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50. Internationales Wissenschaftliches Kolloquium
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# Design and Construction of Long Range Traceable Scanning Probe Microscope

## ABSTRACT

This paper describes a Traceable Scanning Probe Microscope (TSPM) for the pitch and linewidth metrology of 12-inch wafers in semiconductor industry. It consists of a commercial SPM, laser interferometers, a cross roller stage and a three-dimensional piezo stage. A symmetrical and kinematic structure is designed to perform highly stability and accuracy.

## 1. Introduction

In the past few years, different methods were established to characterize micro- and nanometer scaled surface structures of materials. Among those, the scanning probe microscopy is one of the most commonly adopted techniques. Recent advances in the fields of micro- and nanostructuring of surfaces and manufacturing of nano-particles require new nanoscale tools of metrological-grade to meet the customers' increasing demands for greater measurement accuracy and measuring range[1-2]. A TSPM based on a commercial SPM and new design of a carrier structure would be described in details. The capabilities of the newly designed system are: (1) Coarse positioning of 14 mm × 14 mm over 12-inch sample surfaces by cross roller stages and 20 mm in vertical direction by stepping motor, (2) Fine positioning and scanning of sample surfaces of 100 µm × 100 µm × 10 µm by a piezo stage, and (3) Symmetrical and kinematic structure, and minimization of Abbe errors in all three axes.

## 2. Realization of long range traceable scanning microscope

***Design Principles:*** To trace to the SI, all functions of the scanning head of the TSPM except that of generating a feedback signal by the aligned and reflected laser are replaced by more precise measurement and positioning components (see Fig. 1). For the fine positioning, a 3D piezo stage is used to realize the scanning motion. The measurement data in the horizontal plane of all measurement points are produced by two double-beam laser interferometers in order to trace to the SI. Possible pitch and yaw angles can be detected as well. The primary function of the piezo drive of the Quesant scanning head concerning the translation of information of surface heights into driven distances of the cantilever is replaced by the third axis drive of the piezo stage utlizing the same the feedback signals from the photodetector of the scanning head for a closed control loop. The laser beam of a third interferometer is aligned to the bottom of the piezo stage, whereby the information of heights of any surface points that are now translated into driven distances of the piezo stage in its height can be detected and evaluated. Since all orthogonally adjusted laser beams of the three interferometers are aligned to the actual measurement point (tip of the cantilever), measurements can be operated without Abbe errors. A temperature-controlled water circulator is used to maintain system between (20±0.1) °C. Any changes of environment are detected by the integrated pressure and temperature sensors.

***Coarse Positioning and Fine Positioning:*** In order to reach a range of 14 mm × 14 mm × 20 mm to drive 12-inch wafer samples to specified locations, a special positioning stage was designed. It is driven by two servo-motor stages and one stepping motor. The determination of the current position is realized by linear encoders (HEIDENHAIN) and can be used optionally as informational purpose during free positioning or as feedback signal in forced positioning. A Super-Invar piezo stage (PI) mounted on the top of the mentioned positioning stage, with a maximum driving range of 100 µm × 100 µm × 10 µm is carrying the surface samples. Signals for a closed feedback circuit are generated by the integrated capacitive sensors.

***Control Software:*** The integration of the different hardware components demands a great deal programming flexibility from the control software. The development of a LabVIEW based control program allows for the communications in-between all components under one common platform (see Fig. 2). Additionally, the concept of the newly built TSPM offers the possibility to switch back to the previous function of the Quesant SPM using the appropriate software.

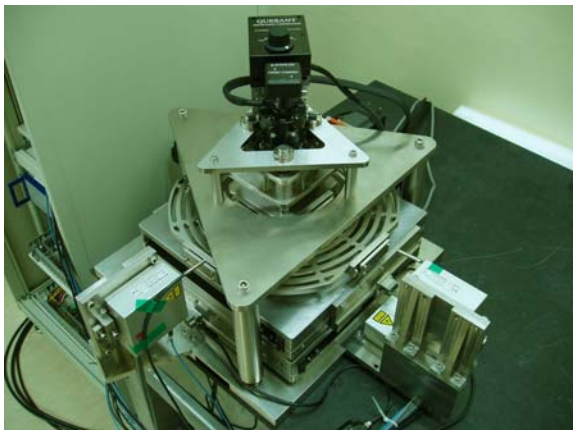

Fig. 1. Photograph of TSPM

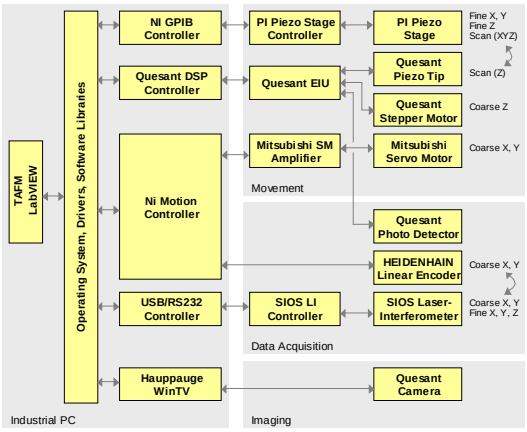


Fig. 2. Control Diagram of TSPM

## 3. Summary

To achieve the dimensional traceability for 12-inch wafers, a long range TSPM has been accomplished. The TSPM was designed on symmetrical Super-Invar mechanical structure and kinematical mounting, and integrated with three laser interferometers, coarse motion of 14 mm × 14 mm × 20 mm by a servo-motor stage and fine motion of 100 µm × 100 µm × 10 µm by a piezo stage. The further applications will be for the calibrations of line pitch, step height, and linewidth standards on 12-inch wafers.

**References:**


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