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Cover photo: "Vitryxx," the bioactive glass powder from SCHOTT, is an important new base material for cosmetic products. The glass-like minigrains have an anti-inflammatory and an anti-microbial effect and will first be used in color cosmetics and deodorants. Eye shadow based on glass powder has also been produced experimentally (see page 8).

Photo: Thomas Bauer
The Image Bank (Background)

Hans Morian
Mainz

Exploring Space

In 1903 SCHOTT supplied the first mirror substrate of a larger dimension for a telescope. Ever since, astronomical mirrors made by SCHOTT have been making decisive contributions to the exploration of the universe. Here are some highlights of the past 100 years.

University of Heidelberg

The first mirror telescope of the University of Heidelberg began operations on the Königsstuhl in 1906. The mirror substrate from SCHOTT measured 720 mm.

Towards the end of the 19th century there was an open competition whether telescopes with lenses or telescopes with mirrors can deliver the better images from outer space. With both types of instruments, experts constantly tried to increase the diameters of the optics and to achieve longer focal lengths. By 1900 mirror telescopes ultimately won the race for a number of reasons. First, larger aperture ratios are possible with relatively short construction sizes. Second, unlike with lenses color distortions do not occur with mirrors. And third, mirrors are much easier to mount, as you can use their entire reverse side. Particularly in the case of large and heavy parts, deformation can be avoided. This cannot be ruled out with lenses as they can only be attached at the edges.

The first mirror telescope

The State Observatory of the University of Heidelberg began to plan a first mirror telescope around 1900. SCHOTT was commissioned to build a mirror substrate with a diameter of 720 millimeters and delivered it to Carl Zeiss in 1903 for final processing. The finished telescope went into operation on the Königsstuhl mountain near Heidelberg in 1906. It was given the name Waltz reflector because it was financed through a generous donation from the private foundation of Käthe Waltz, a relative of the astronomer Max Wolf. He and his staff succeeded in making many epochal discoveries, for example the rediscovery of Halley's comet in 1909 and the identification of countless variable stars. After the addition of a spectrograph and modern CCD detectors, the Waltz reflector was still used for astronomical observations until recently.

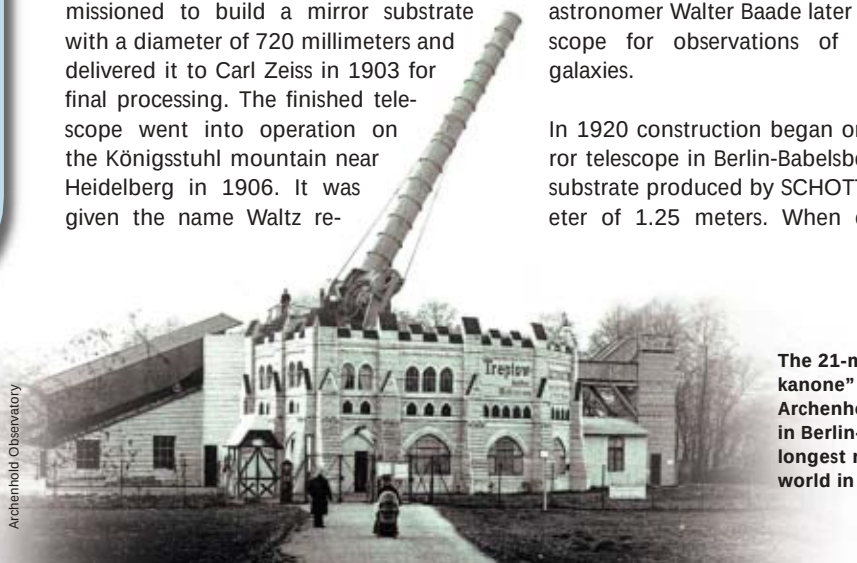
Friedensblitz

In 1907 SCHOTT delivered a mirror substrate with a diameter of 1,020 millimeters to the Bergedorf Observatory in Hamburg.

One-meter mirror telescope

Around 1907, SCHOTT produced a mirror substrate measuring 1.02 meters in diameter – presumably from crown glass – for the Bergedorf Observatory in Hamburg. This telescope was used to expose many photographic plates, which mainly served to search for and to determine the position of comets and planetoids. The famous astronomer Walter Baade later used the telescope for observations of nebulae and galaxies.

In 1920 construction began on a large mirror telescope in Berlin-Babelsberg. Its mirror substrate produced by SCHOTT had a diameter of 1.25 meters. When completed in



Archenhold Observatory

The 21-meter "Himmelskanone" telescope at the Archenhold Observatory in Berlin-Teptow was the longest refractor in the world in 1900.

SCHOTT/Werner Feldmann

In a specially built facility SCHOTT cast the world's largest glass ceramic monolith with a 40-ton melt at a temperature of 1,000° Celsius in 1993. The mirror substrates produced for the Very Large Telescope (VLT) of the European Southern Observatory (ESO) marked the turning point in large-scale telescope technology to still larger mirrors – now constructed in segments.

