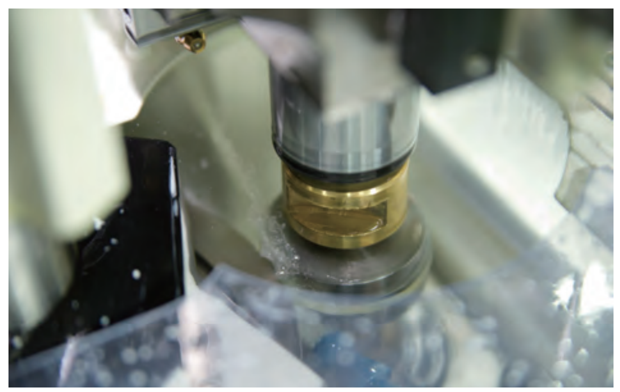
Cleaning dust and dirt from the surface of a lens with water or chemicals.→p.12

6. Process inspection

This inspection will verify the appearance and precision of the lens.→p.13

7. Centering and cleansing

Polishing the outer diameter of the lens in order to bring out the optical axis of the lens. It then undergoes another round of cleaning.→p.14



8. Compounding

To prevent aberrations in a lens, processed aspheric resin is applied onto the surface of some lenses.→p.16

9. Coating

Chemicals and metallic compounds are sprayed onto the surface of the lens, giving it a layer through evaporation coating. This will improve lens characteristics such as its transmittance.→p.18

10. Jointing/Shipping inspection

Optical performance can be improved by pasting lenses of different materials. Inspections are carried out before lenses are transferred for assembly and shipping.→p.22

Production process in Tamron's Foshan Factory may differ somewhat from those in other firms' manufacturing facilities.

Rough Grinding

Rough grinding is the process to polish pre-pressed glass to form a desired lens shape with an approximate curvature radius (R) and core thickness. Relatively large abrasive grains are used to grind the glass at this stage.

1. Delivery of Glass

The affiliated manufacturer delivers glass to the factory after it has been processed to the prescribed refractive index.

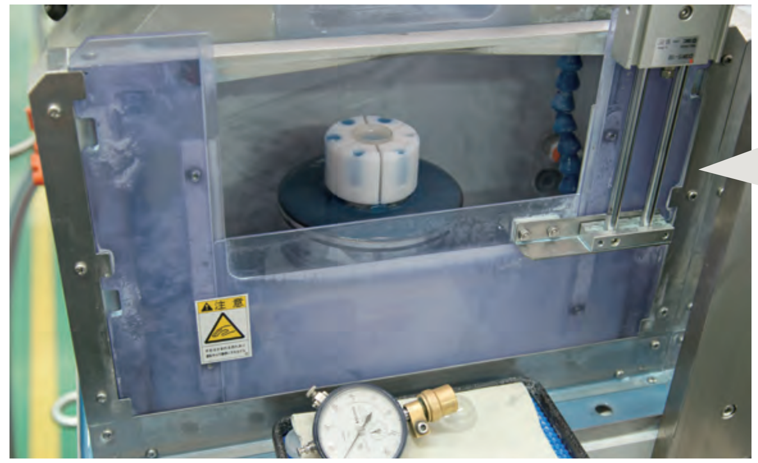
Glass used for relatively small lenses. The degree of transparency remains poor at this stage.

In the rough grinding process, the surface of the lens is roughly polished by a spherical grinder called a “rough grinding machine.” This process removes flaws on the surface of the glass (pressed materials) and molds the glass into the shape of a lens by adjusting the curvature radius (R), thickness and surface roughness.

Glass for relatively large lenses, lined up in a special case.

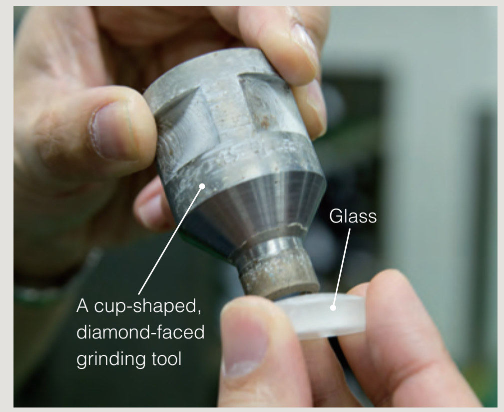
2. Grinding with a Rough Grinding Machine

Glass is fixed to the grinding machine by a jig. The surface is scraped roughly by the diamond-faced grinding machine until it meets the desired shape for the lens.



A rough grinding machine is used to polish the glass. The glass is placed between the grinding plate and the cup-shaped tool, which has diamonds embedded in its grinder and scrapes the surface of the glass.

The process to shape the glass into a concave lens. The cup-shaped, diamond-faced tool rotates to roughly grind the glass.



The process to shape the glass into a convex lens.

The monitor shows the rotation speed, thickness and angles of the grinding machine.

This tool measures the R of the roughly scraped lenses. If the gauge reads “0,” it means the rough grinding has been completed and the lens continues to the next process.

Precision Grinding

Precision grinding is the process to polish the surface of roughly ground lenses to improve their spherical accuracy. Through this process, the lenses are formed into their final shapes.

Precision grinding. During the process, a coolant is used to reduce friction heat created between the lens and the diamond pellets.

For precision grinding, so-called “diamond pellets” – containing abrasive diamond grains – are attached to the grinding plate to polish the surface of the lens. This process increases the spherical accuracy of the lens and advances the approximate curvature radius (R), thickness and surface roughness to their final shapes. The process consists of two steps, “Precision Grinding 1” (S1) and “Precision Grinding 2” (S2), for which different-size diamond grains are used. The first step is S1, with larger diamond grains, while the second step is S2, which uses smaller grains.

The process has two steps, “Precision Grinding 1” (S1) and “Precision Grinding 2” (S2), which are conducted in adjacent parts of the machine.

A test plate. A test plate is a sample that represents the desired shape of the lens, with lenses required to conform to the test plate. The accuracy of R is measured using this test plate.

The machine operator sets the speed and duration of the rotation for precision grinding.

On the right is glass, while on the left is a lens that has undergone precision grinding. The difference in transparency is apparent. After undergoing precision grinding, the lenses are checked for their accuracy in height and thickness before they proceed to the next step.

Polishing

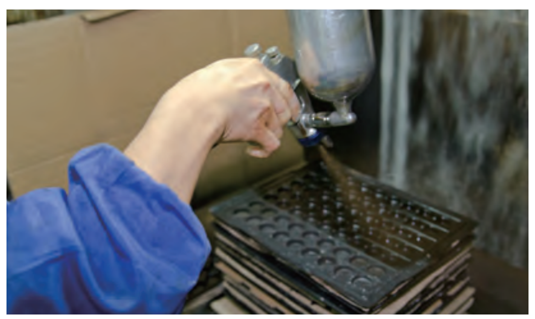
Polishing is the process to finalize the appearance and performance (especially lens curvature) of lenses by improving their spherical accuracy. Special abrasives are used to polish the glass.

1. Applying the Protective Film

Lenses are taken to another room for the application of a black protective film on the opposite side of the surface to be polished. This film protects the opposite surface from flaws, weathering or dirt during transportation or the polishing process.

The protective film is heated at a high temperature for about 30 minutes before being stabilized to the surface of the lens. The picture shows lenses completely covered with a protective film.

