The Microlens Revolution in Automotive Lighting and the Requirements for Future Imprint Production Tools

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SEMICONDUTOR AND PHOTONICS INDUSTRIES HAVE CHANGED THE WORLD

Semiconductor (SEMI) and photonics industries have dramatically changed our world over the last 50 years. Today, both industrial sectors each generate around $550 billion in sales worldwide. However, the two industrial sectors differ fundamentally in terms of the underlying production concepts. The SEMI industry relies on highly parallel standardized processes where billions of logic or memory cells are manufactured on wafers. Standardization allowed the industry to improve processes and machinery to the very limits. Unlike the semiconductor industry, photonics is characterized by a greater variety of products that are typically produced piece by piece. The photonics industry is still dominated by manual process steps with a low degree of automation. The photonics industry is primarily comprised of small or medium-sized companies, whereas SEMI is dominated by very large companies.

THE WAFER-LEVEL CONCEPT

From its inception, there have been endeavors to introduce the wafer-level concept into the field of photonics. In 1966, Professor Adolf W. Lohmann laid the groundwork for a planar optics with the invention of computer-generated holograms (CGH). Kenichi Iga further expanded on this idea with stacked planar optics, enabling the construction of wafer-level optical (WLO) systems, and the invention of vertical-cavity surface-emitting laser (VCSEL). When cameras were integrated into cell phones, the wafer-level camera (WLC) seemed to be the key-enabling technology. A short WLC hype was soon followed by disillusionment. Injection molded lenses pushed WLC already out of the market for the 2MP camera generation. A second WLO hype came with smartphone sensors. Combining VCSELs, detector arrays with stacked micro-optics sounded like a winning concept. Despite its potential, the WLO approach once again faced defeat by the highly cost-optimized injection molding approach. WLO struggled to achieve the necessary yield and cost-effectiveness to compete effectively in the market.

MANUFACTURING EQUIPMENT FOR WAFER-LEVEL OPTICS (WLO)

What was, or better, what is the problem? We lack suitable fully automated and industrialized production equipment for WLO. We still rely on SEMI tools that date back to the 1980s, which have undergone only partial modifications to meet Photonics' current requirements. WLO manufacturing, especially imprint lithography, continues to rely on manual processes, where operators physically handle wafers.

THE MICROLENS REVOLUTION IN AUTOMOTIVE LIGHTING (AL)

Microlens arrays (MLA) are now a new potential key technology for automotive lighting (AL). MLA technology is used for decorative and safety light carpets. The first MLA-based headlights are on the road and provide a dramatic reduction of size, weight, and complexity. MLA headlights could have any form or shape allowing full design freedom, like the recent trend to slim or ultra-slim head lights. Light is visible innovation for the car industry, and the new MLA technology is one of the most promising technological approaches today. In comparison to previous WLO ventures in consumer electronics, the MLA revolution in automotive lighting has a significantly higher likelihood of success. It is not merely a cost-saving measure; it has the potential to completely transform the game. However, the automotive industry is known for its challenging cost roadmaps, and successfully meeting them is crucial for the widespread adoption of any new technology. The success of WLO technology in automotive lighting will heavily rely on achieving fully industrialized and automated production processes. Previous attempts at implementing similar technologies should serve as lessons, emphasizing the need to ensure that this time we achieve successful industrialization and automation of WLO production. Failure is not an option!

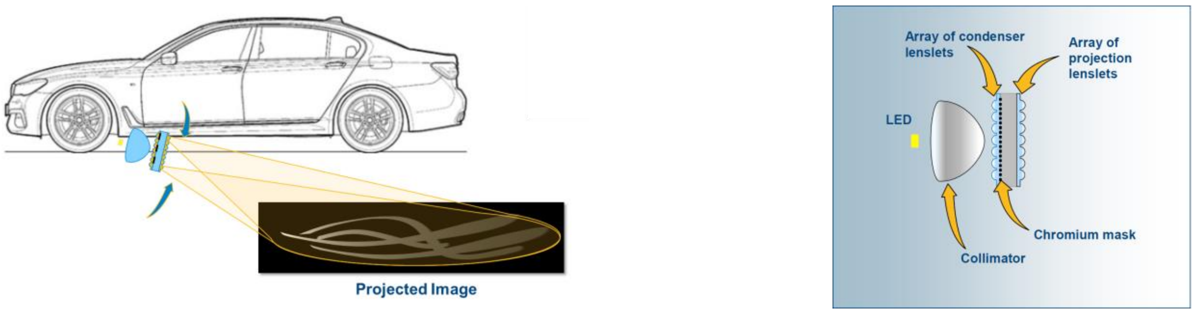

Figure 1. Microlens array (MLA) based light carpet for cars. The MLA light carpet projector is based on a fly's-eye condenser with a micro-structured metal pattern in the entrance pupil.

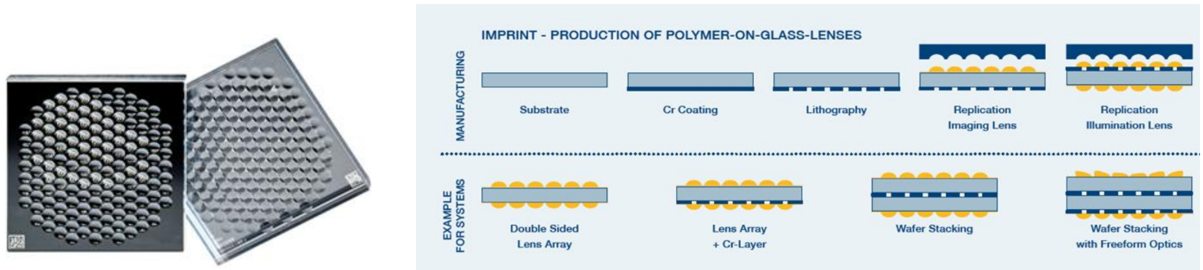

Figure 2. The microlens arrays (MLA) are manufactured by double-sided imprint lithography on 8" wafers. Manufacturing is still done in a manual processing where operators physically handle wafers.

Figure 3. BMW welcome light carpet (left), new concepts for safety light carpets (middle, right).

Figure 4. MLA head lamp module (left, Lucid), Lucid Air (middle) and Genesis G90 (right), first cars with MLA head lamp technology.

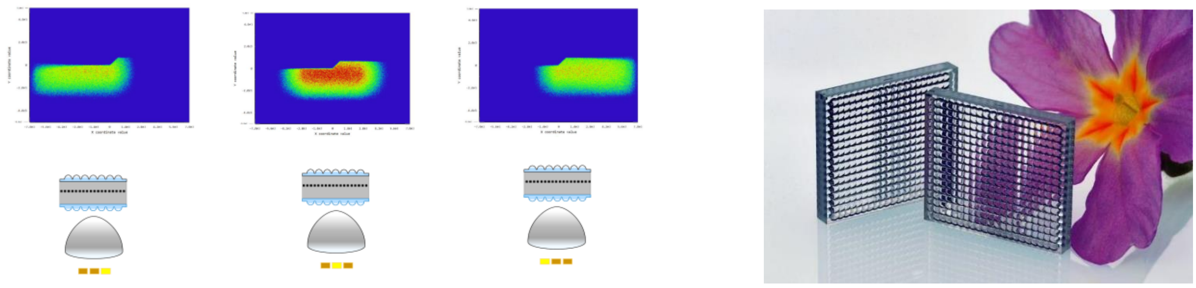

Figure 5. Digital beam steering using MLA head lamps. Each MLA cell could generate a different far-field pattern. Switching car head lamp illumination is achieved by changing the illuminating LEDs.