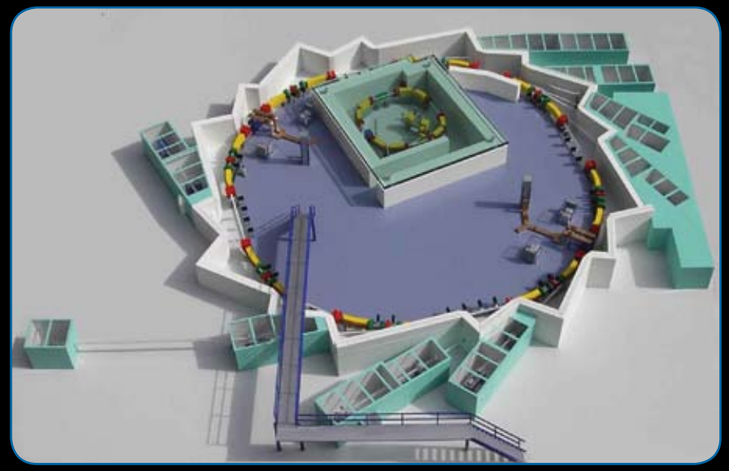
# In a LIGA of its Own

New technologies are the catchword for the modern era in watchmaking. LIGA is the newest technique for creating flawless movement components.

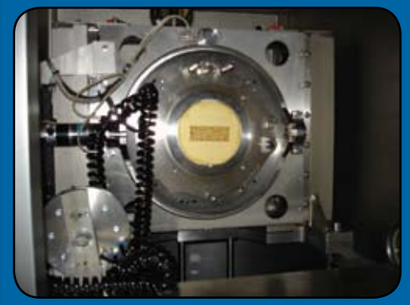
BY ELIZABETH DOERR

H. Moser & Cie.'s gold escapement features gold LIGA components, an industry first.

Dr. Pascal Meyer in a Karlsruhe clean room.



A 3-D rendition of the synchrotron light facility in Karlsruhe.



A mask placed in the X-ray machine in Karlsruhe.

An X-ray mask in Karlsruhe.

This large machine generates the X-ray light needed to expose the tiny LIGA parts.

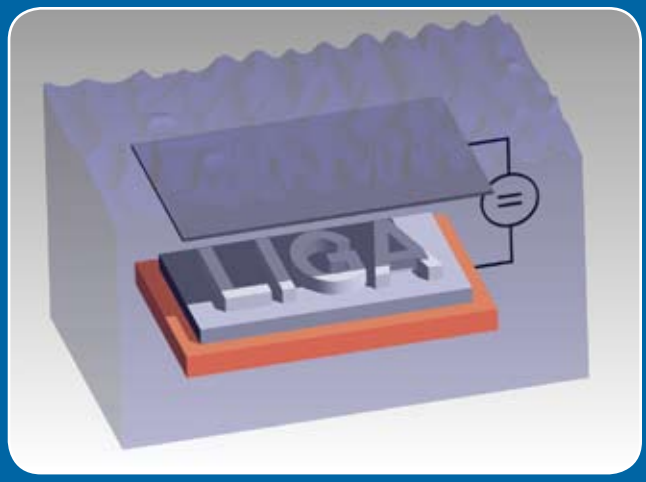
LIGA parts after exposure to X rays in Karlsruhe.

In 2005, after three years of experimentation, H. Moser & Cie. introduced the first wristwatches made with escapement parts in 23.5-karat hard gold manufactured through the LIGA process. Now, many watch firms are researching this innovative, high-tech and potentially revolutionary method of making movement components, first developed largely for medical applications twenty years ago in Karlsruhe, Germany.

Forschungszentrum Karlsruhe, a government-sponsored research institute, developed LIGA, the new process for manufacturing microproducts. Karlsruhe's research center currently employs more than 3,800 people, 1,420 of whom are scientists. Over the years, this gargantuan research institute has accounted for more than 1,800 patents, registered designs, and patent applications.The center is divided into twenty-four institutes, one of which is the Institute for Microstructure Technology (IMT), where LIGA was born.

## The LIGA process

The word LIGA is a German acronym that stands for lithography (*Lithografie*), galvanic (*Galvanisierung*), and plastic molding (*Abformung*). →


### Let's start with the L

The lithographic process is perhaps one that might be familiar as an artistic medium, used for copying and printing. Devised by Alois Senefelder in 1798, lithography is mainly used for transferring something such as text or art onto a smooth surface.

The early principle was simple: A sticky, water-insoluble material was applied to a limestone as the image. A mixture of gum arabic and an acid was used to etch the stone and make it phobic to ink. When ink was added, it adhered to the sticky image, while from the negative image it could just be washed away. Then the image was transferred to paper by pressing the stone onto it. Naturally, this works the other way around as well, making the positive negative and vice versa.

Modern lithography, used for just about any mass-produced item with print on it, such as posters, books, credit cards, and CDs, now greatly depends upon photographic processes that include exposure.

