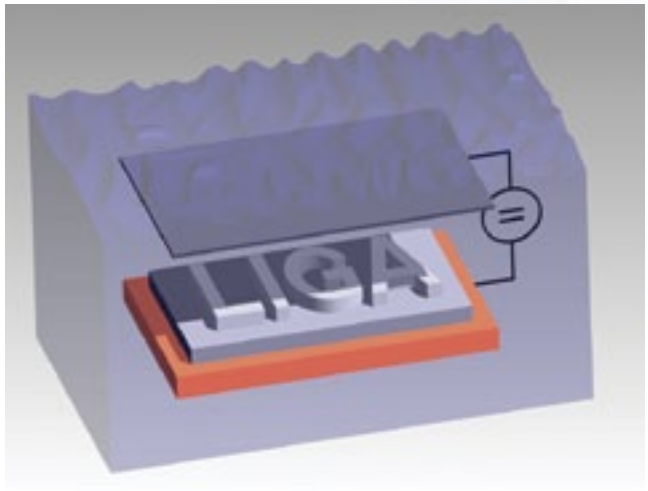
LIGA KNOW-HOW

Over the coming months *QP* will be looking at some of the very 21st-century technologies being applied to the centuries old tradition of mechanical watchmaking. We begin with LIGA, a way of making components to previously impossible levels of precision.

Elizabeth Doerr



The LIGA process

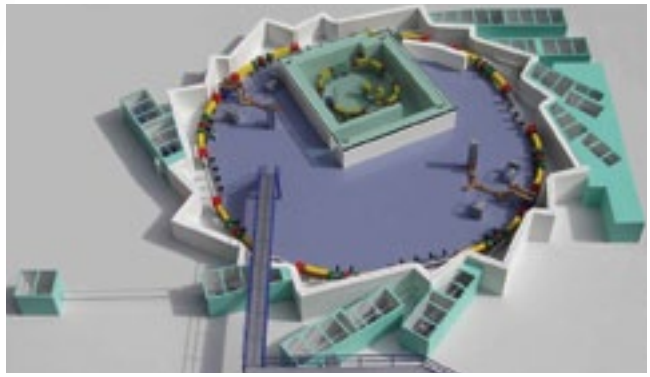
Despite the fact that we in the watch industry refer to it as a 'new technology', LIGA is actually more than two decades old. And although it is natural to assume it was created in a place like Geneva or Bern its roots actually lie in the research done at the German government-funded Forschungszentrum Karlsruhe's Institute for Microstructure Technology (IMT) in the 1980s.

LIGA is actually a German acronym that stands for *Lithographie*, *Galvanoformung*, *Abformung* (Lithography, Electroplating, and Molding) and describes a fabrication technology used to create high-aspect-ratio microstructures (aspect ratio being the ratio of a shape's longer dimension to its shorter dimension) – typical of many watch components. There are two main LIGA-fabrication technologies, X-Ray LIGA, which uses X-rays to create high-aspect ratio structures, and UV LIGA, a more accessible method that uses ultraviolet light to create structures with lower aspect ratios.

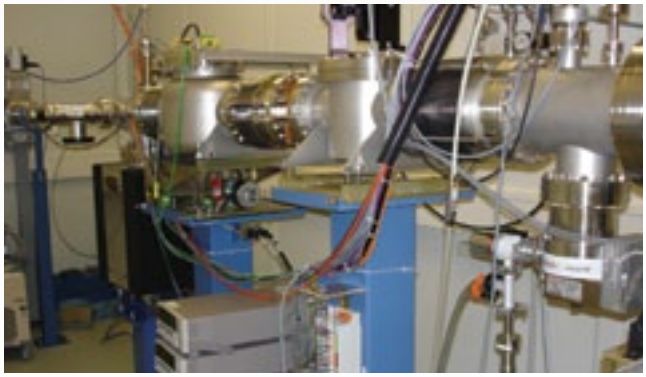
X-Ray LIGA

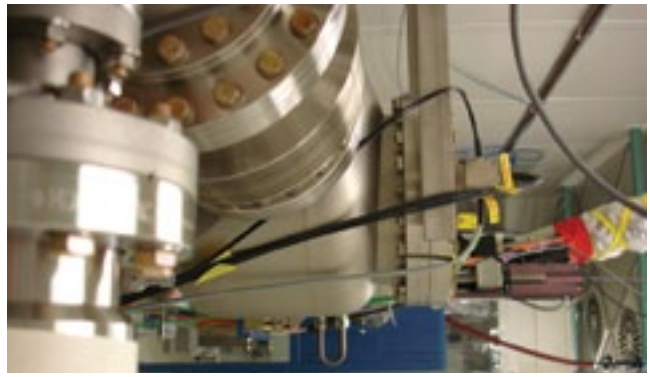
The *Lithographie* or lithography part of the acronym refers to the fact that, like the photographic process, LIGA uses a light source to alter a masked substrate or base material – at IMT this is actually a high energy X-ray frequency supplied by a synchrotron source. The key quality the synchrotron source provides is high collimation, ie the rays remain nearly parallel and spread slowly as the beam propagates. This means the exposure remains precise through the depth of the substrate.