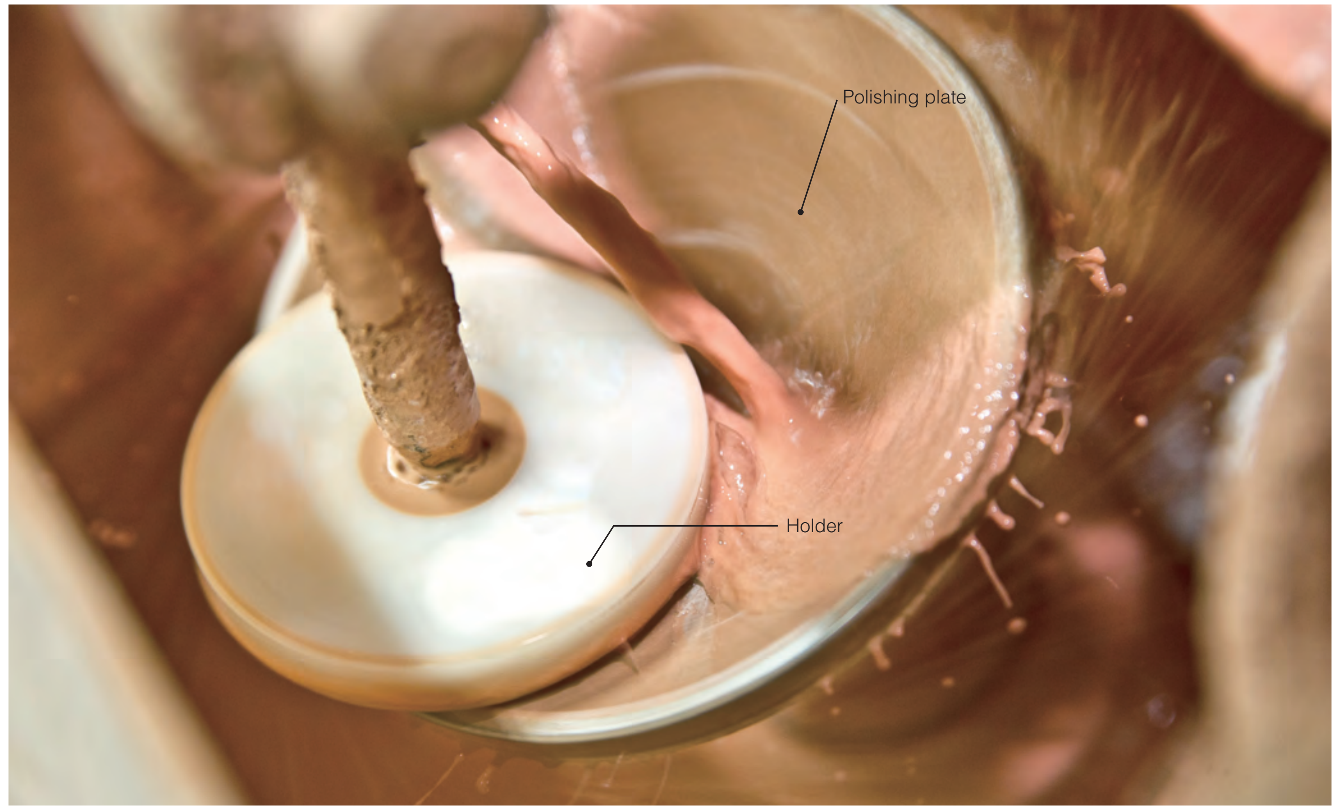
After undergoing precision grinding, a protective film is applied to the opposite side of the lens surface. This film protects the opposite surface from damage during the polishing.
The lens is then affixed to the polishing machine so the surface can be polished. First, the polishing plate is set on the machine, and then the lens is attached to the holder. When the polishing is completed, the lens is transferred to the next step.



The protective film is made of oil. The coating is sprayed on the opposite side of the surface that is to be polished.

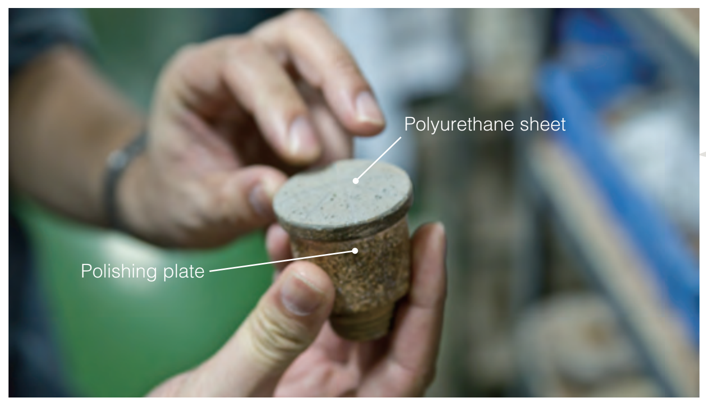
2. Polishing

After being fixed to the polishing machine, lenses are polished with abrasives. In a method similar to the previous processes, the quality of each polished lens is checked exhaustively using the test plate before it can proceed to the next stage.



Lens polishing with brown abrasives. The polishing of relatively small lenses takes about 10 seconds, while large or hard lenses sometimes require several hundred seconds.

Polishing machine. This polishing process is conducted for longer and with even more care than all the previous processes. Dozens of polishing machines can be operated simultaneously.



A polyurethane sheet is attached to the polishing plate, which is made of iron. Since polyurethane is soft, it does not cause any damage to the surface of the lens.

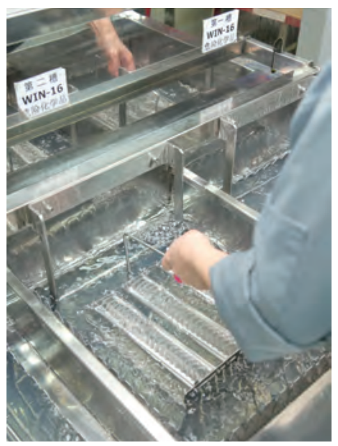
A polyurethane sheet. Depending on the size of the polishing plate, the sheet is cut by scissors and stuck to the plate with glue.

Cleansing

Washing the protective film off the surface of the lens, along with any dust and dirt.
Chemicals, detergent, pure water and alcohol are used in the cleaning process.

The procedure begins with the protective film, any residue of the abrasive agent, dust and dirt being rinsed off. The protective film and abrasive agent are removed with chemicals before the lens is immersed in pure water to wash off any dust and dirt using an ultrasound cleaning process, while the final stage of the process is rinsing with IPA (Isopropyl alcohol).

Two types of water with different degrees of purity are used.

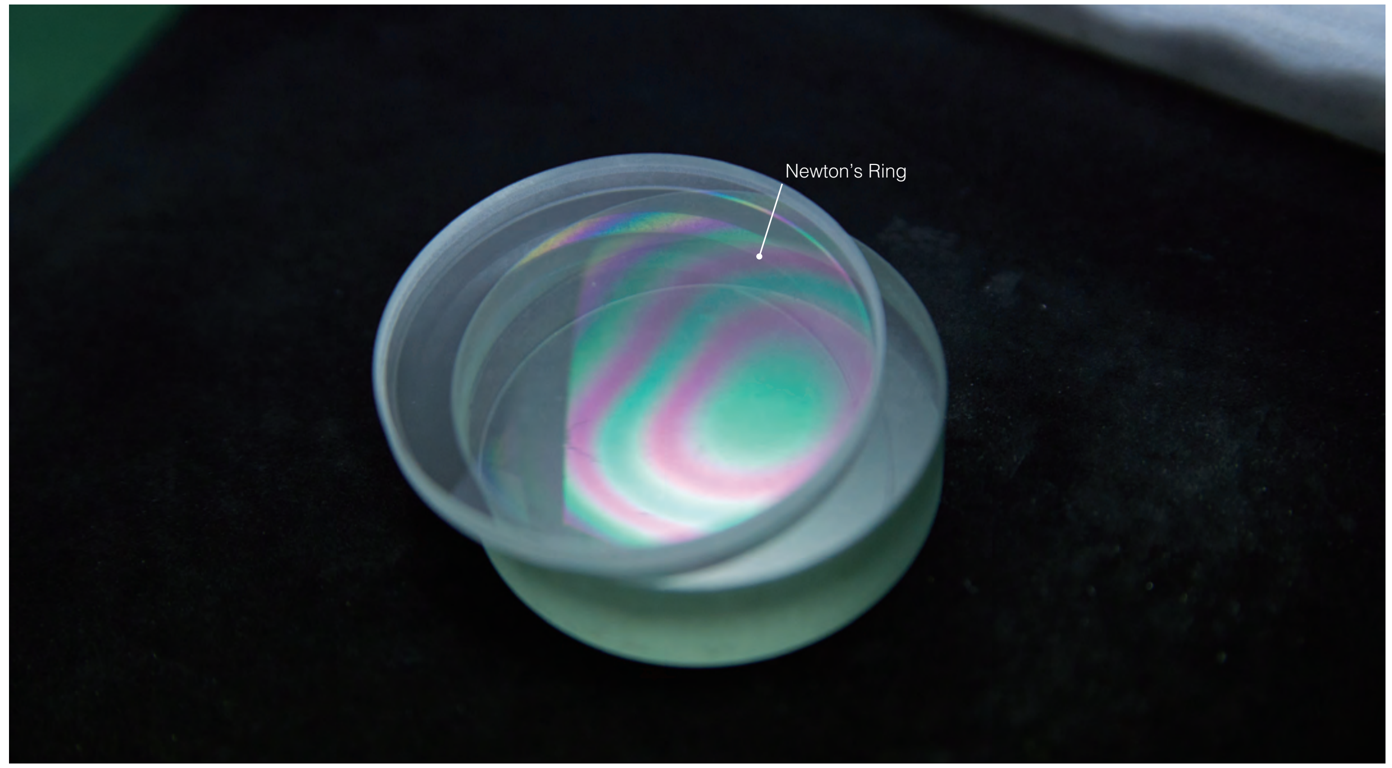


The time spent on cleaning lenses is different in each of the tanks. After a specific period, the lenses are transferred from one tank to the next.