The LIGA process uses light for stabilization, unlike the photography, which uses a gummy substance. In fact, the light that is used at the Karlsruhe institute is actually X-ray light supplied by a synchrotron source (an electron centrifuge), allowing low distortions due to optical effects and rapid exposure.

The X-ray lithography used here—a type of microlithography—is a method that can structure material on an extremely fine scale. For the record, elements smaller than ten micrometers are considered microlithographic, and smaller than 100 nanometers are nanolithographic. LIGA components are considered microcomponents.

LIGA components begin with an X-ray mask that contains the precise shape or shapes of the parts to be manufactured by means of a CAD system. The mask has a carrier transparent to the light, which can be made of a very thin metal such as titanium, beryllium, or glass. The synchrotron light is used to "transfer" or "expose" the structural information onto a layer of polymer. Then a solvent is introduced, leaving behind the structure of the non-irradiated plastic as the primary structure.

### The G

The galvanic part of the LIGA acronym can be better described with a synonym: electroforming. Though galvanics are widely used in watchmaking to seal and beautify components made of various metals, this is not what makes a LIGA component. In the watch industry, galvanics are used for plating by depositing a thin, metallic layer onto an existing

The "lapping" process at Mimotec


Quality control at Mimotec


Mimotec SA in Sion, Switzerland


Mimotec employs 25 people in its Sion factory.


A Mimotec wafer

component. Electroforming is actually component growth in a plating bath atom-by-atom until it reaches the desired thickness.

The spaces generated by the removal of the irradiated plastic material can now be filled with a metal thanks to the electroforming part of the process. Since the layer thickness here is much larger than commonly found in the galvanic coatings of a watch component, the variety of metals and alloys is somewhat restricted with a main focus on nickel, copper, gold, nickel-cobalt, nickel-phosphorus, and nickel-iron.


Dr. Hubert Lorenz, founder and CEO of Mimotec.

Today, LIGA is used to manufacture microcomponents for many industries just in this way.

However, the A in LIGA (plastics molding) can also be utilized to make tools of nickel and nickel alloys for use in plastics and injection molding, an important step in low-cost mass production (think Swatch cases). For metal watch component production, however, the A is not used.

## Enter Mimotec

LIGA—or direct LIGA, as this shortened process without injection molding is known—is perfect for creating horological microcomponents in very high quality. In stark contrast to wire spark erosion technology, LIGA components are perfect every time and require no finishing. There are no burrs, since they are not cut, and therefore do not need to be trimmed or polished to get the desired level of finishing.

The first firm to use the LIGA process for watch-industry purposes was Mimotec, a company name short for Micromold Technology. Dr. Hubert Lorenz, at the time a doctoral candidate at Lausanne's École Polytechnique Fédéral, founded the innovative little company in 1998 with engineer colleague Nicolas Fahrni. Lorenz's idea was groundbreaking for watchmaking.

Using a recipe of an SU-8-based photo-sensitive epoxy developed by IBM, he developed a much more cost-effective system of direct LIGA in order to manufacture precise microcomponents for medical and watch industries. This cost-effectiveness was assisted by the fact that Mimotec uses an inexpensive ultraviolet light source for the exposure process, as opposed to the expensive X-ray light that Karlsruhe's IMT uses.

Lorenz's idea took off. Not only was this technology superb in terms of quality, it was a precise technology associated with low costs in many different ways, and Mimotec cornered the market. Because the components are made in batches on a wafer using the photo mask technology, tooling costs are far lower than with conventional stamping tools. The process allows parts to be manufactured quickly, thus eliminating one major problem among Swiss suppliers: late deliveries. Quick delivery also meant that parts could be obtained quickly for prototyping and testing. In addition, the wafer element of such batch production theoretically guarantees that the first piece will have the exact same quality as the thousandth piece of any given run, ensuring constant quality.

Mimotec can only offer components made by the direct LIGA process in nickel or a nickel-phosphorus alloy. However, these components are hard, stable, and nearly friction-free thanks to their extremely smooth vertical walls. The quality and properties of these components are without a doubt the main reason that many companies are currently exploring and utilizing them.

Until now Mimotec has remained the first company able to offer LIGA components to the watch industry, even beating out the LIGA process's own inventor.

## Research center goes commercial

The marketability of LIGA in the watch industry remained unimportant to Karlsruhe's research giant until one fine day in 1998 when Dr. Jürgen Lange showed up at the door.

Lange was busy founding a new luxury watch brand in Schaffhausen. He envisioned his new brand, H. Moser & Cie., to feature very special movements and a number of elements not to be found elsewhere. One of the unique elements he had dancing around his head was based on a vintage tradition of solid gold watch movements. Lange wanted to make escapement components of pure solid gold.

