# Optical Characterisation Methods for MEMS Manufacturing (OCMMM); Part A: On-chip Integrated Techniques in Combination with Micromirrors

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## 1 Introduction

The European GROWTH project (Ref. G1RD-CT-2000-00261) "Optical Characterisation Methods for MEMS Manufacturing" (OCMMM) will be finished in 2004. Starting in 2001 the proposed project aimed at strengthening MEMS testability at all stages, from the design to the end of life of a microsystem. Electrical characterisation of these devices is a well-proven technique. However, the micromechanical characterisation plays a crucial role as well, both during design and development of microstructures and during chip-production, assembling and life cycles of the finished products. Two optical approaches were pursued to improve the MEMS testability: on-chip integrated techniques as well as external full-field interferometry. The ZfM activities were mainly focussed on the first one, the on-chip integrated optical demonstrators providing local in-situ measurements using Integrated Optics (IO). The micromechanical parameters of actuated MEMS structures are monitored by use of an optical read out, based on a Mach-Zehnder Interferometry (MZI). In loaded demonstrators, an MZI is monolithically integrated into the micromechanical part, while unloaded demonstrators use evanescent field MZI read-out. The first demonstrator was a movable micromirror loaded with the sensing branch of an MZI in collaboration with LOPMD. As unloaded demonstrator a rotatable mirror with evanescent field read-out by MZI has been fabricated in collaboration with MESA+, research institute at the University of Twente, the Netherlands.

## 2 Loaded type demonstrator

According to the idea of this demonstrator type the mechanical behavior of the mirror system can be characterized by the deformation of waveguide films forming a sensing arm of an MZI on top of the mirror and crossing the hinges. The second arm of the MZI is located on top of bulk-Si (Fig. 1). Inserting a light wave, the MZI output signal contains the required information about the optical path difference. The changes of the sensing arm are a result of mirror membrane/ hinge deformations due to local changes of the waveguide refractive index. This offers the extraction of information about the mechanical performance of the micromirror (rotation, out-of plane displacement of mirror plate etc.) [1].

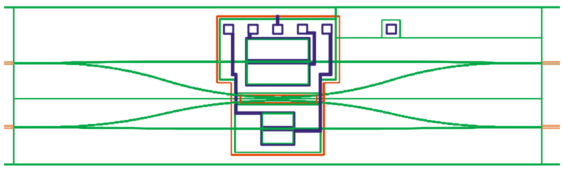

*Figure 1. Schematic drawing of the loaded type demonstrator structure including two types of mirror*

For the MZI structure a single mode buried channel waveguide based on silica/silicon oxinitride/silica structure was selected, performing a low optical attenuation (0.9 dB/cm) and acceptable coupling efficiency (around 50%) from waveguide to a standard fibre. One of the main difficulties of integrating such waveguides is the modification of mechanical properties of the mirror due to the compressive stress caused by PECVD deposition of waveguide films. Despite this and a lot of other challenges: KOH compatibility of waveguide films, adhesion issues, wafer bonding and the multiple wafer exchange between LOPMD and ZfM, finally demonstrators have been fabricated successfully. An integrated device is shown in Fig. 2.

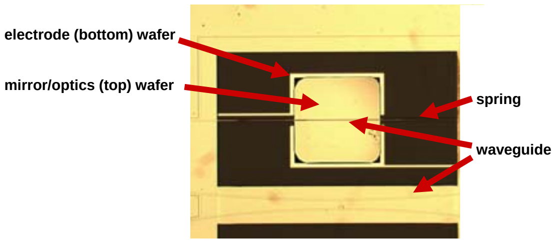


*Figure 2. Microphotograph of an integrated loaded type demonstrator structure after fabrication*

As illustrated in Fig. 3, prototypes of these structures indicate that light is propagating through the waveguide structures. Measurements are still in progress at LOPMD and Warsaw University - Faculty of Mechatronics.

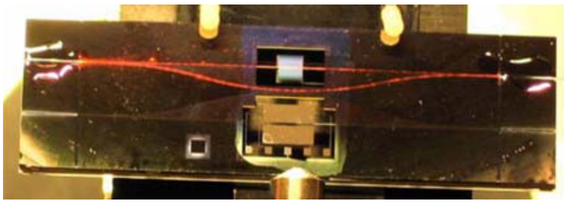

*Figure 3. MZI loaded demonstrator in operation - light path (red) crossing the small mirror is clearly visible; photograph and test assembly from LOPMD*

## 3 Unloaded demonstrators using evanescent field MZI read-out

This work package was established as an alternative method in order to avoid the mechanical contact between waveguide structure and MEMS [2]. Evanescent field sensing of movable objects requires a penetration of the evanescent field of a guided mode by this object, affecting the refractive index distribution within the concerned region. Following this idea a joint concept has been developed enabling a separate fabrication of the mirror and the evanescent field sensing device (Fig.4).

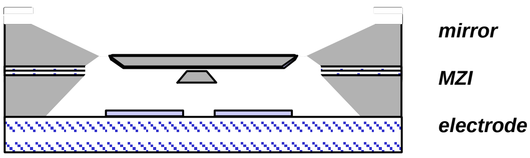


*Figure 4. Schematic drawing of the unloaded demonstrator*

Due to the decoupling of both technologies (MEMS, waveguide structure), the yield of mirror structures fabricated at wafer level (electrode and mirror wafer) was nearly 100 %. The most critical challenge for the completion of this kind of demonstrator turned out to be the wafer bonding processes. The silicon fusion bonding (SFB) of the mirror wafer and the optics wafer is complicated due to an increased surface roughening (caused by etching processes) and by the required metallization of the mirror surface (backside) in order to increase the effect onto the evanescent field sensing. However there is no other option because the distance between sensing device and mirror surface has to be well-defined.

In order to bond this wafer stack with the electrode wafer, adhesive bonding procedures were examined. This way a novel bonding process has been developed by using an epoxy resin [3]. It is characterized by low temperature and a photolithographic patterning. From experimental measurements a surface energy up to 20 $J/m^2$ is obtained. An additional distance between the wafers according to the resin thickness should be not critical in case of the electrode bonding. Demonstrator devices as shown in Fig. 5 are characterized now at MESA$^+$.

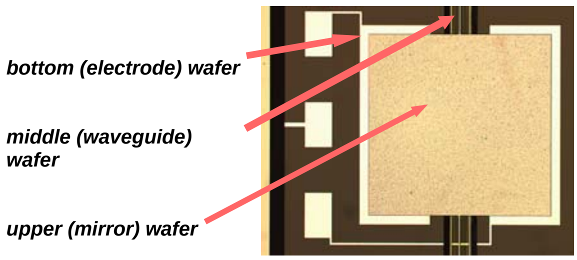


*Figure 5. Unloaded demonstrator after fabrication (at wafer level)*

## REFERENCES

[1] Gorecki, C.; Sałbut, L.; Józwik, M.; *Multifunctional interferometric platform for on-chip testing the micromechanical properties of MEMS/MOEMS*, Photonics West, San Jose, USA, SPIE Proc., Vol. 5343, pp. 63-69, (2003).

[2] Lambeck, P.V.; Worhoff, K.; *Technologies for integrated optical sensors*, SPIE Photonics fabrication Europe, October 2002, Brugge

[3] Reuter, D.; Schwenzer, G.; Bertz, A.; Gessner, T.; *Selective adhesive bonding with SU-8 for zero-level-packaging*, SPIE, Dec. 2004; Sydney, Australia