After cleansing, the lenses are lined up in an orderly manner.

Process inspection

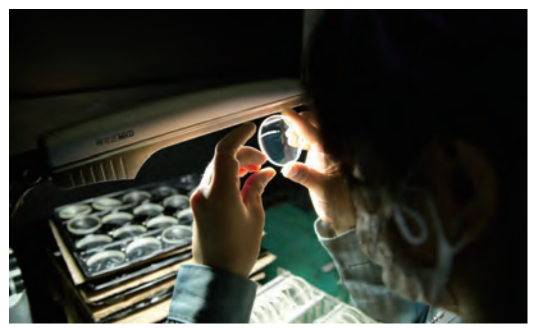
This is a process to inspect the performance and appearance of the lenses up until this point in the manufacturing process. Three inspections are carried out, to examine “spherical surface precision,” “core thickness” and “exterior precision.”



Spherical surface precision inspection: A lens is placed on a test plate to determine its precision by examining the Newton’s Ring that appears on the lens. The number of Newton’s rings differs in accordance with the type of lens.

The entire process brings together the “spherical surface precision inspection” to confirm the precision of the lens, such as its configuration and curvature radius (R), and the “core thickness inspection,” which determines whether the thickness at the core of the lens is correct, while the “appearance precision inspection” checks for any flaws or defects in the exterior.

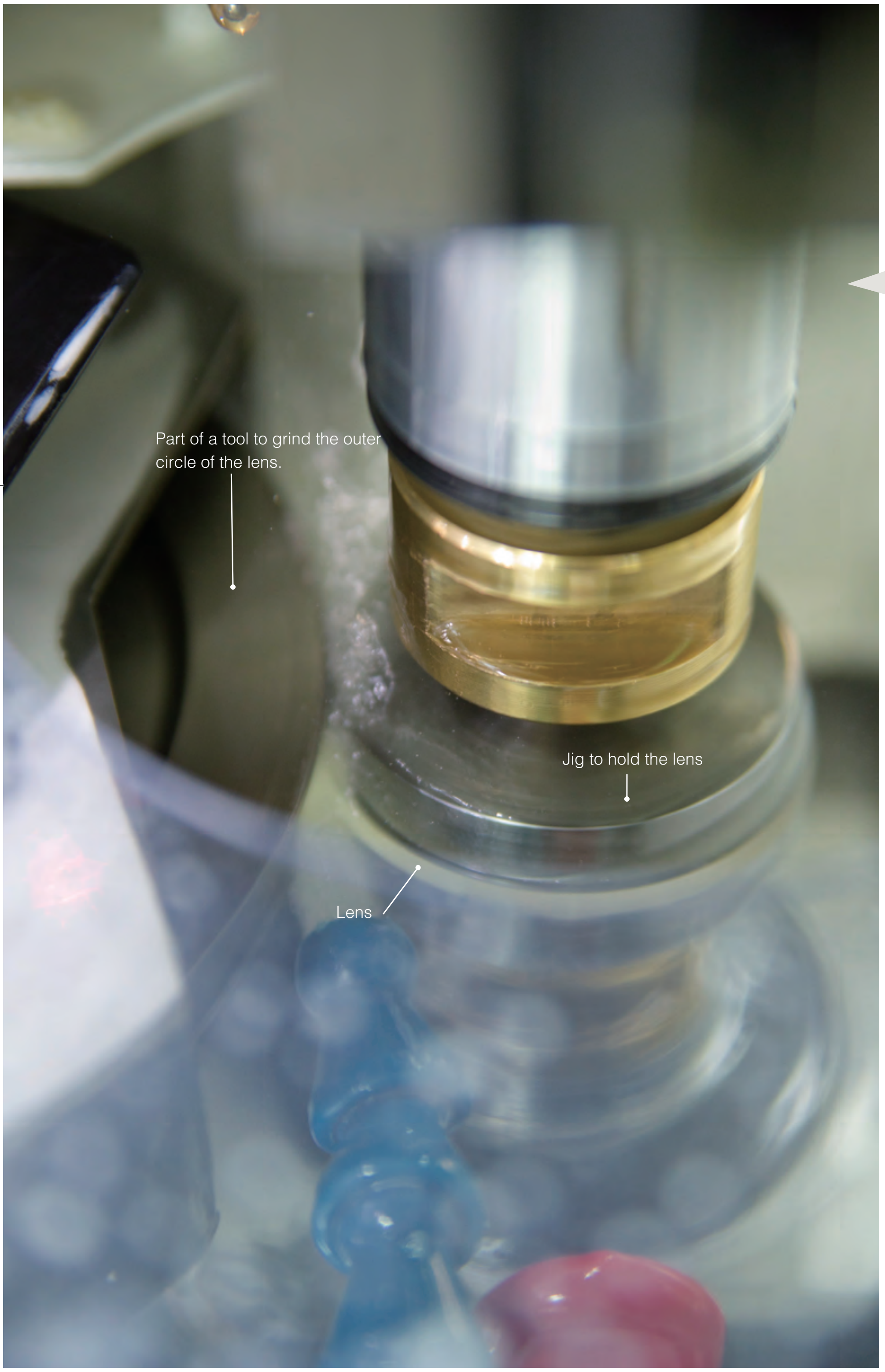
Core thickness inspection: A precision instrument is used to examine the thickness.



Appearance precision inspection: A visual examination is carried out to identify any flaws or dirt by casting light on the lens. If a defect is found, the lens is returned to be ground once more.

Centering and cleansing

In order to draw the optical axis, which is the core of the lens, the outer circle of the lens will be ground to make it completely circular. This is the centering process. When this process is completed, the surface of the lens is once again cleansed thoroughly.



The automatic centering machine. A robot dips the lens into a special oil before the automatic centering process begins.

Automatic centering machine.

A robot grips the lens and automatically moves it to the centering machine for grinding. The automatic centering machine mainly processes large lenses.

Manual centering machine

Centering machine in which the lens is placed manually. The grinding is carried out by the centering machine. Lenses made of soft materials are often centered manually.

Attaching the protective film to avoid damage to the surface of the lens before the centering process.

A lever to precisely determine the grinding amount is beside the hand of the machine operator.

Setting the lens into the holder for grinding.

A lens is placed between jigs for grinding to match the size of the prescribed lens framework.