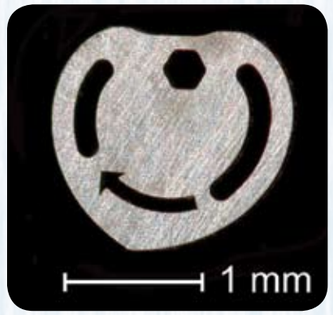
Certainly there is a reason that tricky movement components such as those found in the escapement are no longer made of gold, and one of them likely has to do with the fact that there are better materials available today for reducing friction. However, Lange's idea propelled his visit to Karlsruhe: He wanted his escapement components to be manufactured in solid gold using the LIGA process.

This was interesting, for until then LIGA components had only been made in nickel, nickel-cobalt, and nickel-phosphorus alloys. Gold was not a metal

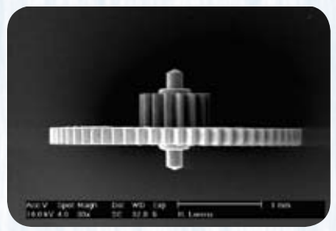

The clean room at Mimotec

The Microworks team: Georg Schwarz, Dr. Joachim Schulz and Dr. Pascal Meyer.

Dr. Joachim Schulz at Karlsruhe's Forschungszentrum.


A heart cam manufactured by direct LIGA.



Mimotec can even manufacture two-level parts.

thought to work well with mechanical LIGA parts. However, the research center's scientists took on the challenge, and actually came up with a hard gold alloy that allowed itself to be electroformed: 23.5 karats pure, the gold is only blended with cadmium and arsenic to allow it the proper hardening properties. This new hard gold is twice as hard as regular gold at 150-160 Vickers, while normal gold can be found at about 70 on the Vickers scale. Above and beyond that, Lange also found a way to specifically harden the walls exposed to mechanical wear by an additional factor of three by subjecting the parts to local ion implantation.

## Microworks

Spurred on by the success and interest shown by the luxury industry in new and interesting technologies, a privatized company has emerged from the research center formed around the nucleus of the main three human proponents. Microworks, as it is now called, is headed up by physicist Dr. Joachim Schulz, aided and abetted by Dr. Pascal Meyer (process engineer) and Georg Schwartz (machine developer). The three enthusiastic scientists make a good team, ready to explore new territories within the watch industry.

It is no secret that all of the major groups and independent watch brands active in the luxury segment of the watch industry have used or experimented with components manufactured by the LIGA process. The benefits of certain components manufactured this way are just far too great not to. However, not all the components used by the watch companies are as experimental and cutting edge as Ulysse Nardin would sometimes have its audience believe. That innovative little company dabbles in just about every new technology available, and was certainly one of the first to help itself to the benefits of Mimotec's nickel-phosphorus escape wheels for use in cutting-edge watch movements such as the Freak.

LIGA is simply a cost-effective way of manufacturing better components, be they innovative in shape, form or function or not. Though not officially confirmed, watch industry giants Rolex and the Swatch Group have also recognized this technology to be a highly beneficial one, even reportedly founding departments within their own organizations able to manufacture their own LIGA components.

"That was simply a matter of time," Mimotec's Lorenz says in answer to the question concerning possible new competition from the industry's major players.

For the moment, however, the playing field is unevenly divided among the two major players, Mimotec and Microworks. As it would seem, Microworks will continue to lead the way in devising new alloys for direct LIGA, while Mimotec's Lorenz is turning his attention even further to other new technologies such as silicon.

"I am interested in verticalizing our facility," Lorenz explains.

"LIGA was born in Karlsruhe," Schulz explicates. "And uses for LIGA will continue to evolve here at the research center. We are excited to be working so closely with the watch industry and we look forward to cooperating with these innovative companies on projects that we are only beginning to imagine. We will put all our scientific know-how and the considerable resources behind us into progressing and beautifying watch technology."

Direct LIGA escapement wheels by Mimotec

## The ABCs of LIGA

"Our only issue is the market," says Mimotec co-founder Hubert Lorenz, winner of the Swiss Economic Award in 2001. "We are interested in the price, quality, and delivery we can offer our close to fifty customers in the watch industry. The market demands that we be cheaper and more precise. With the system we have devised, all of this is possible."

Many of Mimotec's clients are smaller, innovative companies who simply cannot afford to invest in tooling and stamping when developing small, elite series. Direct LIGA is a grand technology for just such purposes. With almost no tooling costs, a new complication can be developed and tested quickly and easily.

And Mimotec's success speaks for itself: Starting in 1998 with only two employees, the company has grown to twenty-five people at its Sion, Switzerland, facility, only very few of which are actually trained beforehand. Most learn at Mimotec to perform the necessary steps to complete the precise nickel or nickel-phosphorus components, the only materials with which Mimotec's LIGA process can work.

The first step is to design the photo mask, which three designers spend their days doing. The photo masks then undergo ultraviolet lithography to produce wafers with the parts' negative in SU-8 epoxy. Then follows the electroplating step, or the "G" in LIGA. At a wet bench, the SU-8 and the wafer are dissolved, leaving behind the desired microcomponents, which are then ground and "lapped" to get the exact thickness desired. The final step comprises only inspection and quality control. Finally, the components are ready to be added to a movement.