Micro-Machined Micro-Optical Bench for Optoelectronic Packaging

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We report a novel scheme for optoelectronic packaging using surface micro-machining technique. *Free-space* micro-optical bench (MOB) enables a large optical system to be monolithically integrated on a small Si chip. Unlike the conventional silicon optical bench technology where waveguides are used to connect various optical devices [1], the MOB integrated active devices with vertical, three-dimensional micro-optical elements in free-space. Stationary and movable micro-optical components are fabricated on Si substrate using micro-machining technique. Pre-alignment of optics is realized by IC-like process: optical lithography. Additional fine alignment after assembly is achieved by the on-chip movable components. Three-dimensional micro-optics fabricated by surface-micromachining technique have been demonstrated [2-3] using micro-hinges and micro-spring latches [4], as shown on Fig. 1. Micro-Fresnel lenses standing on Si substrate with focal length of several hundred μm's to a few millimeters have been demonstrated [2]. In this paper, we present a novel rotatable micro-mirror, and a three-dimensional self-alignment structure (400-μm-tall) for integrating active optical components such as semiconductor lasers or isolators on MOB.

The rotatable micro-mirror is realized by fixing the hinges of folded micro-mirror to a rotatable plate instead of the silicon substrate. The rotatable plate itself is implemented by a suspended polysilicon layer whose center is fixed by a polysilicon hub [5]. The SEM photograph of the rotatable micro-mirror is shown in Fig. 2. The indicator on the lower part of the picture, originally pointing at 0° tick (indicated by the white arrow), has been rotated counter-clockwise by 20° (two ticks). We also introduced a new side-latch to precisely fix the angle of the vertical optical components and enhance their mechanical strength. The side-latch is implemented by a similar polysilicon plate folded in the orthogonal direction. The plate has a V-shape opening on the top edge to guide the mirror plate into a 2-μm-wide groove in the center, as shown in Fig. 2.

In order to integrate the MOB with active optical devices such as semiconductor lasers, we have designed a set of novel self-alignment structures using the same folded polysilicon technology, as illustrated in Fig. 3(a). The edge-emitting laser is mounted on its side for accurate positioning of the active emitting spot. By precise scribing, the optical axis is placed at 254 μm above the Si substrate. The wedge-shaped opening on the self-alignment plates gradually guides the active side of the laser towards the flat edge of the wedges. This unique design allows us to accommodate lasers with a large variation of thickness (from 100 μm to 140 μm thick). The height of the self-alignment structure permits more precise alignment. After assembly, the laser is electrically contacted by silver epoxy. Figure 3(b) is the SEM picture of a laser diode integrated with a micro-Fresnel lens.

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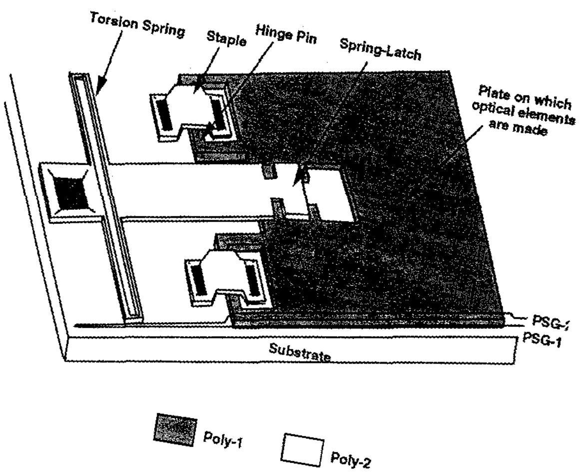

Fig .1. Micro-machined three-dimensional structure before release etch

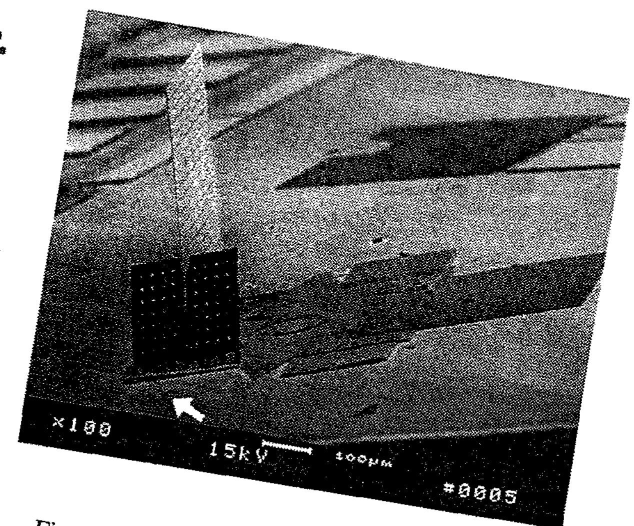

Fig. 2. SEM picture of a rotatable mirror

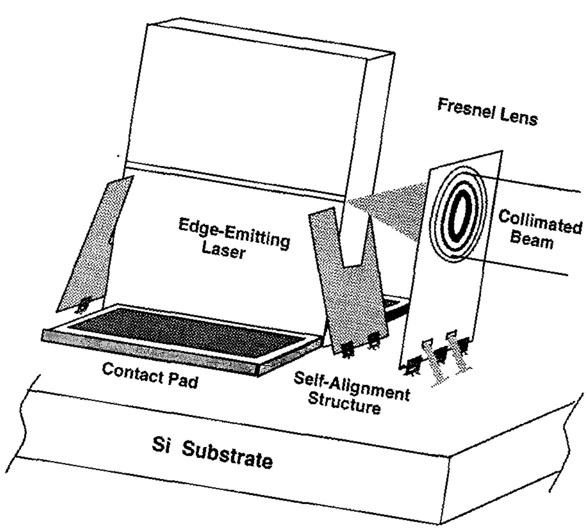

Fig. 3(a) Schematic diagram of hybrid integration of laser diode with micro-Fresnel lens

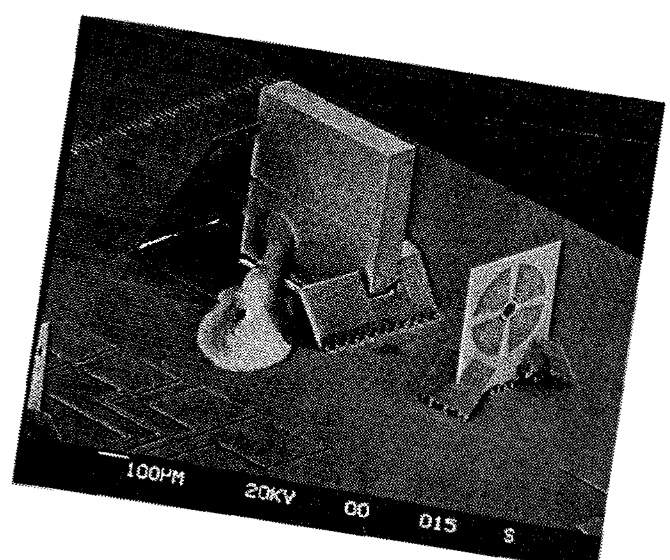

Fig. 3(b) SEM picture of a laser diode hybrid integrated with a micro-Fresnel lens