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 micromirror array 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 micromirrors. 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. 1). The electronic wafer is fabricated using a standard process such as CMOS. In this special case we use the DIMOS-process of X-FAB Erfurt, because high voltages are required. The bond areas are defined as special regions in the layout, which are covered by insulation layers during the whole process. One additional lithography process removes these layers using a combination of dry and wet etching before bonding. 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.

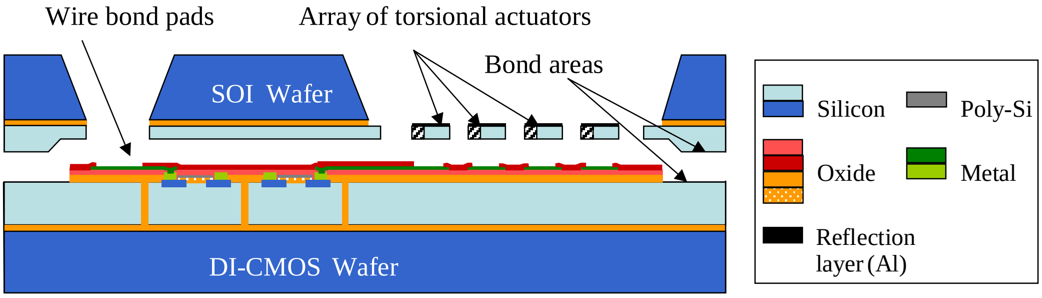

Fig. 1: Cross sectional drawing of the wafers before bonding

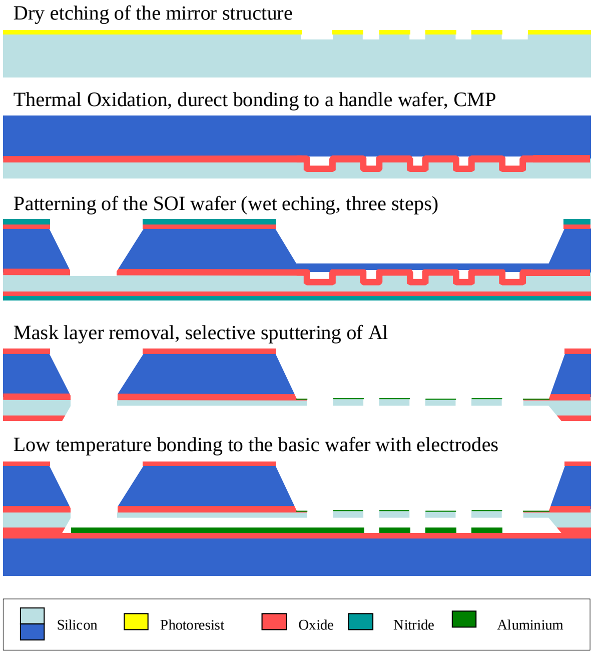

Fig. 2: Technology flow of the micromirror array

Fig. 3: SEM pictures of prototypes

In 2002, a special bulk technology process for the micro mechanics wafer containing the micro mirror array has been developed (see Fig. 2). First prototypes of the micro mechanics device are shown in Fig. 3. The array consists of a line of torsional mirrors, which are driven by electrostatic field (see Fig. 4). A precise process control and a very good uniformity of patterning are necessary to realise the spring dimensions (width of 5 µm, thickness of 5 µm) with acceptable tolerances. The process starts with the pattering of the springs, this way the lateral dimensions will have lowest variation. After bonding to the handle wafer, the SOI thickness is adjusted to the desired value (30 µm). The relatively large working gap (25 µm) is etched at the end of the process using a time-dependent regime. Hence, the thickness of the mirrors and springs can be changed easily, but is strongly influenced by the accuracy of this process. As a result, the deviation of resonant frequencies of the mirrors within an array is mainly influenced by the thickness variations. Measurements of first prototypes (Fig. 5) show frequency deviations of ± 600 Hz (7%) in comparison to the designed value (9 kHz). The micromirror array has been designed for Hadamard transform optics. Here the mirrors are driven to oszillate at their resonant frequency, but with different phase shift. Therefore, much attention will be directed to a further minimisation of frequency deviations.

