Au/In$_2$ Bonding of InP-based MOEMS

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Wavelength division multiplexing (WDM) systems offer the possibility to increase the transmission capacity of optical fibre networks by carrying several channels simultaneously. Reconfiguration of the network and add and drop operations are considered to be an important feature to achieve high flexibility. Hence, new wavelength tunable devices operating at 1.55 µm are of high interest and the fabrication of tunable vertical-cavity devices is particularly interesting.[1]

The InP system is the preferred choice for active devices emitting at long wavelength such as VCSELs. However, one of the intrinsic problems of the InP system is the lack of highly reflective distributed Brag reflectors (DBRs) that have a good thermal conductivity. Techniques such as wafer fusion[2] and complex device fabrication and mounting have been used to obtain output powers of up to 1 mW[3], but the fabrication of widely tunable devices still remains challenging. Here, we propose to transfer InP-based micro-opto electro-mechanical systems (MOEMS) by Au/In$_2$ thermal bonding to substrate carriers featuring a better thermal conductivity. As a result we expect better device performance in the high power, high temperature operation as has been previously presented for vertical external cavity surface emitting lasers at 1.55 µm.

However, the InP-based MOEMS are extremely sensitive to strain and subsequent deformation of the membranes. Hence, the influence of thermal bonding on the intrinsic strain within InP-based MEMS has to be carefully evaluated.

A InP/InGaAs multiplayer structure was grown by MOCVD. Fig. 1 shows a schematic of the epitaxial structure. Similar structures deployed in the fabrication of widely tunable filters showed excellent behaviour.[4]

To ensure the formation of a homogeneous bond, 30 nm Ti and 150 nm Au have been evaporated on top of the MOEMS structure and 30 nm Ti, 150 nm Au, 600 nm In and 20 nm Au on top of the silicon substrate. The epitaxial structure was bonded to the silicon carrier substrate by applying a pressure of 10 MPa and a temperature of 200°C for 30 minutes. After bonding the active layer to the carrier substrate, chemical-mechanical polishing was used to remove the InP substrate and the etch-stop. Mesas were patterned by CH_4 based reactive ion etching using a SiN_x mask forming circular plates that are supported by four arms. The InGaAs layers are selectively removed by $FeCl_3/H_20$ wet etching while the holding pads are protected by a resist layer. Critical point drying has been used to avoid sticking of the membranes. Details of the process can be found elsewhere.[5] Fig. 2 show a scanning electron micrograph of the fabricated structure.

White light interferometry (WLI) has been used to evaluate the influence of the thermal bonding on the mechanical behavior of the InP-based micro-mechanical structure (Fig. 3).

A spherical deformation of the entire structure, even the solid holding pads, can be seen. Fabricating the same structure without Au/In$_2$ bonding showed no curvature at all. This indicates the creation of an additional strain due to the bonding procedure. However, in this case the bending is beneficial for the use in MOEMS since the membrane forms a concave mirror as seen from the cavity that will ensure stable device performance during actuation.

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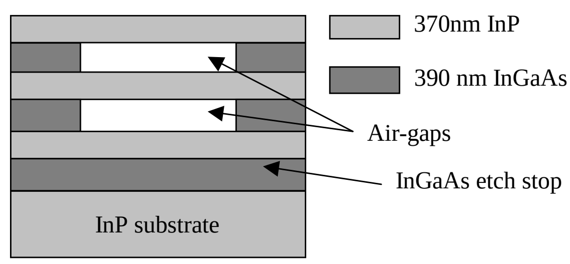

Fig. 1 MOEMS epitaxial structure

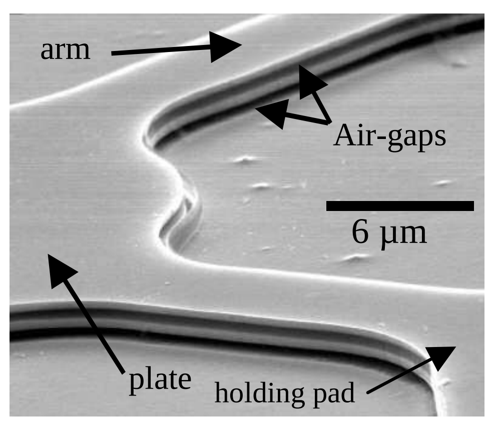

Figure 2 SEM of the circular plate and two supporting arms

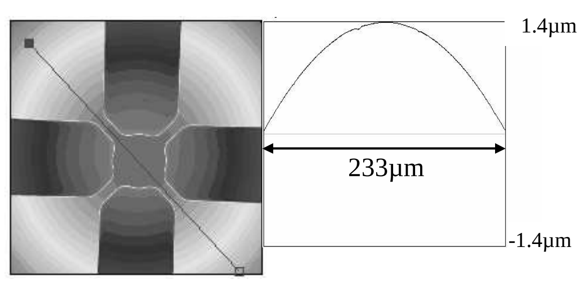

Fig. 3 WLI measurement on a InP membranes symmetrically supported by four arms