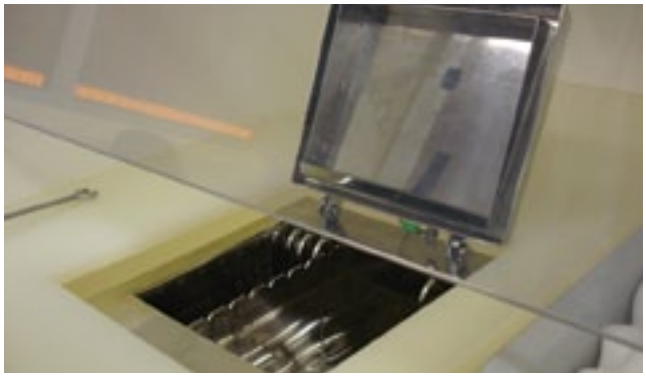
The LIGA process begins with an X-ray mask outlining the shapes of the parts to be manufactured. The mask has a carrier transparent to the light, which can be made of a very thin metal such as titanium or beryllium or glass. The synchrotron light is used to 'transfer' or 'expose' the shape into the polymer substrate. A solvent is then introduced, removing the exposed material.



The Karlsruhe Institute for Microstructure Technology (IMT) had the advantage of being able to help itself to the Forschungszentrum's synchotron X-ray machine. Right: a rendering of the building-sized equipment. Below: Various segments of the machinery.







The *Galvanoformung* (electroplating) part of the acronym refers to the electrodeposition of the component material into the voids left by the solvent. (In the watch industry 'galvanics' usually means plating a thin metallic layer onto an existing component.) Since the layer thickness of the component 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.

The A in LIGA (*Abformung* or plastics molding) can also be utilised 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.

UV LIGA

The first firm to use the LIGA process specifically for watch industry purposes was Mimotec (a company name short for Micromold Technology), founded by Dr Hubert Lorenz – a doctoral candidate at Lausanne's École Polytechnique Fédéral – and engineer Nicolas Fahrni in 1998. Lorenz's idea was groundbreaking: Using photosensitive epoxy (based on IBM's SU-8), he developed a more cost-effective system of direct LIGA in order to manufacture components for both the medical and watch industries. The critical difference between Mimotec's and Karlsruhe IMT's processes is that Mimotec uses a much cheaper ultraviolet light source instead of the synchrotron X-ray source used at IMT.

Lorenz's idea took off. Not only was this technology superb in terms of quality and precision, it was significantly cheaper. Needless to say, Mimotec cornered the market for LIGA components. 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 a major problem among Swiss suppliers – that of late deliveries.

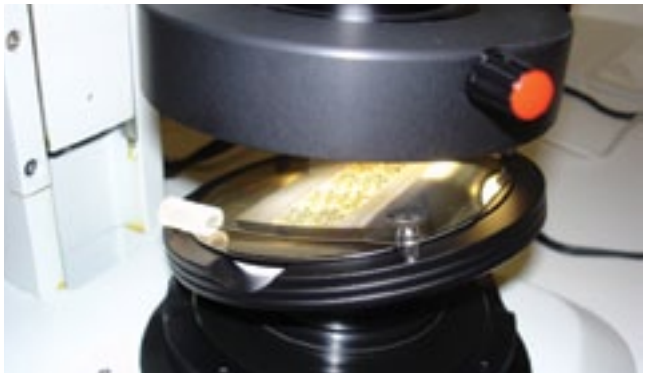
The speed of the process also meant that parts for prototyping and testing could be obtained quickly. In addition, the wafer element of such batch production theoretically guarantees that the first piece will have the exact same quality as the thousandth piece of any given run, ensuring constant quality.

Mimotec only offers 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 some 75 companies are currently using them.

Commercialising the research center

Marketing LIGA to the watch industry remained unimportant to Karlsruhe's research giant until 1998, when Dr Jürgen Lange, the founder of H. Moser & Cie, showed up at the door. He was looking to make escapement components out of pure

Top left: Masks in Karlsruhe. Top right: Masks in Mimotec during light stabilisation. Bottom left & right: Finished LIGA components under microscope inspection in Karlsruhe.



Mimotect LIGA processes including lapping (left and far left), light stabilisation (below left) and quality control (below).

gold, thinking the LIGA process might be able to produce a friction-free gold.

As already stated, up until that point, LIGA components had only been made in nickel, nickel-cobalt, and nickel-phosphorus alloys. Gold was not thought to work well with mechanical LIGA parts. However, the research centre's scientists took on the challenge, and actually came up with a hard gold alloy that allowed itself to be electroformed: 23.5cts pure, the gold was blended with cadmium and arsenic, which made it twice as hard as regular gold at 150-160 Vickers compared to 70 Vickers normally. 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.