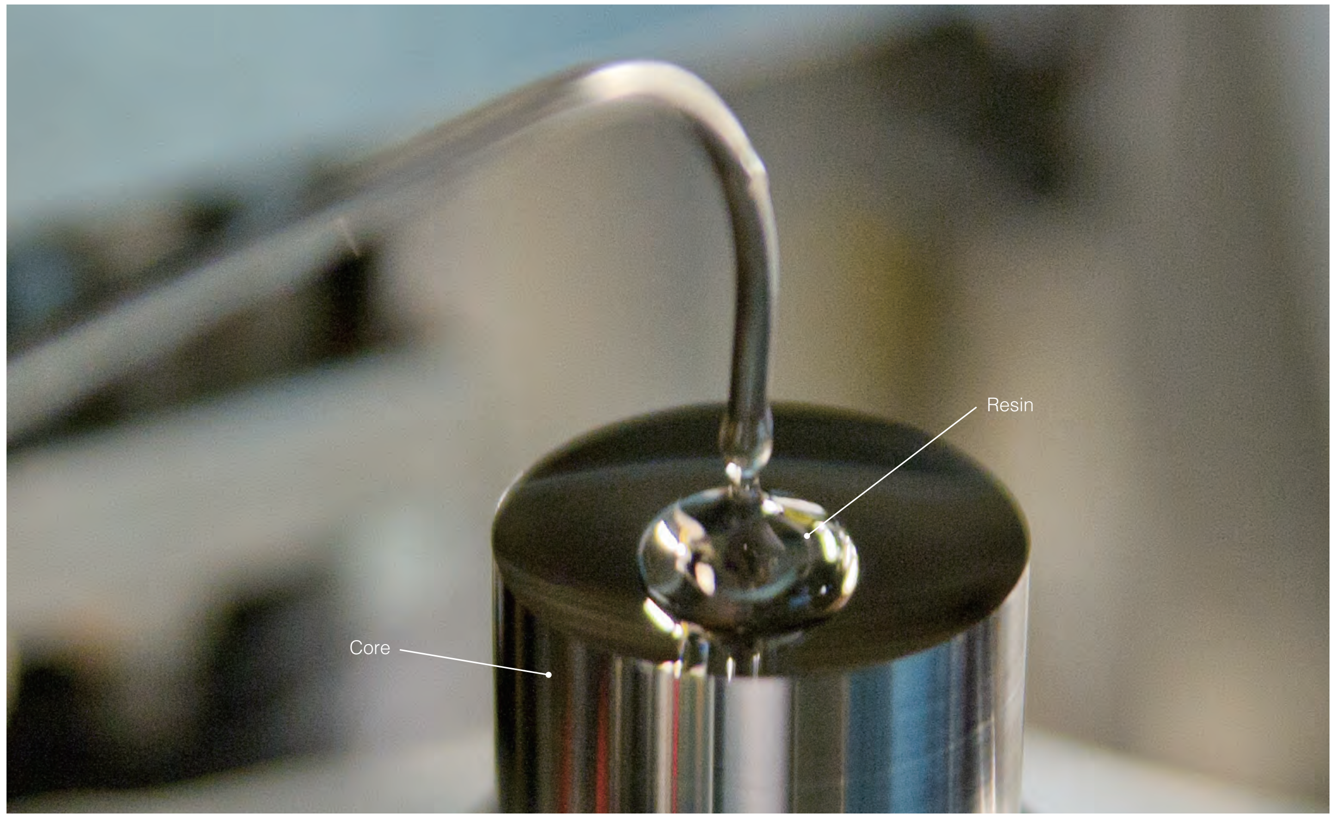
The optical axis, the line that appears in the core of the lens, is absolutely critical to the performance of the lens. The centering process is to grind the outer circle while avoiding decentering from the optical axis, and to finish the lens so that the shape matches the configuration of the pre-set lens framework.

An automatic cleansing machine being used to wash oil, dirt and dust off the surface of the lens. Ultrasound cleansing is also conducted at this point in the process.

Compounding

This is a process required in the production of compound aspherical lenses. A compound aspherical lens can effectively eliminate or correct spherical aberrations and distortions.

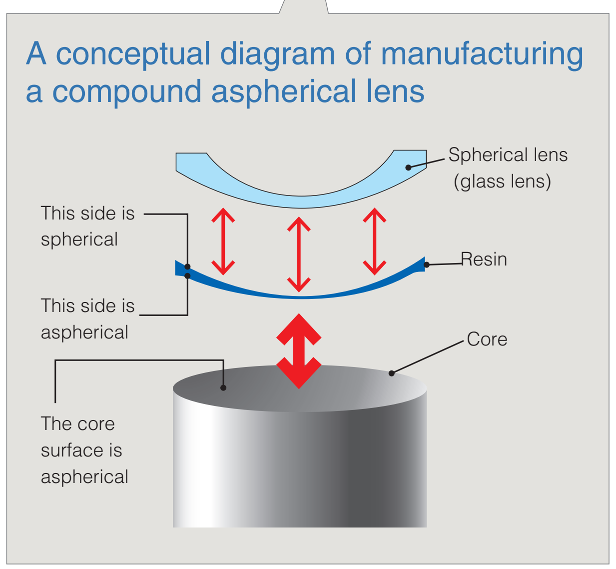
1.



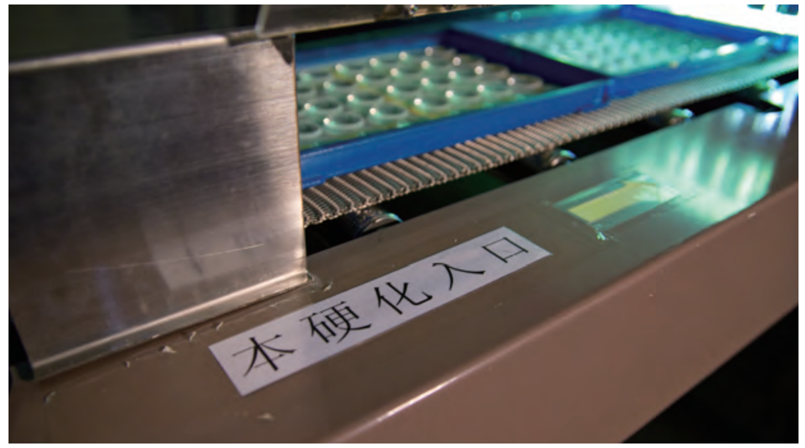
Liquefied resin is dropped on the aspherical surface of the core. The amount of resin applied and its thickness is carefully controlled.

2.

The resin is compounded into the spherical lens and temporarily hardened by being exposed to ultraviolet radiation. An appearance inspection is then carried out to ensure that no dirt has contaminated the process and that the lens and resin are aligned.

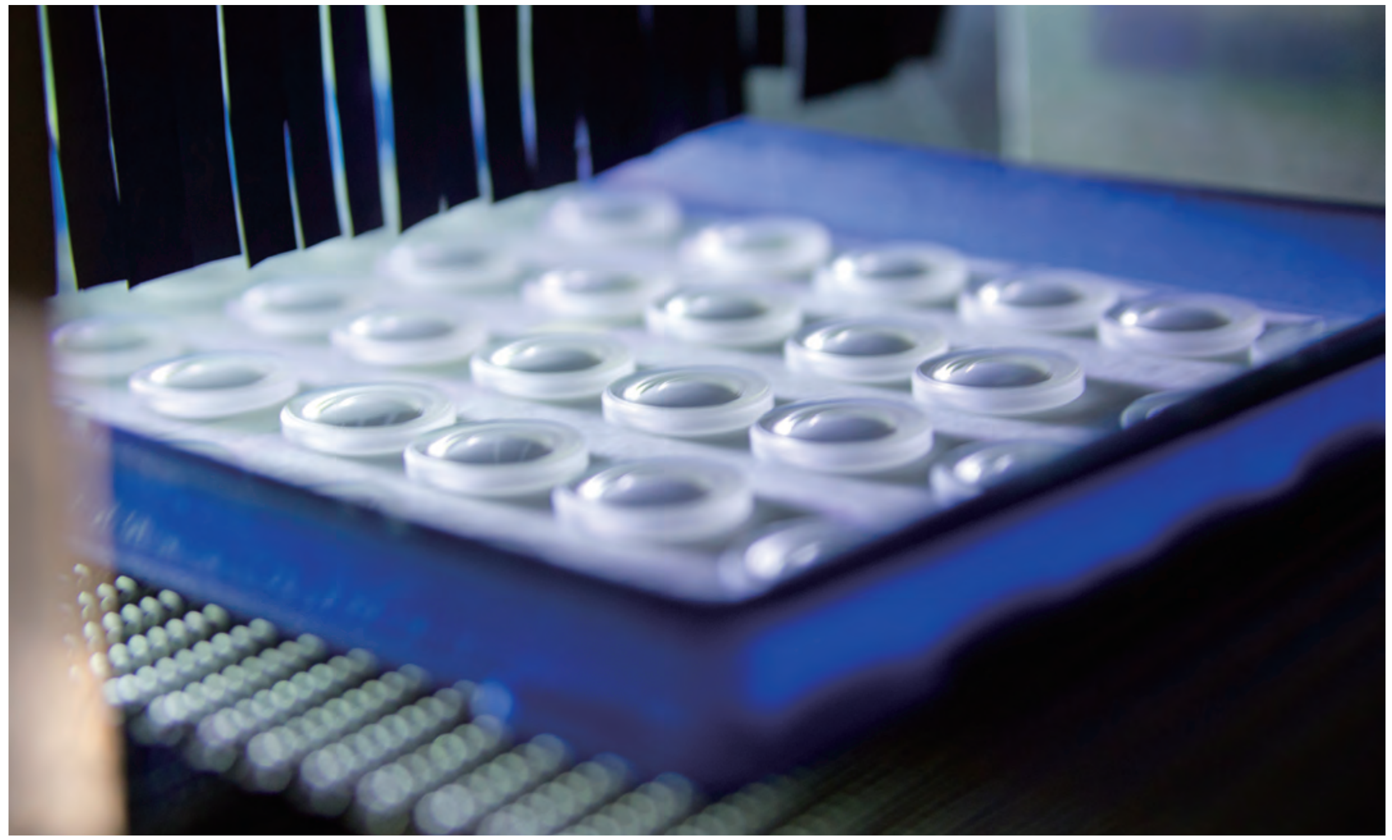


3.



