Subproject C4: "Microelectronic compatible scanner arrays of high frequency"

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Within the subproject C4 a novel concept of combining micro mechanics with microelectronics is under investigation. A micro mirror array (Fig. 1, 2) which is designed to work in a spectrometer has been chosen for a demonstrator of this technology. It consists of an array of programmable reflecting micro mirrors. Drive electrodes beneath the plates (gap size 25 µm) allow them to be deflected either statically or in resonance. The shapes of the first and second vibration modes are shown in Fig. 2, as calculated by FEM simulations. The dimensions of the springs are 300 µm in length, 5 µm in width and 5 µm in height. The size of the optical area is 7 mm x 0.9 mm. Low temperature bonding is used to realise a special kind of integrating the control electronics: the MEMS wafer is directly bonded onto an electronic wafer, which also contains the drive electrodes (see Fig. 3). The low temperature bonding process (including oxygen plasma activation and subsequent DI water rinsing as well as annealing at 200°C) has been developed during the previous period of the SFB 379. The fabrication technology for the micro mirror wafer based on a special SOI process has already been reported in 2002.

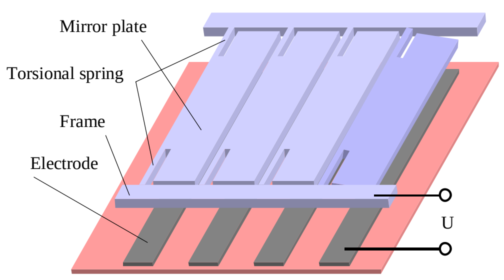

Fig. 1: Construction and drive scheme

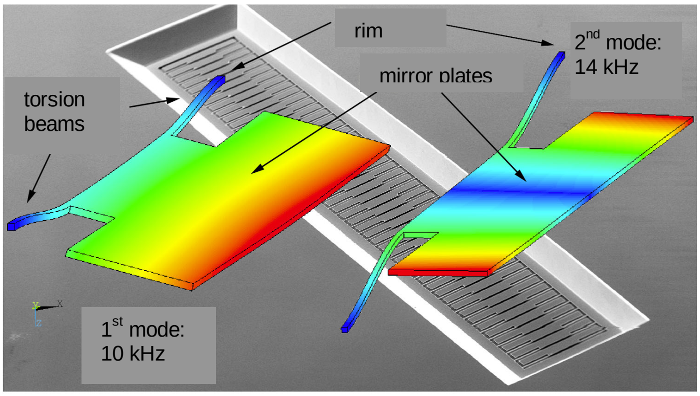

Fig. 2: FEM simulation of vibration modes

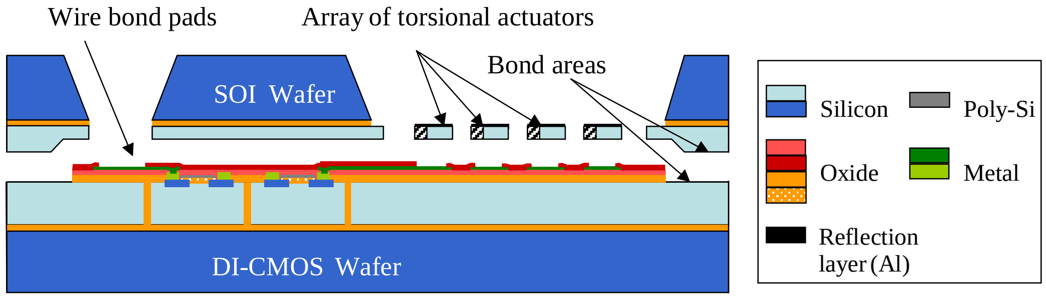

Fig. 3: Cross sectional drawing of the wafers before bonding

In 2003, the technology for the integrated arrays has been developed and first prototypes were fabricated. The basic wafer includes part of the drive electronics, e.g. high voltage amplifiers, sample & hold and logic. It is fabricated by a standard process such as CMOS. In this special case we use the DIMOS-process of Alpha Microelectronics Frankfurt/Oder and X-FAB Erfurt, because high voltages (up to 100 V) are required to drive the micro mirrors. The bond areas are defined as special regions in the layout, which are covered by insulation layers during the whole process. There are no changes necessary in the process flow of the electronics wafer. Just one additional lithography process removes the insulation layers from the bond areas prior to bonding, using a combination of dry and wet oxide etching. This way, the initial (polished) Si surface serves as bond surface. In Fig. 4 a detail of the electronic wafer is shown, indicating the bond areas (surrounding chip frame, support posts around the mirrors). The low temperature bonding process has been successfully applied to the wafers. Fig. 5 shows an IR picture of a perfectly bonded chip, the bonded regions appear as bright areas (marked by arrows). The yield of bonded area was about 70%. Fig. 6 shows a SEM picture of the integrated array.