1924, it was the second largest reflector in the world after the telescope at the Mount Wilson Observatory in California in the United States with a diameter of 1.52 meters, and Babelsberg was the best equipped observatory in Europe.

The outbreak of World War II ended astronomical research for the time being. In 1946 the Babelsberg telescope was disassembled by the Soviet Union, confiscated as war reparations and transported to the Crimea, where it is still in operation today.

Two-meter reflecting telescopes

The development of large-scale astronomical equipment came to a standstill in Germany until 1948. This was the year the director of the Astrophysical Observatory in Potsdam, Professor Hans Kienle, filed an application for a two-meter telescope from the German Academy of the Sciences: "A two-meter universal reflecting telescope is urgently required by the German astronomists in order to be able to return to the forefront of astronomical research with such a high-performance instrument....The construction of this telescope will at the same time provide effective proof of the efficiency of the 'Jenaer Werke' of Carl Zeiss and SCHOTT."

After receiving the commission in June 1949, SCHOTT used ZK 7 glass to produce a mirror blank with a diameter of 2.15 meters and weighing more than 3,000 kilograms. This type of glass was characterized

SCHOTT

The first postwar mirror substrate that SCHOTT produced from ZK 7 optical glass in 1949 weighed three tons.

SCHOTT / Heinz Göttert

Quality control of a "Zerodur" disk: with the introduction of "Zerodur" glass ceramic, SCHOTT Glas in Mainz set a new international standard for astronomical mirror substrates from 1970 on. This engineering material is characterized by its zero thermal expansion.

by a heat expansion that is about half as much as other crown glasses used at the time and was therefore far more suitable as an engineering material for astronomical mirrors. The two-meter reflecting telescope began operations at the Thuringian State Observatory in Tautenburg near Jena in 1960.

Mirror substrates made of "Duran" borosilicate glass

Around 1962 came the conversion to astronomical mirrors made from materials with still lower thermal expansion coefficients than that of ZK 7, for example quartz glass and glass ceramic. Using a continuous melting process, SCHOTT Glas in Mainz succeeded in casting mirror substrates with diameters of between one and two meters from "Duran" borosilicate glass. For example, the largest Egyptian telescope in Heluan was equipped with a 1.95-meter mirror made from "Duran." The European Southern Observatory (ESO) still uses a reflector with a "Duran" mirror in Chile. It has a diameter of 1.6 meters and continues to deliver excellent images.

The largest "Duran" disk with a diameter of 2.7 meters was cast in 1963. The casting process lasted several hours and the six-month cooling process took place in an annealing furnace that was specially built for this purpose.

Mirror substrates made from "Zerodur" glass ceramic

An extraordinary milestone in the production history of SCHOTT Glas was the development of "Zerodur" glass ceramic. Its most important property is its zero thermal expansion, which in the case of large telescopes is crucial for images free of distortions. The first large-scale "Zerodur" project for an astronomical application was initiated when the Max Planck Institute for Astronomy (MPIA) in Heidelberg commissioned SCHOTT to produce mirror substrates of 2.3 and 3.6 meters for the German-Spanish Calar Alto Observatory in southern Spain.

Up to 1980 several "Zerodur" reflectors were built in the conventional, stable and massive form. These mirrors usually had a ratio of diameter to thickness of 6:1.

Thin mirrors for telescopes with active optic systems

The introduction of active optic systems in the 1980s ushered in a completely new kind of telescope mirror. The mirrors are produced so thinly for these systems that their shape can be selectively adjusted with the help of electronically controlled mechanisms. Variations from the ideal shape can thus be constantly corrected. This concept led to a clear reduction in costs because far less material and time are required for production. In addition, much less mass has to be moved in adjusting the telescope.

The prototype of this new telescope generation was the New Technology Telescope (NTT) of the European Southern Observatory (ESO). In the case of the primary meniscal mirror, the ratio of diameter to thickness was 15:1 (diameter 3.6 meters, thickness 0.24 meters). It was delivered in 1986.

Astronomical mirrors for telescopes of the 8- to 10-meter class

This revolution in large-scale telescope construction paved the way for still larger telescopes equipped with mirrors with diameters of eight to ten meters. For the construction of Very Large Telescopes (VLT), the ESO commissioned SCHOTT in 1988 to produce four "Zerodur" mirror substrates, each with a diameter of 8.2 meters. For this project, SCHOTT developed a novel centrifugal casting process in which the casting mold has a curved bottom and constantly rotates. The first 8.2-meter mirror substrate was delivered in 1993. Three further substrates were supplied each year for the following three years. In the meantime, all four of the large telescopes transmit a wealth of observational data from outer space.

New techniques were introduced for astronomical mirrors with still larger dimensions – such as for the Keck I and Keck II telescopes with diameters of 10 meters located in Hawaii or for the 10.4-meter Grantecan telescope currently under construction on La Palma. These mirrors are no longer produced in one piece, but instead are composed of numerous hexagonal mirror segments. Particularly high demands are made on optical finishing and assembling: all segments are constantly repositioned so that they work together to produce the best possible image quality.

