Tunable Fabry-Perot Filter for Infrared Radiation

Karla Hiller[1], Steffen Kurth [2], Norbert Neumann[3]
[1] Chemnitz Univ. of Technology, Center for Microtechnologies
[2] Fraunhofer Institute for Reliability and Microintegration
[3] InfraTec GmbH, Dresden

1. Introduction

This contribution deals with the design, fabrication and test results of a micromachined first order Fabry-Perot (FP) filter that is intended for use as a tunable filter in advanced infrared gas analysis. Flexibility and performance of such a device are more sophisticated than a simple fixed filter approach particularly if gas mixtures have to be analyzed in which the gases are characterized by adjacent or overlapping absorption bands. The new approach is based on a Fabry-Perot interferometer with an air cavity, which is electrostatically tuned (Fig. 1). In the intended infrared gas analysis application the FP filters require extremely flat, coplanar and smooth reflectors with a high reflectance to achieve a narrow bandwidth of about 50nm, a high tuning range of at least 1800 nm and a high peak transmittance of about 70%.

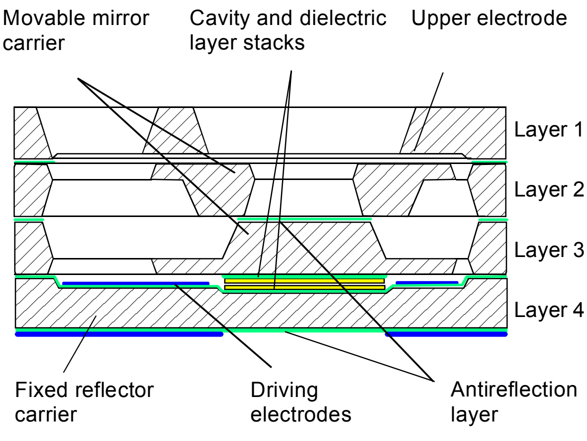

Fig. 1. Cross sectional drawing of the FP filter

2. Design and fabrication

The FP filter is fabricated by bulk micromechanics technology to achieve optimal interference conditions. Relatively thick (300 µm) silicon wafers are used as the carriers for both the fixed and the movable reflector. The reflector (2.2 x 2.2) mm² is located in the center of the driving electrodes, the suspension with diagonal beams, and the rim of the filter. Diagonal bending beams located in the corners of the rim elastically suspend the moveable reflector and are arranged to form a parallel spring suspension. This provides the necessary vertical movement and the necessary rigidity to minimize any tilting of the movable mirror carrier.

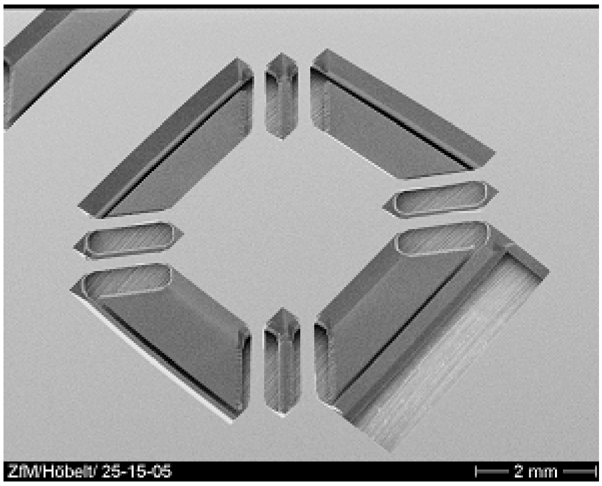

Fig. 2 SEM image of the movable mirror carrier with the parallel spring suspension

In a first approach the springs have been formed in layers 2 and 3, and the parallel spring suspension was created by bonding these layers together (see Fig. 1). The new approach can realize the parallel springs within one wafer by using asymmetric masks (one on each side) and a simultaneous, symmetric wet etch process. 12 diagonal bending beams with a trapezium cross section are formed (Fig. 2). With this method the number of layers can be reduced, which leads to a simplified technology and an increased process yield.

3. Optical design

Distributed Bragg Reflectors consisting of deposited alternating quarter-wave layers of low refractive index silicon dioxide and high refractive index polycrystalline silicon are used as reflectors. Because of the relatively high ratio of refractive indexes n_H/n_L of 2.4 a wide highreflective zone from (3…5) µm and a high maximum transmission of 94% were obtained already with a $(HL)^2$ layer stack (Fig. 3 and Fig. 4). High effort was necessary to minimize curvature and roughness of the reflector and to improve the antireflection coating of the reflector carrier. The roughness of the layer stack has been reduced to 1.7 nm applying low-temperature deposited polycrystalline silicon as high refractive index material.

