Hot embossing glass -- to the nearest micrometer

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The finished lens array is at a slant behind the lower die set of the hot embossing equipment. (© Fraunhofer IWU)

The lens is what matters: if lens arrays could be made of glass, it would be possible to make more conveniently sized projectors. Fraunhofer researchers have now developed a process that allows this key component to be mass produced with extreme accuracy.

Projectors are getting smaller and smaller. Now that pictures are available in digital format almost everywhere, we need projectors to beam giant photos and films onto walls. Projectors contain lenses that spread the light from the pixelated source in such a way as to illuminate the image area evenly. Until now, this was done using complicated arrays of lenses placed one behind the other. Recently, the same effect has been achieved using flat lens arrays made up of thousands of identical microlenses. This kind of array takes up much less space and does not need to be painstakingly assembled and aligned. To date it has only been possible to manufacture these lens arrays from plastic, but the light source in conventional projectors is hot enough to melt them.

To get around this problem, Jan Edelmann and his team at the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz have developed a process for manufacturing lens arrays from glass, whereby the surface structure of the array is hot embossed into viscous glass at temperatures of between 600 and 900 degrees Celsius. “The main challenge is to keep the material exactly at the temperature where it is malleable but not yet molten,” explains the project manager. “That is the only way to guarantee that components made from it will be within the prescribed tolerances to within a few micrometers.”

The first step is to produce the forming die equipment, using tungsten carbide which is machined with ultra-precise grinders. “Of course, we have to take into account right from the beginning that the high temperatures will cause both the glass and the equipment to expand, but at different rates”, says Edelmann. “So the die has to be a slightly different shape from the workpiece that we are looking to produce.” Considering that 1700 absolutely identical square microlenses must fit into an area of just five square centimeters, it is not hard to imagine the level of precision that is required, and it is no surprise that it takes hours to produce the die. Once it is finished, the die is given a wear-resistant coating of precious metal.

During hot embossing, which takes place in a vacuum chamber, it is important for the glass and the equipment to be kept at a constant temperature until the workpiece has been ejected from the mold. The reason for this is that, during the cooling process, the glass shrinks more than the equipment. Tensions would otherwise arise and the lenses, only millimeters thick, might shatter. For ease of handling, the IWU researchers have given the workpiece an edge. Here, too, precision is of the utmost importance. Both stamping dies must be aligned exactly with one another, and there must be no slippage or distortion when they are pressed together.

The team from IWU has overcome all these problems and succeeded in producing arrays from high refraction glass that have extremely smooth surfaces and where alignment faults across all 1700 microlenses are smaller than 20 micrometers. “This is a world’s first,” says Edelmann happily. The process is suitable for use in mass production, and could bring the price of such components down to a tenth of what current lenses cost. Furthermore, arrays of this kind are not only important for projectors. They could also be used to broaden and homogenize laser beams, for example in industrial welding machines.

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