The 100th anniversary

In April 2003 SCHOTT delivered a 4.1-meter mirror substrate made from "Zerodur" for the world's largest wide field survey telescope called VISTA (Visible and Infrared Survey Telescope for Astronomy). It was commissioned by a consortium of 18 British universities as an "entry" to the European Southern Observatory. It will be VISTA's task to search the skies for interesting objects that will then be investigated in greater detail by the Very Large Telescope. ◂

The four Very Large Telescopes on Cerro Paranal in Chile are each equipped with 8.2-meter "Zerodur" mirror substrates. The effective mirror diameter of all the telescopes is 16 meters.

ESO (European Southern Observatory)

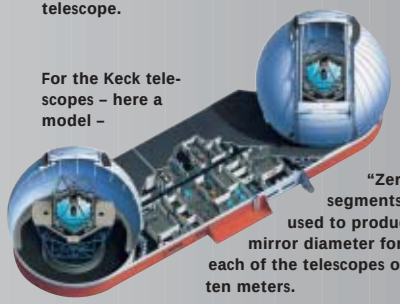
A High-Tech Material for Superlatives

For more than 30 years, "Zerodur" glass ceramic has been astronomers' material of choice on Earth and in outer space. Here is a summary of some of the spectacular projects with mirror substrates made from "Zerodur":

1970 – 1975	Mirror substrates with diameters of 1.3 meters, 2.3 meters and 3.6 meters for three telescopes of the MPIA (Max Planck Institute for Astronomy) on Calar Alto in southern Spain.
1975	2.3-meter mirror substrate for the biggest telescope in India.
1984	Eight "Zerodur" cylinders for the German X-ray telescope known as ROSAT (ROentgen SATellite), which was used in space from 1990 to 1999.
1986	An extremely thin 3.6-meter mirror substrate for the New Technology Telescope (NTT) of the ESO, the first telescope with active optics.
1990	24 cylindrical mirror substrates for the X-ray telescope known as "Chandra," which was launched with a space shuttle in 1999.
1990	3.6-meter mirror substrate for the Galileo TNG telescope on La Palma.
1986 – 1990	42 hexagonal segments made from "Zerodur" with a diameter of 1.8 meters for KECK I, a 10-meter telescope on Mauna Kea, Hawaii.
1991 – 1993	42 "Zerodur" segments for KECK II.
1993 – 1996	Four 8.2-meter mirror substrates for the Very Large Telescope (VLT) of the ESO, the world's largest glass ceramic pieces produced from a single cast.
1993 – 1996	100 1.0-meter hexagons for the 9-meter American-German Hobby Eberly Telescope (HET).
1997	Lightweight 2.7-meter mirror substrates for the Stratospheric Observatory for Infrared Astronomy (SOFIA), an infrared telescope on board a jumbo jet.
1999 – 2002	42 mirror substrate segments for GRANTECAN (Gran Telescopia Canaria), a 10.4-meter telescope on La Palma.
Since 2001	40 "Zerodur" hexagonal segments with a diameter of one meter for the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) in China.
1997/2002	Two weight-reduced secondary mirror substrates with a diameter of 1.7 meters for the 6.5-meter U.S. "Magellan" telescope.
2002	Sample fabrication of "Zerodur" precision mandrels for the production of mirror segments for the planned "Constellation X" X-ray telescope of NASA.
2002 – 2003	4.1-meter mirror substrate with a particularly strong curvature for the Visible and Infrared Survey Telescope for Astronomy (VISTA), the world's largest wide field survey telescope.

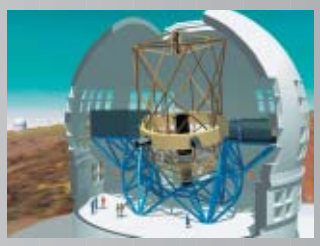
SCHOTT/Heinz Göttert

Mirror cylinders made from "Zerodur" glass ceramic for the ROSAT X-ray telescope, and later also the "Chandra" telescope.



Tom Connell/ Wildlife Art Ltd. © 2000 Weldon Owen Inc.

For the Keck telescopes – here a model – "Zerodur" segments were used to produce a mirror diameter for each of the telescopes of ten meters.



GTC

GRANTECAN (model): the telescope with a 10.4-meter mirror made from "Zerodur" segments will be the largest telescope in the Northern Hemisphere.

LAMOST

With the LAMOST the Chinese will have a powerful telescope at their disposal in the near future. SCHOTT has delivered 40 hexagonal segments for this telescope.

SCHOTT/Jürgen Hartmann

Weight-reduced, "honeycombed" mirror substrates made from "Zerodur" glass ceramic are used in the "Magellan" telescope.

SCHOTT/Thomas Bauer

4.1-meter mirror substrate for VISTA, the most powerful wide field survey telescope in the world.