The lens is again exposed to UV radiation to fully harden it. The lens and resin are attached firmly.

4.



Aspherical lenses after UV radiation.

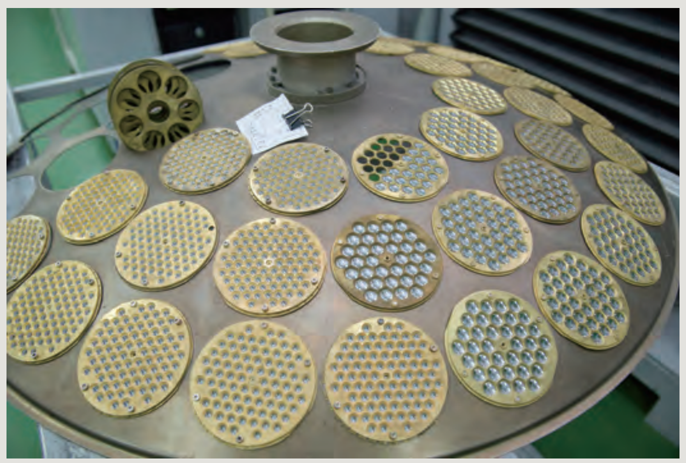
Aspherical lenses have been developed as an effective method of eliminating spherical aberration and distortions.
The compounding process involves resin being pasted on the glass, which becomes the base to make the aspherical shape of the lens and is then hardened with UV radiation.
Aspherical lenses come in wide array of forms as well as the compound aspherical lens, such as glass-molded aspherical lens, and are used with various types of camera lenses.

Coating

The coating process involves the application of thin layers of chemicals and metallic compounds (derivatives) to the surface of the lens by vacuum deposition.
For camera makers, this is currently the most competitive area in technological innovation and manufacturers are investing their own technology heavily in this area.

Inside the coating machine

The coating machine applies multiple coatings to the surface of the lens. The interior of the machine is maintained as a vacuum. The quality of the coatings is ensured through the vacuum deposition of chemicals and metallic compounds to the lens surface with a high voltage electrical current.



The coating dome. Before being coated, lenses are placed in an umbrella-like dome and installed on the upper right section of the device, as seen on p.19. This picture shows a coating dome for relatively small lenses.

The coating dome where the lenses are placed is installed here. Evaporated chemicals rise up and adhere to the lenses through vacuum deposition.

The coating process involves elements such as chemicals being sprayed and applied to the lens. This is done by using the properties and functions of light spectrum (such as light reflection, transmittance, absorption and refraction) from the visible light range to the infrared and ultra-violet light ranges.
There are two main reasons why lenses are coated. One is to prevent light reflection into the lens in order to increase transmittance, while the second reason is to prevent flare and ghosting.

1. Setting

The lenses are placed in a container called a "palette" and installed in the coating dome. This process is conducted in a clean room separate from the coating area.

Dust particles are removed by an air shower whenever anyone enters the clean room.

The coating domes before the lenses have been placed in their holders, are being taken down from the shelf.

After the exteriors of the lenses are checked for flaws or dust particles, they are placed in the palette and into the coating dome.

2. The vacuum deposition process

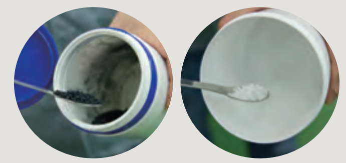
Thin layers are formed by evaporating chemicals and metallic compounds, which are then sprayed onto the surface of the lens via a high voltage electrical current.

The coating dome with lenses placed, is taken out of from the shelf. The clean room where lenses are placed into the coating dome, and the vacuum deposition processing room are adjacent to this area.

The coating dome is installed on the upper part of the coating machine. Chemicals and metallic compounds are sprayed from below onto the lens.

The vacuum deposition process can be monitored through a viewing window.

Chemicals burning at high temperature.



Several types of chemicals are used, such as oxidized aluminum, with high and low levels of refraction index.

Containers for chemicals (left) and granulated chemicals that have melted and solidified (right).

Lenses that have just undergone vacuum deposition. For spherical lenses, multiple coatings are used. The composition of the coating differs according to the lens.

Jointing/Shipping inspection

This is the jointing process, where optical quality is improved (chromatic aberration is reduced) by pasting lenses of different materials (with different degree of refraction) with optic-specific adhesives.

A jointed lens needs to appear to be a single lens. If this is not achieved, the optical axis will be out of alignment and cause chromatic aberrations.
Completed jointed lenses are ready for shipment but will go through the same inspection process as described on p.13, before continuing to the assembly line.

1.

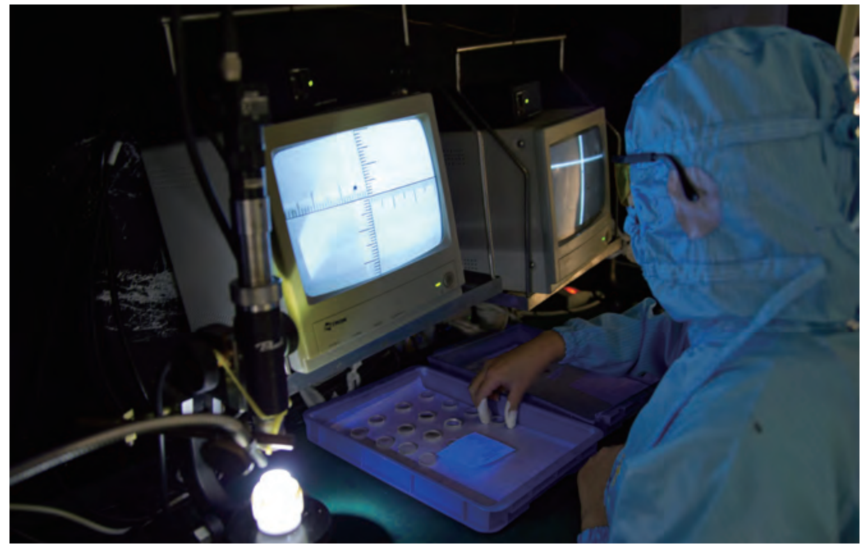
Initially, the appearance is checked for flaws.

The point at which the outer appearance is checked and where the lenses are adhered to each other are in the same operations line.

2.

An optic-specific adhesive is applied to the surface of the lens. The amount of adhesive used is controlled by a computer. The adhesive is applied between the layered lenses and then spread evenly by a machine.

3.