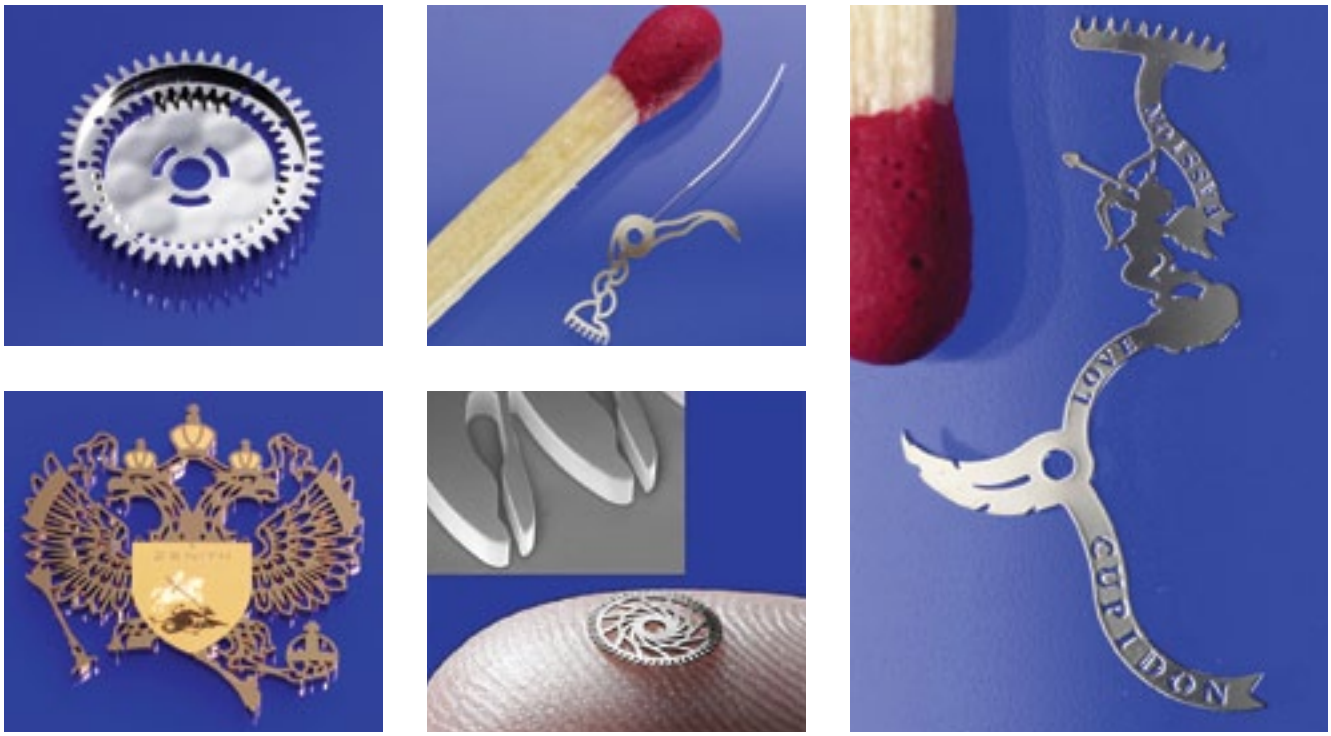
In 2005, after three years of gold experimentation, H. Moser & Cie's wristwatches were finally introduced to the watch world. This was a great success for the IMT department. No one else had ever achieved making LIGA parts in such a precious and interesting metal and the possibilities it has opened up are tremendous. Although Lange now uses another process to manufacture his escapements, the success and interest shown by the luxury sector, spurred physicist Dr Joachim Schulz and process engineer Dr Pascal Meyer to set up a new company, Microworks, which continues to explore new commercial applications for LIGA.

The Mimotec difference

"The market demands that we be cheaper and more precise. With the system we have devised, all of this is possible," says Lorenz, winner of the Swiss Economic Award in 2001. "We are interested in the price, quality, and delivery we can offer our customers in the watch industry."

Mimotec's success speaks for itself: starting in 1998 with only two employees, the company has meanwhile grown to 26 people at its Sion facility, most of whom have been trained from scratch in the process at Mimotec.

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



A selection of parts made by Mimotec using the UV LIGA technique.

Moser & Cie's LIGA produced gold components: escapement dragon lever (below left), HMC341 movement (below right) and escapement module (bottom).

and the wafer are dissolved, leaving behind the desired micro components, which are then ground and 'lapped' to get the exact thickness desired. The final step comprises only inspection and quality control. And – *voilà*! – the components are ready to be added to a movement.

Common technology?

It is no secret that the lion's share of the luxury segment of the watch industry has used or experimented with components manufactured using the LIGA process. Ulysse Nardin 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 a cost-effective way of manufacturing better components, be they innovative in shape, form, or function – or not. Even giants of the watch industry such as Rolex and the Swatch Group have recognised the benefits, reportedly founding departments within their own organisations able to manufacture their own LIGA components. "It was simply a matter of time," Mimotec's Lorenz quips. His company has meanwhile diverted its attention to other new technologies such as silicon. "I am interested in verticalising our facility," Lorenz explains.

And Microworks' Schulz concurs: "LIGA was born in Karlsruhe and uses for the process will continue to evolve here at the research center. We will put all our scientific know-how and the considerable resources behind us into progressing and beautifying watch technology."

Further information: www.imt.kit.edu www.mimotec.ch