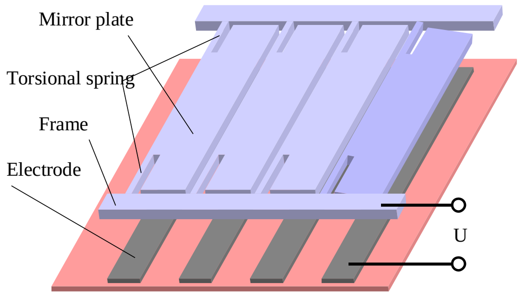

Fig. 4: Principle of electrostatic drive

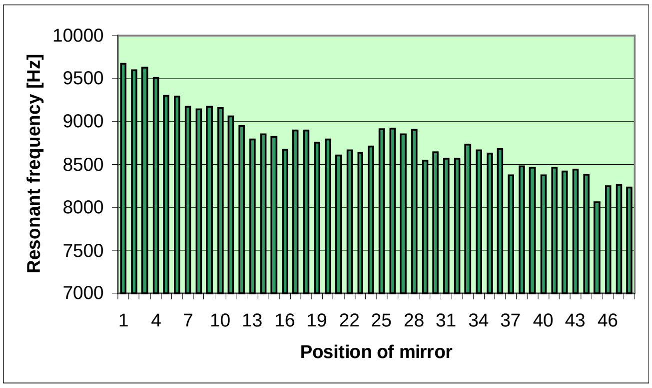

Fig. 5: Histogram of resonant frequencies within an array

Also in 2002 we started the work for the integrated arrays. Fig. 6 presents a cut-away drawing of the integrated array. The electronics design has been carried out at Chemnitz University in co-operation with the company Alpha Microelectronics GmbH Frankfurt/Oder. Based on a special DIMOS process, voltages of more than 100 V can be provided for the amplifiers. For fabrication of the electronic wafers, standard technology flow is applied exclusively. The compatibility to the bonding process is established by a special design using "bond areas" (see Fig. 7). A special equipment and mark concept will allow the alignment of the 6" DIMOS-wafers to the 4" mechanics wafers. First bonding experiments will follow within the 1st quarter of 2003.

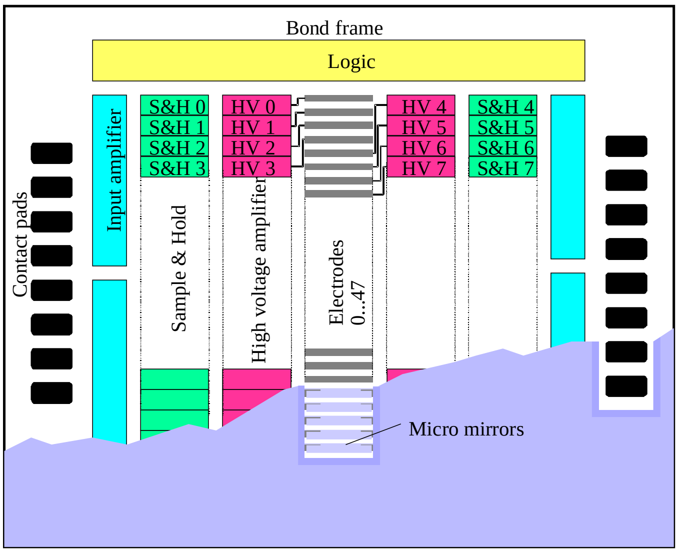

Fig. 6: Schematic design of the integrated array

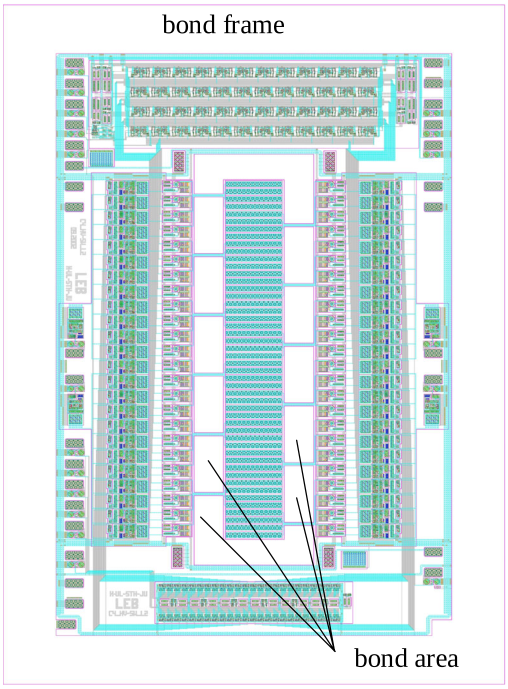

Fig. 7: Electronic chip layout

After development and test of the low temperature bonding process itsself, now the research work concerning wafer bonding has been focussed on characterisation of the bonding behaviour and the bonding mechanism at low temperatures. Fourier transform infrared spectroscopy (FTIR) is a powerful tool to analyse the chemical composition at semiconductor surfaces and interfaces. Especially the H-related species such as Si-H, Si-OH, H_2O, CH_x, which are significant for the bonding process, can be detected. The multiple internal transmission (MIT) set-up (Fig. 8) has already been established and tested successfully. Due to the large number of passes through the interface and the use of p-polarised light the sensitivity to the bonding interface layer is much enhanced in comparison to outer surface absorption.

