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Automated Multiscale Measurement System for Technical Surface Inspection

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Abstract:

Inspection systems with multiple sensor systems offer the opportunity to select the most suitable sensor according to the measurement task. A challenging objective consists of an automatic selection of the relevant sensors and their embedding into an effective measurement chain. In this publication, we present the implementation of an automated multiscale inspection strategy into a system for the inspection of MEMS and micro lens arrays and give an extended outlook on future challenges which have to be solved to adapt such a system to inspect complex technical components.

Introduction

To ensure the production quality in modern fabrication lines for micro components, automated inspection systems with a high throughput are required [1, 2]. These systems have to inspect a large measurement area within a short time with submicron accuracy over specific regions of the specimen.

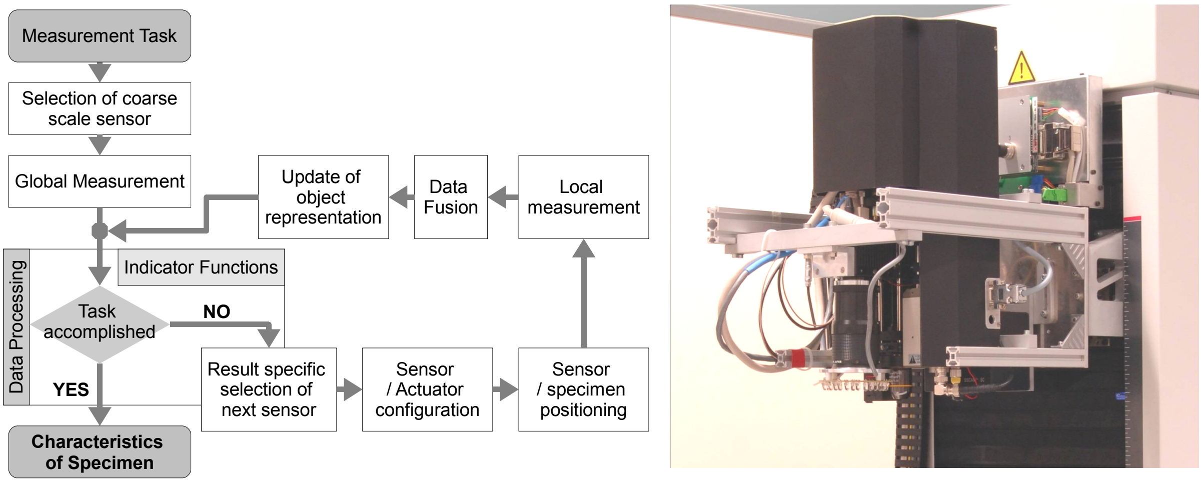
Inspection systems based on a single sensor approach cannot fulfill these strict requirements due to the fact that common sensors have a restricted area related resolution. A possible solution is to use a hierarchical multi sensor inspection system; this additional degree of freedom gives the opportunity to balance the conflict between resolution, field of view and measurement time. Therefore different strategies for the sensor fusion have been developed. The most promising strategies are the hierarchical sequential approach [3, 4] and the parallelization approach [5]. While the second approach offers higher resolution combined with less defect detection uncertainty using a fix arrangement of sensors, the first approach offers more flexibility and the opportunity for a sensor adaptation during an inspection cycle when more information becomes available.

In this contribution we refer to the hierarchical multi sensor approach and present the latest results for the inspection of MEMS and an extended outlook for the inspection of technical surfaces with an automated multiscale measurement system (AMMS).

Automated multiscale measurement strategy and hardware implementation

The automated multiscale measurement system (AMMS) is based on an active exploration strategy (fig. 1a) [6]. The inspection starts with a fast overall measurement of the complete specimen. The data from this global measurement is evaluated for resolved defects and for hints to possible unresolved defects by image processing algorithms. These hints for possible unresolved defects, so called indicators, can be changes of the sensor raw signal, e.g. changes of the signal form of a scanning confocal or a scanning white light interferometer, or changes in the measurement data near the noise level of the system, e.g. very low intensity variations in dark field measurements etc.. For the identification and characterization of the indicated regions on the specimen, more detailed measurements with more suitable sensors are performed as a sub measurement task.

