Parallel imaging with micromachined self-actuated piezoresistive proximal probes

P. Zawierucha, M. Zielony and T. Gotszalk,
Wroclaw University of Technology, Faculty of Microsystems Electronics and Photonics, 50-372 Wroclaw, Poland

J. Zöllner, Y. Sarov, A. Frank, Tzv. Ivanov, and I.W. Rangelow,
MNES, IMNE, FEI, Technical University of Ilmenau, Gustav-Kirchhoff-Str.1, 98684 Ilmenau, Germany

N. Nikolov,
Microsystems Ltd., 9010 P.O. Box 147 Varna, Bulgaria

R. Pedreau, Paule-Emile Latimer
ID-MOS, 16, Cours du Général de Gaulle, 33170 Gradignan, France

In this article we will present the application and properties of the one dimensional VLSI NEMS-chip (Very Large Scale Integrated Nano Electro Mechanical System) incorporating 32 proximal probes for high speed atomic force microscopy measurements (Fig.1). Each array cantilever integrates a thermal deflection actuator (enabling DC tip deflection up to 1 micron and excitation of resonance vibrations in 1^{st},2^{nd} and 3^{rd} Eigenmode), a piezoresistor acting as a deflection detector and a microtip with radius of 10 nm, (Fig. 2) [1]. The self-actuated piezoresistive cantilevers are very sensitive and versatile tools that have broad applications in a variety of nanotechnology fields. Parallel operated cantilever arrays, can be used to increase the sensing area and imaging throughput. The integration of the piezoresistive readout and the actuator provide a promising solution in realizing a compact non-contact atomic force microscope with a parallel cantilever for imaging of large surfaces with high speed [2].

In order to maintain the constant force acting on the cantilever tip we monitor the cantilever resonance vibration and control the constant current flowing through the micro-heater so that the amplitude of the resonance oscillation remains stable. The measurement and control system is based on ASIC electronics, which supports 2x8 cantilever chips. The first block of the ASIC is the preamplifier integrating low-noise blocks for the detection of the cantilever deflection, band pass filters ensuring the proper signal to noise ratio and stable piezoresistor supply current sources. The second one is the signal buffer and converter integrating drivers for the cantilever static and resonance actuation and high speed amplitude detectors. The scanning stage is based on a precise piezoelectrical actuator for XY scanning movement (up to 400x400 microns). The mechanical head, in which the cantilever array (Fig.2) is mounted, integrates a coarse cantilever-sample approach mechanism (Fig.3). A DSP based system with 128MByte RAM memory is used for the data acquisition while surface scanning. In this way it is possible to collect data from up to 128 cantilevers. For the actuation of array cantilever vibrations an external block of 32 direct digital synthesis (DDS) generators is applied. In order to control the distance between the cantilever and surface a set of digitally adjusted PID controllers is used. The entire scanning system is controlled using data acquisition and control software running on the PC host computer. In this way it is possible to set the parameters of the scanning process, define cantilever excitation and set the PID controller parameters. In this paper we will also present results of the metrological calibration of the piezoresistive deflection detector and thermal deflection actuator of every array cantilever, which was performed using electrical methods and optical fiber interferometry. In addition we will present routinely done typical parallel images using 16 cantilever array where the distance from cantilever tip to the next tip is 150µm.

[1] K. Ivanova *at al.*, J. Vac. Sci. Technol. B 26, Nov/Dec, p. 2367, 2008
[2] I. W. Rangelow *at al.*, Microelec. Eng. 84 (2007) 1260 – 1264

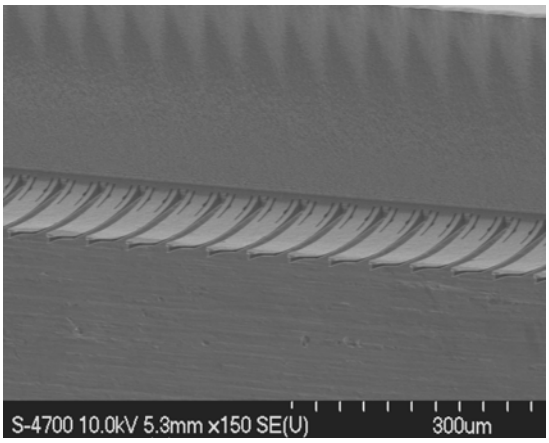

Fig. 1. Detail of micro-machined array of self-actuated piezoresistive cantilevers

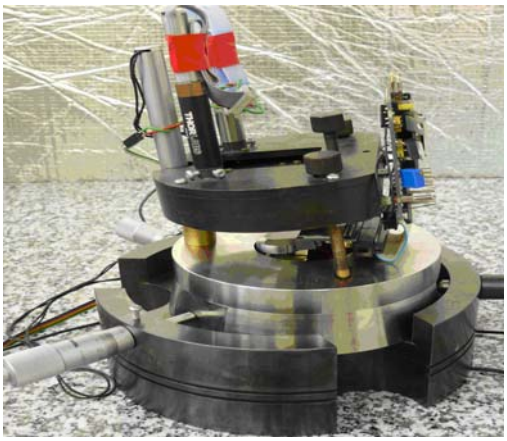

Fig. 2. Scanning stage and ASIC based measurement electronics for the signal acquisition from array of self actuated piezoresistive cantilevers

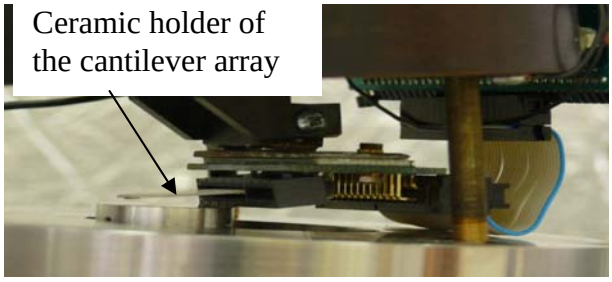

Fig. 3. Scanning head with the cantilever array