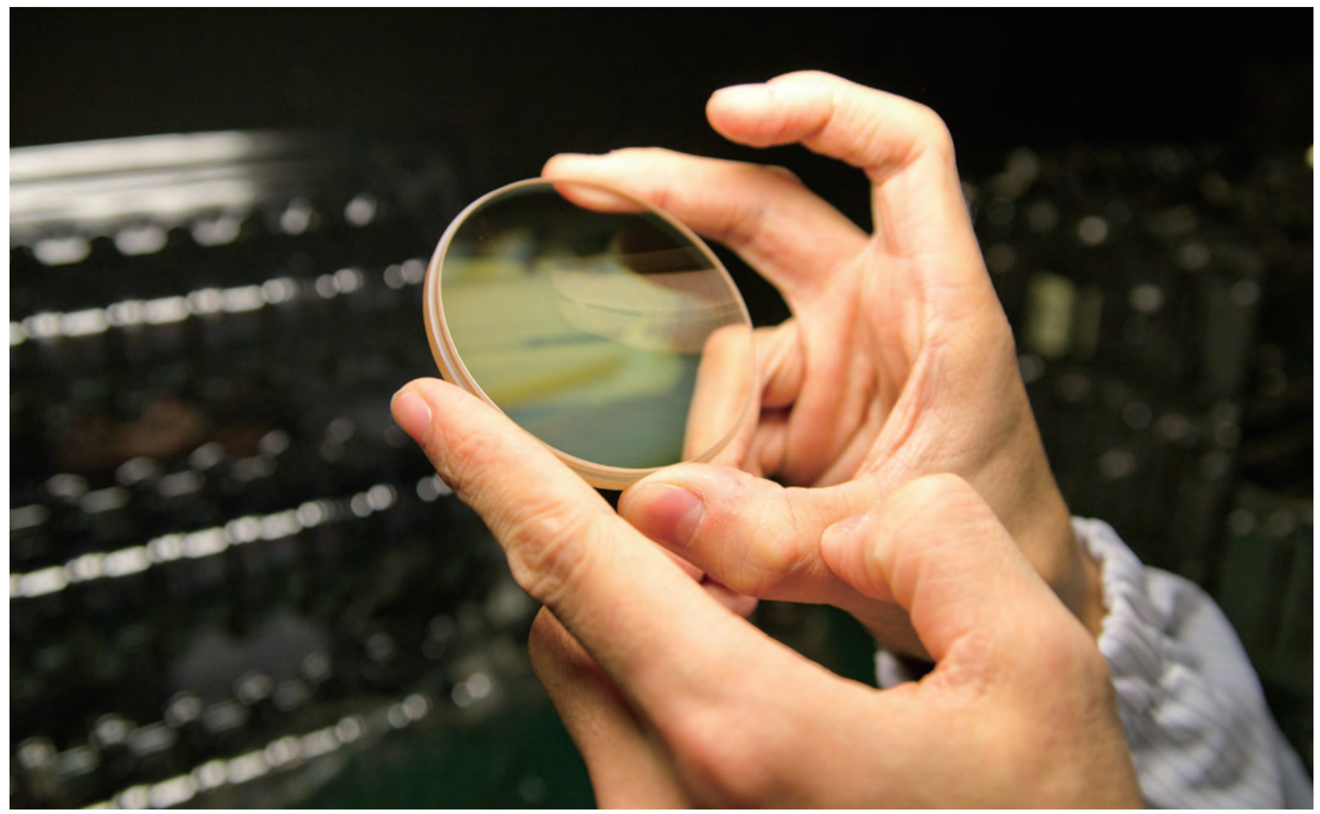
Because the optic axis is out of alignment after the lenses have been layered, a process to centralize and correct the optic axis is carried out. After this, exposure to UV radiation is used to temporarily harden the lenses.

4.

Adhesives smeared out to the periphery are wiped off in a process known as “edge removal”.

5.

A jointed lens is finally completed after approximately 30 to 80 minutes of hardening. It is now ready for the final checks – “core thickness inspection,” “spherical surface precision inspection” and “appearance precision inspection”– before being shipped.

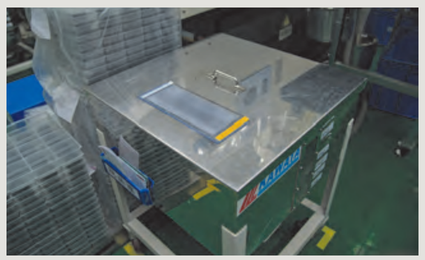


Molding

A camera lens has many interlocking, molded plastic components of various shapes that surround the lens element. This position on the production line manufactures the precision plastic components that are critical to optical products and fabricates and controls the metal molding dies that are used to make the plastic components.

Inside the molding station.

More than 10 molding machines are lined up. The machines manufacture plastic molding components for different lenses.



A stockpile of plastic is prepared beside each machine.

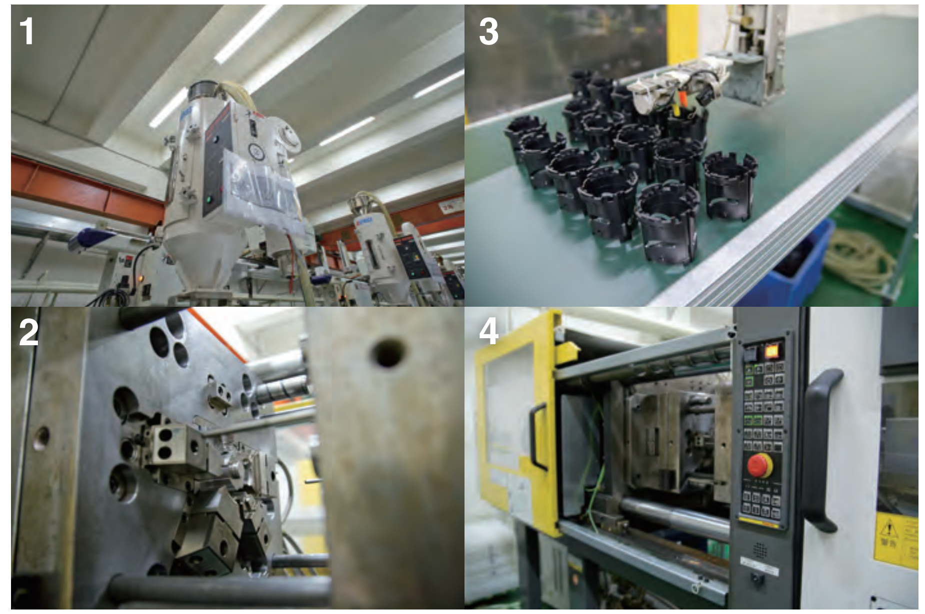
Plastic pellets that are used to make the components. The ratio at which the plastics are combined is altered for each component.

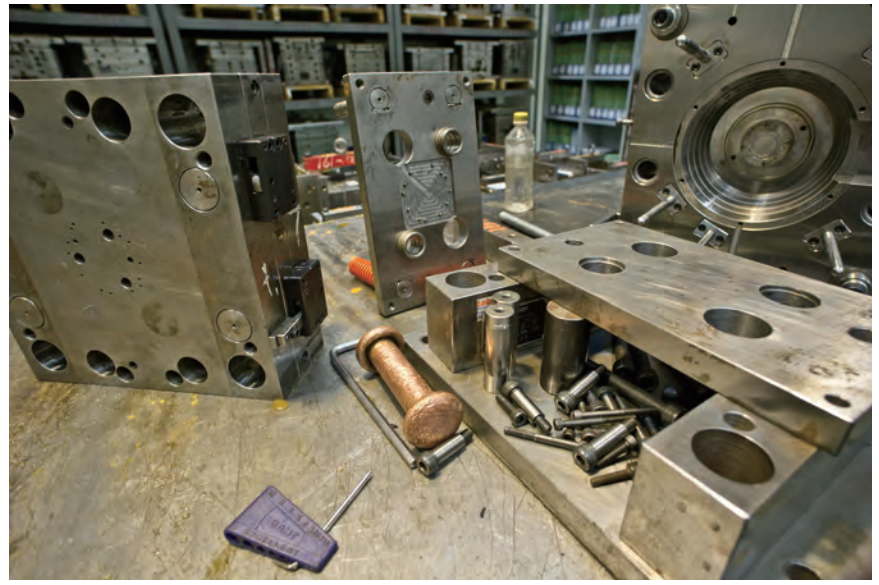
Plastic components include such parts as the focusing ring, which is rotated to bring the lens into focus, the lens barrels and the frames that keep the lens element secure in the designated position. All the plastic components are manufactured through this molding process.

The basic process starts by placing the raw plastic into a molding machine that has been fitted with the appropriate metal mold. The plastic is heated, cooled and dried, before finally emerging from the molding machine as a finished component that has been precisely molded into the designated shape.

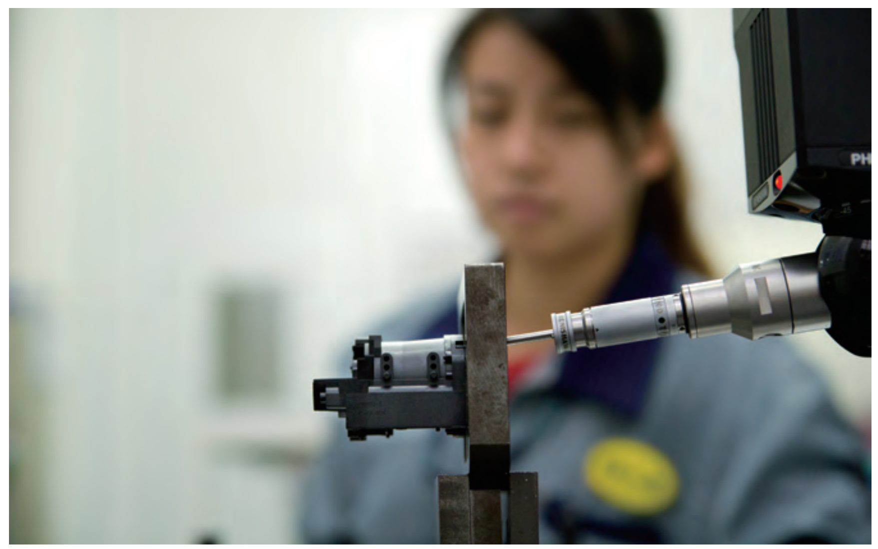
Molding machine parts

1. The appropriate amount of plastic is poured into the upper part of the molding machine.
2. Metal molding dies are placed inside the molding machine. Melted plastic is poured into these individual molds.
3. A robotic arm removes the finished plastic components from the molding machine.
4. A side view of the installation site of the metal mold dies. The machine has a number of settings, including for temperature, time and type of metal molds.





