Chapter 9
Tactile Dimensional Micrometrology

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Abstract Tactile dimensional micrometrology faces different challenges in quality control of microsystems. Among all, the measurement in three dimensions and the great variety of different materials are great challenges. A microprobe has been optimized to solve both problems. It makes three-dimensional measurements of coordinates and forces. Recently observed probing force dependent systematic deviations of tactile measurements are reported which reveal the necessity of exact probing force setting and calibration especially for microprobes. The probing force calibration by means of a high-resolution compensation balance and a new piezoresistive microforce sensor are described. For the complete calibration of micro measuring machines new dimensional standards for the 3D calibration of microprobes and positioning systems are presented.

9.1 Introduction

The excellent mechanical properties of silicon give silicon microprobes great metrological potential for quality control of microsystems. The development of an optimized piezoresistive silicon 3D microprobe, its metrological properties and its application for hardness and elasticity measurements are described in Sect. 9.2. The contribution is not restricted to the coordinate measuring properties but also concentrates on the force measuring properties of this probing system. The motivation for investigating the force properties are material dependent deformations during the tactile measurement process. Since modern microsystems are composed of different materials, different deformations occur and lead to systematic measurement deviations.

Problems occur if soft materials and materials of different mechanical properties have to be measured (Fig. 9.1). Microsystem structures which are composed of different materials such as Si, SiO$_2$, Cu, Al, SU-8 or NiFe, deform during tactile measurement as a function of the Young's modulus and the
viscous modulus, the hardness and the scanning speed (Fig. 9.2) [3]. In the third section details are given of the calibration of probing forces using a compensation balance and a new piezoresistive micro force sensor, which is insensitive to the loading position. Application of 3D microprobes in a coordinate measuring machine leads to a demand for dimensional standards to measure both, the properties of the probing system and the properties of the positioning system. Dimensional standards which have been developed for that purpose are presented in Sect. 9.4.

9.2 3D Microprobes

Tactile metrology became more important for the manufacturing of hybrid microsystems in recent years. Apart from optical methods tactile metrology is an important tool for quality assurance. Optical measuring methods often reach their limits, especially for the dimensional measurement of three-dimensional objects, which can have undercut structures. In these cases tactile metrology is the only possibility to check the accuracy and to ensure the functionality of micro mechanical components. The conventional coordinate measurement technique offers 3D probing uncertainties down to 0.2 μm. Conventional probing-systems have probing spheres with a minimum diameter of 300 μm and probing forces of several mN. The measurement of hybrid microsystems requires smaller probing elements, smaller probing forces and smaller measuring uncertainties. Extensive research in development and optimization of tactile probing systems has been carried out in the last years [25].