SPIE Newsroom

10.1117/2.1201003.002684

Next-generation test equipment for high-volume wafer production

Kay Gastinger and Odd Løvhaugen

A novel parallel inspection concept enables high-speed, multifunctional microelectromechanical-systems production control.

Quality control is one of the main bottlenecks in the production of micro-opto-electromechanical systems/microelectromechanical systems (MOEMS/MEMS) because each structure on a wafer is serially inspected and scanned stepwise over the entire wafer area. This is time consuming and requires inflexible and expensive equipment. The forthcoming requirement of 100% production control, in particular for safety-related applications, exacerbates this situation.

Standard wafer diameters for high-volume MOEMS/MEMS production are 150 and 200mm (6 and 8 inches, respectively). The structures that must be inspected typically cover areas of $100\mu m^2$ to $10mm^2$. Therefore, the inspection ratio ranges from approximately 10^{-3} to 10^{-7}, with further increases for typical defect sizes (usually $<10\mu m$ across). To cover an 8in wafer with a diffraction-limited optical imaging system, we would need a minimum capacity of 13Gpix. This creates significant hardware challenges (for instance regarding camera design, frame grabbers, and storage memory), but also software-related obstacles.

As part of the European Commission-funded SMARTIEHS project,[1] we are developing a novel wafer-inspection method using an adapted array of sensors for 2D scanning.[2] This parallel wafer-level testing improves throughput by two orders of magnitude. The multifunctional capabilities of the instrument make it applicable for a broad range of MOEMS/MEMS devices, eliminating the need for multiple specialized testing stations. In addition, the flexibility of our concept enables designing standardized test equipment, which translates into lower hardware costs. The optical probing wafer is specific to a MOEMS/MEMS design. However, it is fabricated by a standard process (like the needle cards used for wafer-level testing in the semiconductor industry).

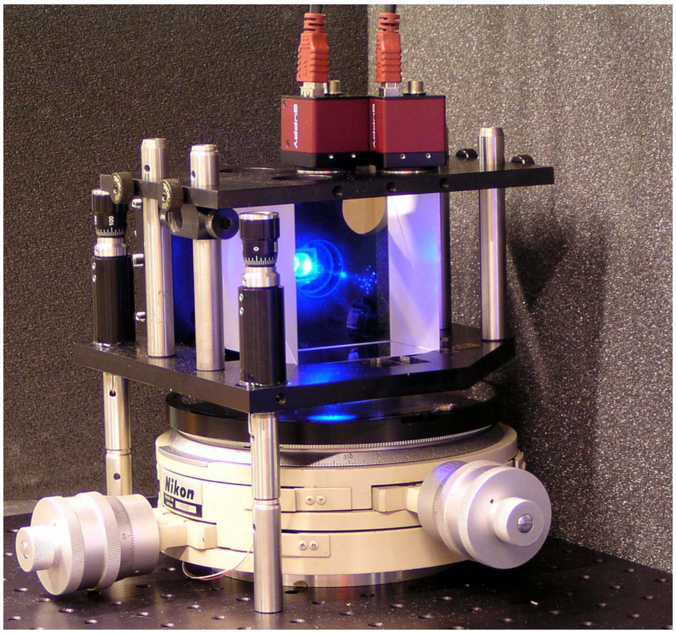

Figure 1. Proof-of-principle demonstrator of our five-channel interferometer array.

SMARTIEHS focuses on test applications requiring verification of device functionality under physical stimulation. This is particularly applicable to devices where the cost of packaging is significant because wafer-level testing helps to exclude bad devices early on in the production process. The project also may be considered a concept study of the potential of parallel, multifunctional inspection for the MEMS industry. It also addresses manufacturers' needs to monitor and control production processes to optimize their yield, because advanced wafer-level testing enables extraction of device parameters (such as the thickness and integrity of membranes) over the entire wafer and without interference caused by packaging.

Continued on next page

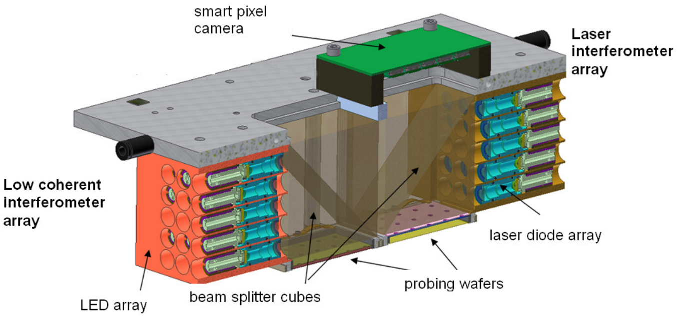

Figure 2. *Configuration of the optical unit of the SMARTIEHS inspection system. The smart-pixel camera is moveable between the two modules. The MOEMS/MEMS wafer for testing is held by a chuck underneath the probing wafers.*

We are also developing a novel concept based on a wafer-to-wafer inspection approach, where we adapt exchangeable micro-optical probing wafers to the MOEMS/MEMS element that requires testing. As a result, the measurement time can be reduced by a factor of more than 100 for an 8in wafer. Different parameters can be tested at the same test station using exchangeable components that are each designed to measure specific parameters. The project aims to develop two probing wafers based on different interferometer arrays, one for deformation and geometric characterization, and one for dynamic MEMS testing. Illumination, imaging, and excitation modules can be interchanged if required by the spatial distribution of the MOEMS/MEMS structures or functionality. The array configuration can be nonregular and optimized for time-efficient inspection strategies.