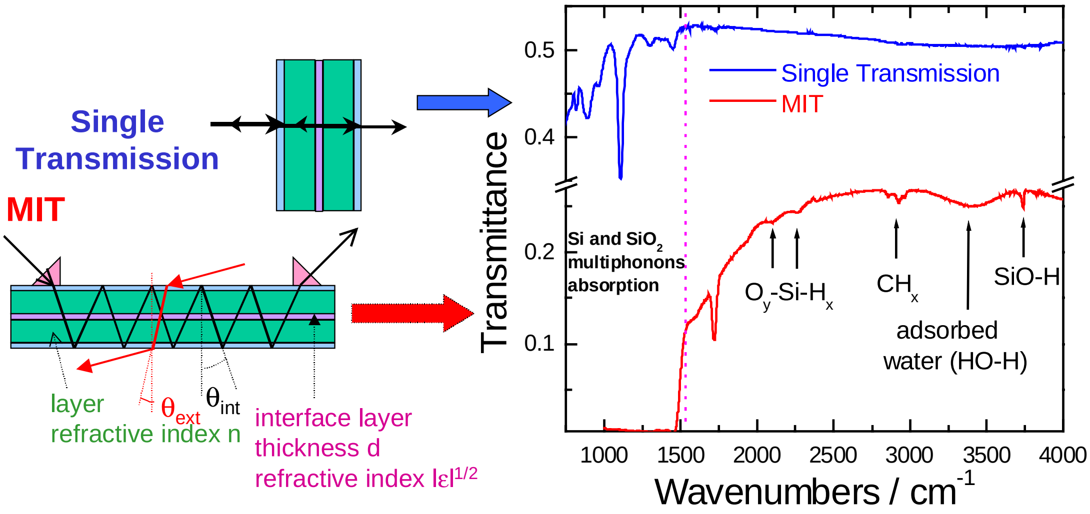

Fig. 8: MIT experimental setup and IR spectra of a Si-Si-compound

The special MIT setup using external prisms allows the analysis of wafer compounds without special preparation of probes. On the other hand, the IR light can be coupled into the probes at different angles and with different optical path lengths, therefore the sensitivity can be adjusted. Furthermore, a low vacuum heating chamber has been constructed. This equipment allows in-situ observation of the chemical species during annealing up to 400°C. IR Spectra of Si-Si-bonds with different pre-treatments for surface activation are presented in Fig. 9 and 10, indicating the different arrangement of water molecules and Si-OH-bonds at the interface. The change in transmittance spectra for different pre-treatments can be correlated to bond strength measurements. Presently the in-situ observation is limited to temperatures of 225°C due to the high doping level of the CZ-grown Si of the wafers. Ex-situ measurements have been taken also for Si-Si-compounds after 400°C, 800 °C and 1100 °C.

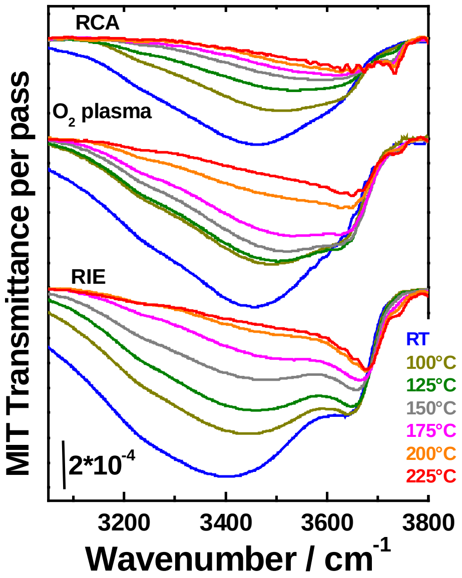

Fig. 9: In-situ MIT IR spectra of Si-Si bonded sample

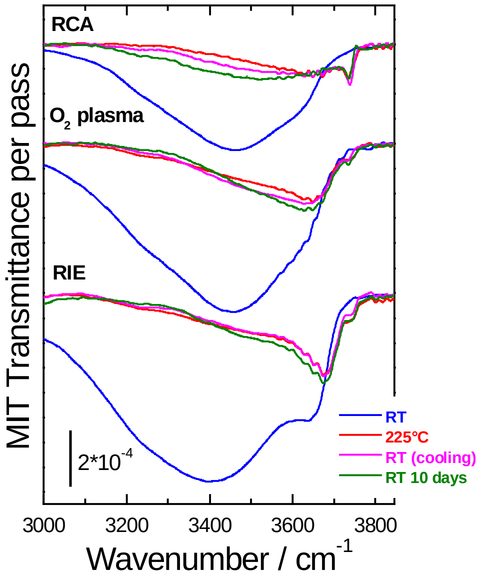

Fig. 10: MIT IR spectra of Si-Si bonded sample at RT, 225 °C, after cooling down and storage in air for 10 days