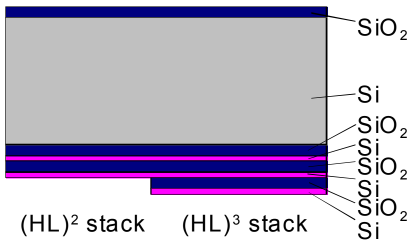

Fig. 3. Configuration of the $(HL)^2$ and of the $(HL)^3$ reflection layer stack

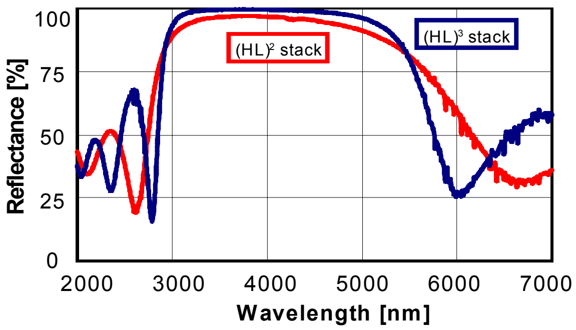

Fig. 4. Spectral reflectance of the reflection layer stacks (measured data)

4. Test results

Fig. 4 shows the reflectance measured on $(HL)^2$ and $(HL)^3$ reflection layer stacks. The optical and electromechanical concept has been proven on etalons with a fixed resin (SU8) spacer and on tunable FP filters. The results (presented in Fig. 5) confirm the suitability of smooth layer stacks to achieve a transmittance of about 75% and a spectral bandwidth of 50 nm. A broadband multilayer antireflection coating (ARC) improves the transmittance in the entire spectral range of (3…5) µm and reduces the ripple caused by internal reflections in the silicon substrate. It is obvious that a single quarter-wave ARC consisting of silicon dioxide or silicon nitride shows reduced performance in comparison to the multilayer ARC.

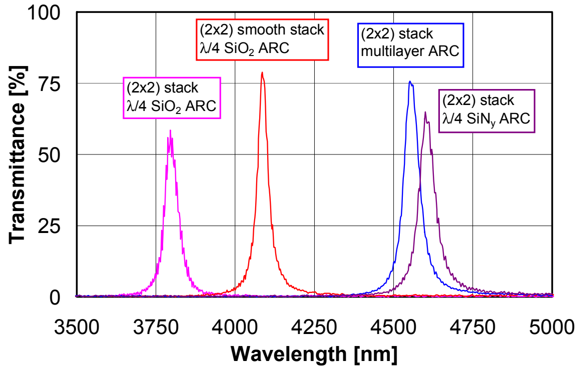

Fig. 5. Transmission characteristic of FP filters with various fixed cavity size

The tunable FP filters were designed with an optical reference wavelength of 3600 nm. Two different types have been completed. A first one provides a variation of the cavity spacing between 1300 nm and 1850 nm for a tunable wavelength of (4…3) µm. A second one performs a variation of the cavity spacing between 1300 nm and 2550 nm in order to cover a spectral range of (5...3) µm. The spectral bandwidth of the short-cavity filter is about 60 nm and the peak transmittance about (60…50)%. Applying a voltage of 24V a high tuning range from 3900 nm up to 3000 nm is achieved (see Fig. 6). The spectral bandwidth of the long-cavity filter at the long-wavelength end is broadened and the blocking is less compared to shorter wavelengths. It is assumed that the lower reflectance of the reflector at about 5µm (see Fig. 4) is the reason for this phenomenon. A narrow pass band of 50 nm bandwidth has been observed in the range of shorter wavelength.

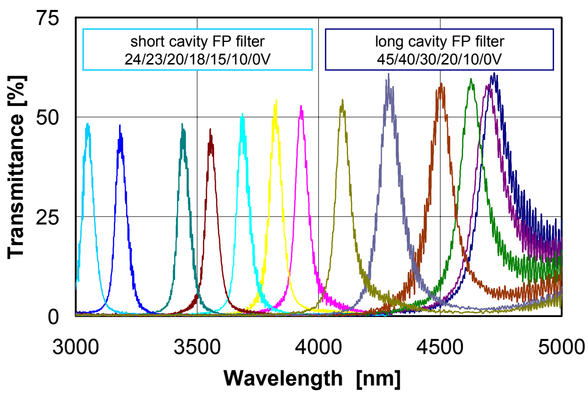

Fig. 6. Transmission characteristic of tunable short cavity and long cavity FP filters with different tuning voltage