Our wafer-to-wafer concept addresses the production of complete interferometers in an array arrangement using standard microfabrication technologies. We demonstrated the system's multifunctionality using two different probing-wafer configurations, 5×5 arrays of low-coherent and laser interferometers (see Figure 1). We mounted the inspection system on a commercially available wafer-handling and positioning setup (e.g., a PA 200 SÜSS prober[3]). We used the prober's wafer chuck to mount and position the MOEMS/MEMS wafer. The inspection system consists of a scanner and an optical unit. The high-accuracy scanning unit comprises three voice coils as well as three measurement interferometers. The configuration of the optical unit (see Figure 2) includes the two different interferometer arrays. The light sources are arranged in an array and positioned on either side of each interferometer unit. A beam splitter guides the light towards the probing wafer.

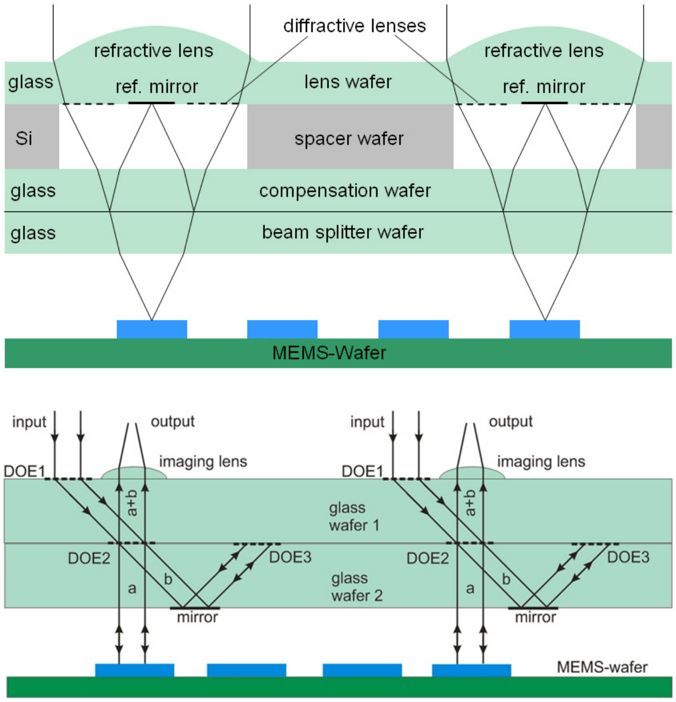

Figure 3. *Configuration of the two different interferometer arrays on the probing wafer. (top) Mirau-type low-coherent-interferometer array. ref.: Reference. Si: Silicon. (bottom) Twyman-Green-based laser-interferometer array. DOE: Diffractive optical element.*

The interference signals are generated in the micro-optical interferometers, which are fabricated in a regular matrix on a 4in wafer stack. We are pursuing two different approaches (see Figure 3), a refractive Mirau-type[4] and a diffractive Twyman-Green-type interferometer.[5] We designed a distributed array of 5×5 smart-pixel cameras for detection of the interferometer signals. The cameras feature optical lock-in detection at the pixel level. The subsequent signal processing is based on the 'on-pixel' processing capacity of the camera array.[6] Each micro-interferometer image will thus be detected by 140×140-pixel subarrays distributed in the image plane.

SMARTIEHS is a European Commission Framework Programme 7 project with eight partners based in six European countries. It is coordinated by SINTEF (Norway) and includes Warsaw University of Technology (Poland), the German Fraunhofer Institute for Applied Optics and Precision Engineering (IOF) and the Institute for Microelectronic and Mechatronic Systems, the CNRS (France), the Swiss Center for Electronics and Microtechnology (CSEM) and Heliotis (Switzerland), and Techfab (Italy) as partners.

Continued on next page

10.1117/2.1201003.002684

Author Information

Kay Gastinger and Odd Løvhaugen
Optical Measurement Systems
SINTEF Information and Communication Technology
Trondheim, Norway

Kay Gastinger completed his Master's degree in electrical engineering at the Technical University Ilmenau (Germany) in 1997 and received his PhD in physics from the University of Oldenburg (Germany) in 2006. He joined SINTEF in 1997, where he is a senior scientist as well as coordinator of the SMARTIEHS project.

Odd Løvhaugen obtained his MSc in physics from the Norwegian Institute of Technology (Trondheim) in 1972. He joined SINTEF in 1996 and is currently a senior scientist as well as the scientific coordinator of the SMARTIEHS project.

References

1. http://www.ict-smartiehs.eu/ SMART InspEction system for High Speed and multifunctional testing of MEMS and MOEMS (SMARTIEHS).
2. K. Gastinger, K. H. Haugholt, M. Kujawinska, and M. Jozwik, *Optical, mechanical, and electro-optical design of an interferometric test station for massive parallel inspection of MEMS and MOEMS*, **Proc. SPIE 7389**, p. 73891J, 2009.
3. http://www.cmicro.com/home.
4. K. Gastinger, K. H. Haugholt, A. Røyset, J. Albero, U. D. Zeitner, and C. Gorecki, *Design of a micro-optical low coherent interferometer array for the characterisation of MEMS and MOEMS*, W. Osten and M. Kujawinska (eds.), **in Fringe 2009: 6th International Workshop on Advanced Optical Metrology**, pp. 611–617, Springer, 2009.
5. M. Józwik, M. Kujawińska, U. D. Zeitner, and K. H. Haugholt, *Optical design of a DOE-based laser interferometer for inspection of MEMS/MOEMS*, W. Osten and M. Kujawinska (eds.), **in Fringe 2009: 6th International Workshop on Advanced Optical Metrology**, pp. 485–488, Springer, 2009.
6. S. Beer, P. Zeller, N. Blanc, F. Lustenberger, and P. Seitz, *Smart pixels for real-time optical coherence tomography*, **Proc. SPIE 5302**, pp. 21–32, 2004.