A crucial point for this strategy is the selection of suitable system configuration (e.g. number and type of sensors, positioning etc.) for the inspection system and the automated selection of best suitable sensor and valid indicator detection algorithms during an inspection. Therefore an assistant system for automatic hardware configuration and indicator detection function generation is necessary. In [7] [8] first results of our assistant system are shown.



a) b)

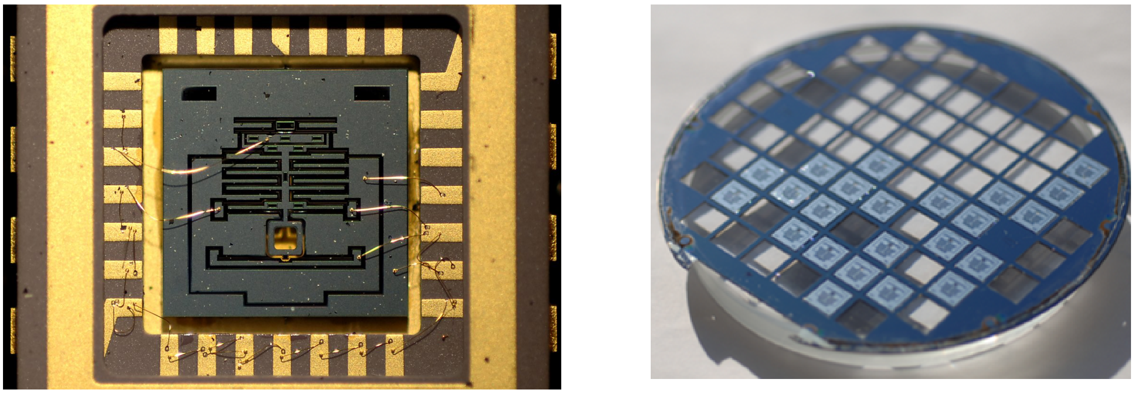
Fig. 1: (a) AMMS-Strategy and (b) Sensors of the AMMS Demonstrator

For an exemplary inspection of flat wafer scale specimens, a demonstrator based on a modified Mahr MFU 100 with an operating volume of 200 mm x 300 mm x 360° was realized (fig. 1b). To fulfill the different requirements of multiple sensor systems and to increase the positioning accuracy, a custom made control system has been developed and implemented [9]. The machine uses a self developed sensor support that offers slots for up to three different sensor systems. In the current configuration the systems uses a video microscope (VM) with a telecentric lens with different measurement modes (dark & bright field, back plane illumination for spot observation) in the first scale. The microscope employs a colour camera with 1.4 million pixels and a field of view (FOV) of 19 mm x 12 mm. In the second sensor mount a confocal microscope (CM) is used for topography measurements. Depending on the mounted front lens, FOVs varying from 3840 µm (5x lens) to 192 µm (100x lens) and axial resolutions ranging from 0.9 µm down to 0.02 µm are available [10].

Implementation for microlens array and MEMS inspection

For the first proof of principle, micro lens arrays have been chosen as test objects and reliability analysis has been performed [11]. Although micro lens arrays are wafer scale objects with feature tolerances within sub micron scale, they are still cooperative specimens due to their low geometric complexity and homogeneous surface properties.

More complex objects are micro electro-mechanical systems (MEMS). As an example we took the micro calibration devices developed by the IMTEK, Freiburg (fig. 2) [12]. The overall size of the micro calibration MEMS that are used is 8 mm x 8 mm, while the smallest features, the combs, have a width of 10 µm and a gap of 4 µm. The inspection task for the AMMS is to find critical defects on a complete wafer (fig. 2b) with up to 72 MEMS.



a) b)

Fig. 2: (a) photo of the IMTEK-in-plane calibration device; (b) 3” Wafer with micro calibration devices, 72 MEMS before separation.

The devices consist of the following critical components: optical detection areas, comb drives, springs and flexures, contact areas and contact lines, the moveable mass system, and the base structure. Typical defects of the devices during the fabrication process are broken / missing combs or springs, cracks, and scratches in all regions of critical components. Further more the devices have to be tested for pollution or fabrication errors which could lead to blocked comb drives and springs or creating shortcuts. For the characterization of cracks, shortcuts in the comb region and blocked comb drives the sensor resolution has to be better than the 4 µm gap.

For the inspection of the MEMS the AMMS-demonstrator is used with the VM in the first scale to identify the region of the comb drives, springs, bond pads and possible scratches, and with the confocal microscope with a 10x magnification (lat. Resolution ca. 10µm) in the second and with a 50x magnification (lat. Resolution ca. 2µm) in the third scale for comb drive and scratch characterisation [13]. The algorithms for the defect detection of scratches and broken combs are described in detail in [13]. The algorithms for the comb drive region detection will be described in more detail in a future publication. Figure 3 shows some exemplary measurements for the inspection of the MEMS-wafer. Defects below measurement resolution of the second scale sensor (fig. 3b, 3c) were indicated properly and then characterized by the third scale sensor.

