1:30pm - 1:45pm
OPM1.1 **Room B2**

Integration of Thin Film Photonic Devices Onto Micromachined Movable Platforms

Scott T. Wilkinson, Young W. Kim, Nan M. Jokerst, and Mark G. Allen

The integration of compound semiconductor emitters and detectors with micromachined devices to form *micro-opto-mechanical systems* (MOMS) offers significant opportunities in applications ranging from sensing to optoelectronics packaging. For example, a significant fraction of the cost of many current optoelectronic components and systems is consumed by the alignment of the fiber or package to the optoelectronic device. The development of MOMS, as described below, offers an opportunity for low cost alignment of optoelectronics through the integration of thin film devices with micromachined movable actuators.

Previous work aimed at MOMS has focused almost exclusively on the micromachining of gallium arsenide or other compound semiconductor materials [1-2]. However, there are several advantages in using silicon: the mechanical properties of silicon are very good, the developed silicon micromachining base is much larger, and the developed silicon circuit fabrication base is also much larger. However, silicon does not efficiently emit light. Our approach to MOMS is to employ the Georgia Tech epitaxial liftoff process to bond a thin film compound semiconductor photonic device onto a micromachined movable platform, forming a micro-opto-mechanical system which combines all of the advantages of silicon and other micromachining materials with the optical properties of compound semiconductors. Also, the separation of the thin film device from the growth substrate sufficiently reduces the weight of the optoelectronic device to avoid impeding the actuation of the micromachined device.

Movable micromachined platforms have been demonstrated previously by this group [3]. These devices are constructed of polyimide, a flexible material with excellent micromachining properties. The structure employs a deposited sacrificial layer that is etched away after the structure is completed so that the platform is suspended above an array of actuation strips. Through the appropriate application of external voltages (typically around 35V) between the platform and actuation strips, these platforms can be electrostatically actuated in both the vertical and lateral directions by as much as 15 μm and 5 μm, respectively.

The thin film semiconductor photonic devices used in this work were AlGaAs / GaAs / AlGaAs double heterostructure p-i-n devices. These high quality single crystal structures were grown lattice matched on top of a sacrificial AlAs layer which had been grown lattice matched to a GaAs substrate. The as-grown layer structure is GaAs (substrate) / AlAs (undoped, 0.2 μm thick) / $Al_{0.3}Ga_{0.7}As$ ($n = 3 \times 10^{17}$ cm^{-3}, 0.5 μm thick) / GaAs ($n < 10^{14}$ cm^{-3}, 1.1 μm thick) / $Al_{0.3}Ga_{0.7}As$ ($p = 1.3 \times 10^{19}$ cm^{-3}, 0.5 μm thick). By etching away the sacrificial layer, the thin film epitaxial devices may be separated from the substrate and deposited onto arbitrary host substrates [4,5]. The Georgia Tech epitaxial liftoff procedure employs a transparent diaphragm to align and selectively deposit thin film devices onto host substrates [6]. Since the device is inverted during this transfer procedure, both the top and bottom of the device can be processed while the thin film device is supported by either the growth or host substrate. This technique has been used at Georgia Tech to bond GaAs and InP based compound semiconductor emitters, detectors and modulators onto arbitrary host substrates[7-9]. These integrated thin film devices exhibit electrical and/or optical performance which is comparable to or better than their on-wafer counterparts.

The transfer diaphragm process was used to deposit thin film p-i-n devices onto micromachined movable platforms. Before release of the platforms, a 250 μm x 250 μm AlGaAs / GaAs / AlGaAs thin film device with a bottom ohmic contact was aligned and bonded onto the gold coated 360 μm x 360 μm or 200 μm x 200 μm platform. An insulating layer of polyimide was then spun onto the platform and chiplet, and a top contact window to the thin film device was opened using reactive ion etching (RIE). The top ohmic contact was defined such that it ran down two of the four legs of the platform that were not connected to the bottom device contact. An additional layer of polyimide was spun onto the top contact and thin film device for protection during platform release. The polyimide was then removed from around the platform and its legs using RIE, resulting in the final polyimide platform structure with an electrically connected, integrated thin film photonic device. Finally, the platforms with integrated devices were released from the substrate by etching away the copper release layer in $FeCl_3$ solution.

We have successfully actuated a 360 μm x 360 μm (shown in Fig. 1) and a 250 μm x 250 μm polyimide platform with an electrically contacted 250 μm x 250 μm thin film device on top. Through the application of approximately 35 V between the center actuation strip and platform, vertical movement was demonstrated. Since the copper release layer was approximately 2.5 μm thick, this was the range of vertical actuation achieved. Also, horizontal movement was demonstrated through electrical actuation by applying a potential between the platform and one of the outer actuation strips. We have also demonstrated a working 250 μm x 250 μm photonic device atop a platform structure. This device was operated in both forward and reverse bias and exhibited an I-V characteristic comparable to on-wafer p-i-n structures when probed at the base of the platform legs. The current increased with increasing light intensity, indicating standard detector behavior.

We have successfully demonstrated that semiconductor photonic device structures can be combined with standard micromachined devices resulting in a manufacturable micro-opto-mechanical system, which is a first step towards an integrated emitter/fiber or detector/fiber alignment system.

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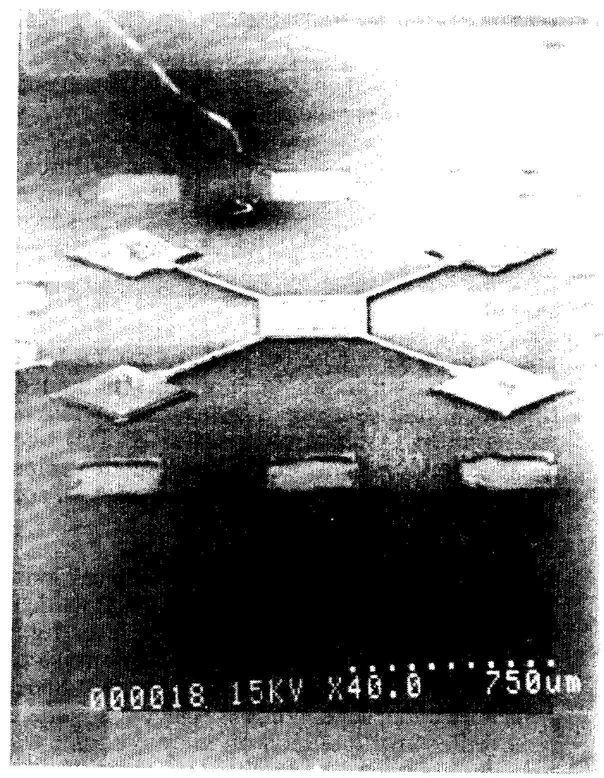

Figure 1 : Photomicrograph of a 250μm x 250μm p-i-n structure on 360μm x 360 μm micromachined movable platform.