Alongside the molding machines, skilled workers assemble the molds and make fine adjustments as required.



The finished components are taken to a different room for the form and groove widths to be inspected. A three-dimensional measuring device with precision down to 1 micron is used to check the accuracy.

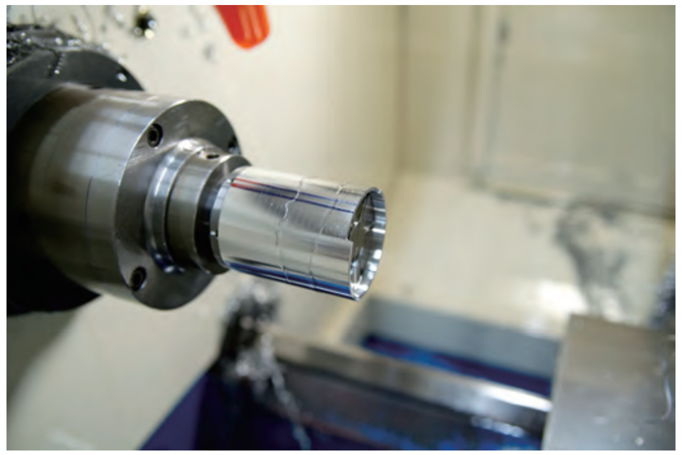
Metal processing

In addition to the lens and plastic components, digital single-lens cameras have metal components that are made from aluminum and other metals. During the processing of the metal, the parts are worked into the desired shape and undergo steps to improve their strength and durability.

1.

Aluminum die-casts before processing. The surface has not been polished and the grooves have not yet been cut.

2.



The surface is shaved and polished to a mirror-like finish. The aim is to reduce friction when the parts come into contact with each other.

3.

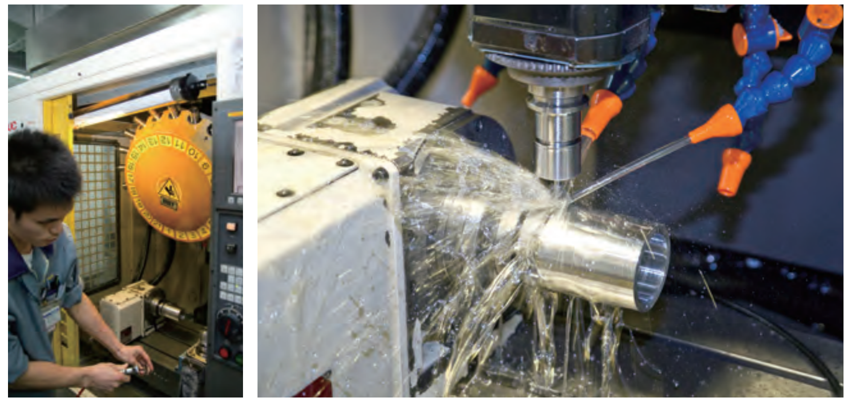
The die-cast on the right has not been polished; the one on the left has completed the polishing process. The difference is apparent. A mirror-like finish is an important part of metal processing.

The processing of the metal involves a series of procedures that include shaving the metal using a numerical control (NC) lathe, polishing the surface to give it a mirror-like finish, heating components at high temperatures to prevent deformation, machine-drilling holes as required and groove-carving to make cams and grooves. After all these processes have been completed, the precision of the surface finish and shapes are measured.

4.

Metal components are placed inside a heating compartment. The dies are heated at a high temperature for several hours.

5.

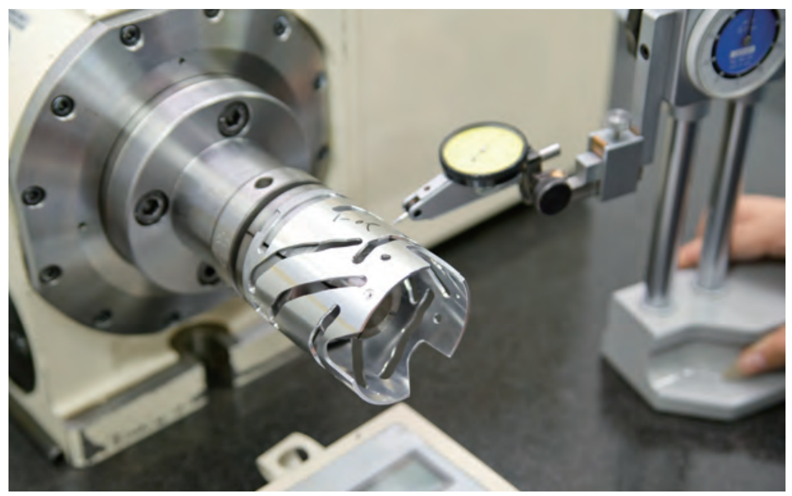


Holes are drilled during the machining process. The holes allow parts to interlock with each other. The drill forms are changed as required.

6.

A technician is measuring the angles of the groove of a metal component that has completed the groove-carving process. This becomes the cam for the lens unit.

7.

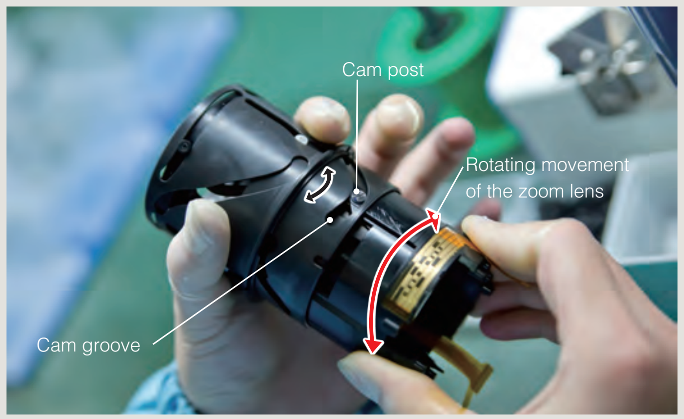


The processed parts are taken to the metal processing measurement room. The roughness of the surface and the angle, length and width of the cam grooves are verified. In this photograph, whether the cam groove width has been carved to specification is being checked.

Assembly production

The lens, plastic and metal components that have been separately manufactured are now ready to be assembled into a camera lens unit. The components are assembled one at a time, with the utmost care. It should also be noted that rigorous inspections are carried out at every step. Here, we will take a look at the assembly of a zoom lens.

A technician carefully attaches the cam mechanism, a critical component in a zoom lens, to the main body.



The mechanism that moves the lens component when the barrel is rotated.

The first step is for the cam to have grooves cut into it. Cam posts are set into the cam groove (more precisely, a lens barrel with posts) and the movement of the cam and the cam posts facilitate the movement of the lens. As can be seen from the photograph, the grooves on the cam are designed to allow the shaft to lengthen and shorten. When the zoom lens is rotated, the cam and the cam posts move along the groove, allowing the lens to move.

The assembly process can be roughly divided into a “Sub-line” that assembles various components into larger components (known as ASSY), and the “Main-line,” which puts together ASSY components to complete the final product, which is the lens unit. Here we will take a look at the major procedures for both the sub-line and the main-line. (Note: The procedures may not necessarily follow this precise order).

Initially, the surface of the lens is cleansed with a cleaning agent. The lens is then placed inside a lens casing and set in place.

1. Assembly on the Sub-line

Taking the diaphragm ASSY and the image stabilization ASSY as our examples, we will follow the steps required for their assembly.