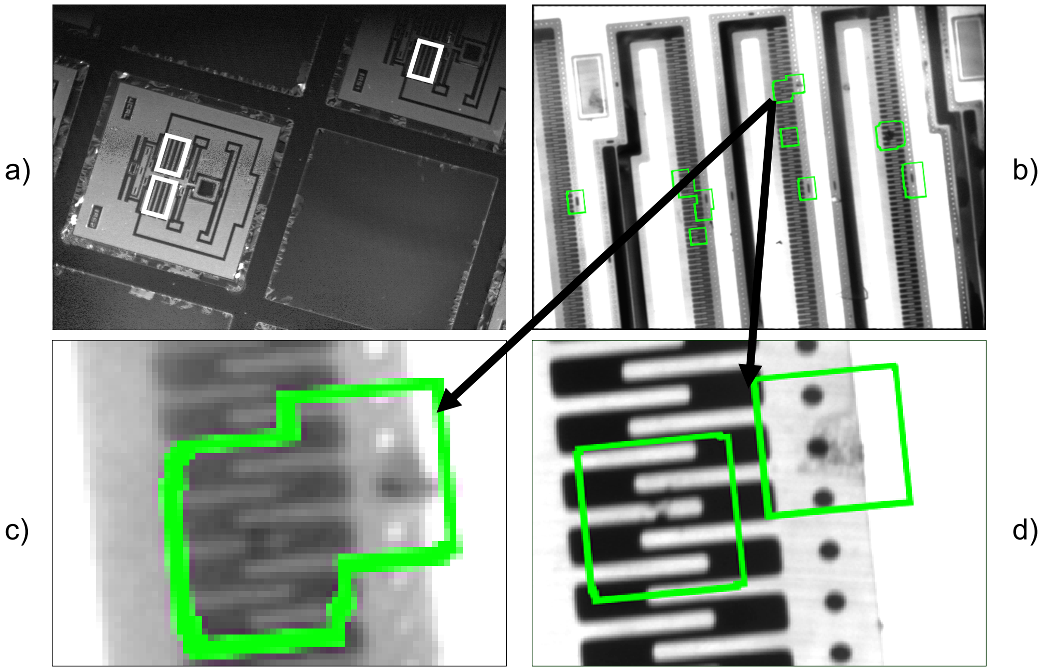


Fig. 3: Inspection of complete MEMS wafer, (a) VM image of MEMS-wafer with evaluated comb drive regions, (b) confocal intensity image taken with 10x, (c) digital zoom of (b) and (d) zoom of the defect region measured using 50x confocal.

The overall inspection time of the system depends on the number of defects on the samples and the number of false detected defects. If we assume 20 FOVS for the second scale per MEMS (10 defect indications from scratch detection and 10 for the comb drives) and further 20 possible FOVs for all comb drives for the third scale, one MEMS can be inspected in around 9 minutes. For instance, the complete 3” wafer with its 72 MEMS can be inspected in 11 hours.

Summary and outlook for future challenges

We presented an automated multiscale measurement system and its implementation for MEMS inspection. The results of the exemplary inspected MEMS wafer show the advantages of this strategy, the reduction of the inspection time and therefore a fast nearly hundred percent control of MEMS during fabrication.

The upcoming challenges for the automated inspection systems include the adaptation to object classes with complex three-dimensional surfaces. The inspection task of such objects, like gears or cam shafts, are often a combination of local defect detection as well as an evaluation of geometric features in a global context. Hence, the multiscale measurement strategy has to be modified and extended. First, the inspection sequence has to be extended by elaborated stitching methods, which help to merge all data points, registered in the same or different scales, within one common coordinate system. This aim cannot simply be accomplished by a full a priori calibration of every available axis, due to iterative uncertainties in the machine setup and its different axes, temperature drifts, optical distortions and aberrations in the sensor systems. While investigating objects with a maximum height lying within the field of depth of the sensor, every single acquired data set contains dense height information for the following defect detection. However, in the case of complex three-dimension objects, the object's surface often has to be measured and sampled in different directions in order to get the required surface information from areas having different gradients. Then, data fusion already is an important prerequisite for further examinations.

The second challenge will be an automated field of view planning based on a priori information like CAD-data or previous measurements to calculate the new regions of interest (ROI) according to the defect sizes and the best orientation of the sensor to this ROI. Additionally, this planning step should detect and merge ROIs which can be captured by the same next measurement. Then, again the local gradients of these ROIs have to be taken into account in order to guarantee high quality measurements. If one ROI consists of areas with highly differing gradients, the field of view planning must be able to split the ROI into sub-areas with respect to common detection angles.

In case of the sensor selection and adaptation, first results for a hardware selection assistant have already been demonstrated [7]. The last major challenge will be the automated selection and optimization of the data evaluation algorithms (image processing). In [8] the architecture and basic implementation of such an assistant system is described. This system has to be implemented and tested for the high diversity of complex technical surfaces.

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