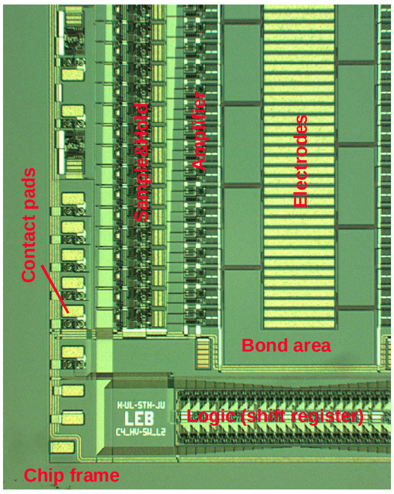

Fig. 4: Detail of electronics

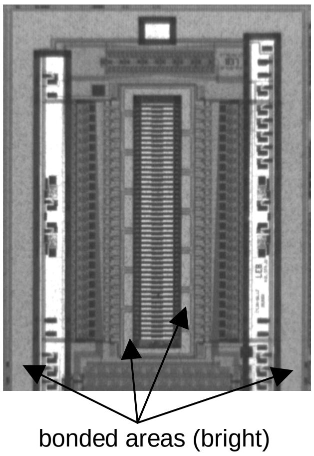

Fig. 5: Infrared picture

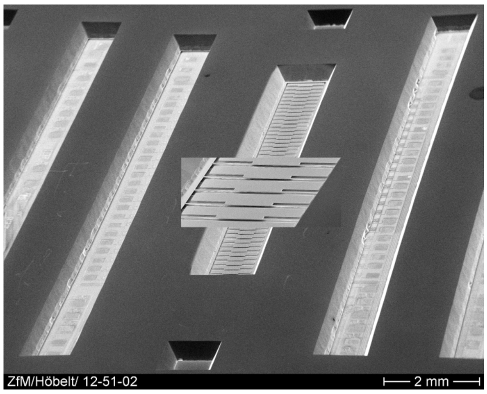

Fig. 6: SEM picture of the integrated array

Both mechanical and electrical functionality of the prototypes have been successfully tested for the first prototypes. To give an example for the correct work of the electronics, Fig. 7 shows the transfer characteristics of the HV output amplifier and the attached sample & hold circuitry. Channel 2 contains the analogue input signal with a shape of a ramp, channel 1 shows the output signal with a decreasing voltage (100 V ... 36 V), as expected a good linearity is demonstrated.

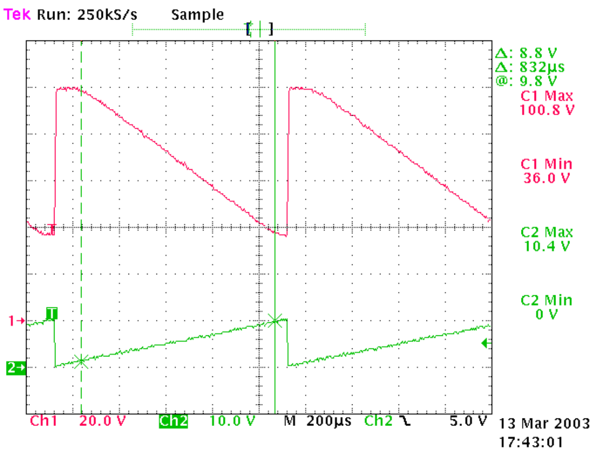

Fig. 7: Transfer characteristics of the HV amplifier and sample & hold

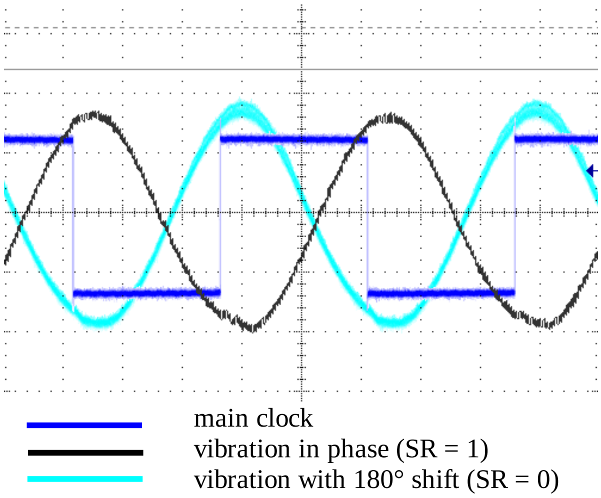

Fig.8: Vibration with different phase controlled by the SR bit

The micro mirror array has been designed for Hadamard transform optics. Here the mirrors are driven to oscillate at their first order resonant frequency, but with different phase shift. This resonance frequency has been indicated at 8.5 ... 9 kHz, which is close to the designed value. The quality factor of about 20 has been expected in this range. Deflection angles of 10° (necessary for the application) have been reached with voltages < 80 V. The phase shift for mirrors in the Hadamard matrix switched "on" should be 0°, whereas the mirrors switched "off" vibrate with 180° phase shift. Fig. 8 demonstrates the vibration of a single mirror element controlled by the SR bit. Presently the work is focussed on the characterisation and parameter definition for the whole array to work as a complex unit and on the application within the spectrometer.

[1] K. Hiller, S. Kurth, N. Neumann, R. Hahn, C. Kaufmann, M. Hanf, S. Heinz, T. Gessner, W. Dötzel, G. Ebest: *Application of low temperature direct bonding in optical devices and integrated systems,* Proceedings of MICRO SYTEM Technologies 2003, pp 102-109

[2] K. Hiller, R. Hahn, C. Kaufmann, M. Hanf, S. Heinz, T. Gessner, W. Dötzel, G. Ebest: *Technologieentwicklung für ein Mikrospiegelarray mit integrierter Elektronik*, 6. Chemnitzer Fachtagung Mikromechanik & Mikroelektronik, Oktober 2003, S. 54-59