Diaphragm ASSY and image stabilization ASSY

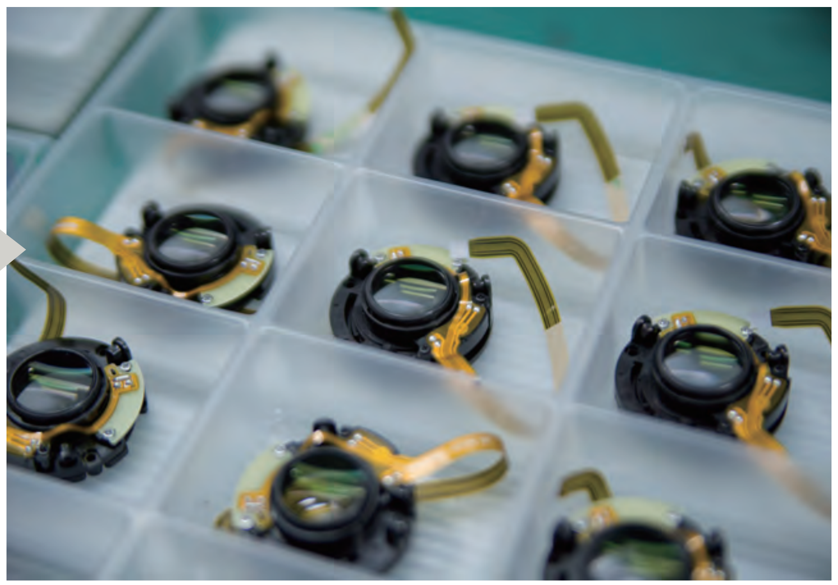
Assembling the diaphragm ASSY

A technician uses tweezers to pick up the diaphragm blades and lays out the required number of components.

A diaphragm motor is placed on diaphragm blades on a jig.

A technician constructs a motor to move the diaphragm.

A diaphragm motor undergoes checks of its pulse, aperture and energization.



After adjustments to the pulse and size, the diaphragm ASSY is now ready to go.

Checking the performance of the image stabilization ASSY

In order to complete a valid inspection, the image stabilizing lens component that makes up the image stabilizing ASSY is checked thoroughly.

Combining the diaphragm ASSY and the image stabilizing ASSY

The image stabilizing ASSY (above) and the diaphragm ASSY (bottom) are put together.

After the diaphragm ASSY and the image stabilizing ASSY have been combined, a technician makes sure that the optical axis is aligned.

AF Motor

A reduction gear (the silver component) and other parts are combined to create the AF motor. The AF motor uses a Piezo Drive. Tamron was the first company to adopt the Piezo Drive in an AF motor for a camera lens unit.

A technician uses electric signals to make sure that the motor is working.

2. Assembly on the Main-line

In this process, the respective ASSYs, the lens and the lens barrel are assembled – with the familiar camera lens appearing before our eyes. During this process, numerous components will be put together and an exhaustive series of checks are carried out to ensure that the optical axis is aligned, that the focusing works and that the electrical interlocking with the camera body is secure.

1.

A technician makes sure the image stabilizing ASSY and the lens are in the correct position before combining the components.

2.

The shaft frame is interlocked with the main body. The cam with vertical grooves, integral for a zoom lens, is also added.

3.

A dust-repellent sheet is attached using tweezers, before the front frame is placed over it.

4.

The brush (or electric contact) is added. The brush is a component that allows the lens element to recognize such information as the focal length of the zoom lens and the position of the zoom ring.

5.

The AF motor and the reduction gear ASSY are attached to the body.

6.

The main circuit board is attached. The main circuit board receives instructions from the camera body through the lens mount and conveys orders to the respective lens components. It serves as the "brain" of the lens unit.

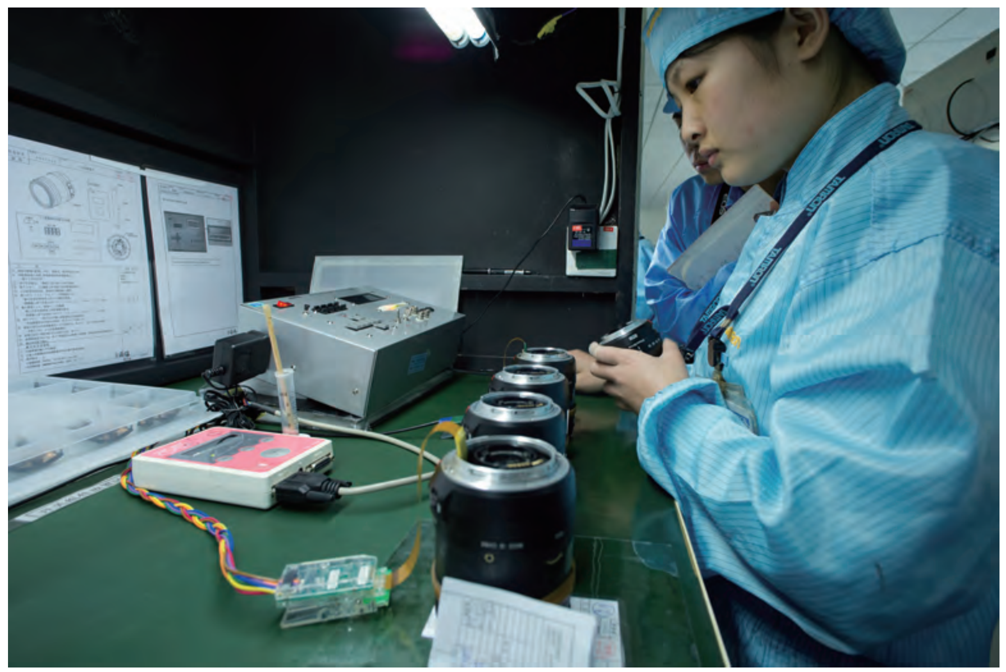
7.

The rear lens barrel is attached. This barrel forms the back side of the lens unit.

8.

The mount is placed on top of the rear lens barrel. The mount is the part that connects with the camera body.

9.



To ensure the lens operates correctly, data pertaining to image stabilization and so on is written to the main circuit board.

10.

"Group 2", "Group 4" and "Group 1" are added to the main body, followed by the front lens element. (A group of lenses, whether single or multiple, are counted in "groups").

11.

Adjustments are made to the flange focal distance to ensure the focus works correctly at infinity (i.e. when focusing on far away subjects). If necessary, washers, which come in various thicknesses, are added to ensure accuracy.

12.

Image resolution adjustment. The resolution of the lens is checked inside a dark room. A sheet printed with patterns and numbers is inserted between the lenses and the image is projected onto a mirror at the front to verify the resolution.

There are specific scales and standards to test the visibility of the numbers and patterns that are projected onto the mirrors.

13.

A masking plate, to prevent unwanted light from entering the device, is applied. The flange focal distance is tested once more, followed by a re-adjustment of the image resolution.

14.

The camera and lens are connected by a cord to check the precision of the diaphragm as well as aperture diameters.

15.

The lens is attached to the camera and a technician checks the AF/MF switch, the level of operating noise and overall smooth operation.

16.

A technician rotates the zoom lens to get a feel for the torque and response.

17.

A visual check is then conducted for overall operation, the exterior, debris or marks – concluding the Main-line assembly process for the lens unit.

18.

The product is then taken to the quality assurance department for a final check. Here, a fresh pair of eyes will give the unit a final once-over, check the exterior and test the camera.

Packaging

All finished lenses are transported to the packaging station. The important point here is to avoid defective or inadequate packaging and to ensure “traceability.”

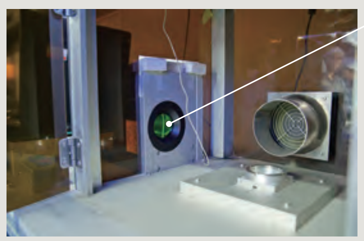
Packaging is carried out on assembly lines. The number of packages to be packed each day is set according to timing and by type of lens.

1. Serial Number stamp

“Traceability” is the process to keep track of when and where a product was manufactured. Each lens has a serial number stamped on it for easy management.

1.

Machine to stamp serial numbers. The monitor shows the serial number and the position of the stamp.



A laser beam is used to etch the serial number on the lens.

2.

The door is closed and the button is pushed to activate the laser beam.

The button has settings for “start” and “emergency stop.”

3.

A serial number etched by a laser.

2. Packaging operation

Packaging is carried out efficiently and systematically. The workbench is a conveyer belt that can be adjusted for speed. And packaging per hour is well managed and controlled.

1.

Lenses before packing.

2.

Outer packaging boxes are assembled and seals are pasted on them.

3.

Lenses are carefully wrapped in protective sheets and placed in the outer packaging boxes.

4.

Bar codes are read to register serial numbers. This process allows shipping dates to be stored.

5.

After the products have been packed, they are weighed. Defective packaging can be checked here.

6.

Boxes are packed in lump.

3. Random quality inspection

Some of the boxes containing lenses are opened for random inspections. Final checks are carried out on the quality of the products inside the packages.

After a thorough inspection is carried out, the packed cartons are stored before being shipped to all corners of the world.