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TuP3

Self-Assembled Micro-XYZ stages for Optical Scanning and Alignment

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The XYZ micropositioning stages are perhaps the most commonly used components in free-space optical systems built on laboratory optical benches. They are extensively used to position optical elements, perform optical alignment, or fine-tune optical circuits. Such optical systems, however, are bulky and difficult to integrate with conventional technologies.

The micromachining technology has been shown to be a promising technology for miniaturizing such optical systems on a single chip [1]. However, micro-XYZ stages compatible with the micromachining technology have not been demonstrated until very recently [2,3]. Two different approaches were reported for micromachined XYZ stages with three independent degrees of freedom. Gonzalez et al., reported a bulk-micromachined XYZ stage [2]. It is basically a scaled down version of the macro scale XYZ stages without ball bearings. However, it requires substantial assembly, and cannot be batch fabricated. We have reported a surface-micromachined XYZ stage that is batch fabricated and self-assembled [3]. It is fully actuated, and large travel distance (> 120 μm in all three directions) and fine step resolution (27 nm) have been achieved.

In this paper, we report on an improved micro-XYZ stage with *bi-directional* scratch drive actuator (SDA) array. The SDA [4] has many attractive advantages that are desirable for optical systems, e.g., large force, compact area, long travel distance, and extremely fine moving steps. However, when implemented in the polysilicon surface-micromachining process with shared bottom electrode, such as the MUMPs service offered by MCNC [5], all the SDA's connected to the same structure are electrically shorted and cannot be driven separately. This poses a severe limitation on its capability. For example, the SDA can only move in the forward direction, and a spring is required to pull the stage back to the initial position. Here, we demonstrate a new technique to implement the *bi-directional* SDA array. By using a hard-backed photoresist patch to connect separate polysilicon plates, the two conducting polysilicon structures are mechanically joined but remain electrically isolated. Therefore, two SDA arrays with opposite moving directions can be mechanically connected and separately actuated, as shown in Fig. 1. The hard-baked photoresist is rugged, and compatible with the releasing process. Likewise, the SDA's in the X-direction and those in Y-direction can be individually controlled. Bi-directional movement of the XYZ stage has been successfully demonstrated.

Microfabricated optical elements can be directly integrated on the micro-XYZ stage. Figure 2 shows the scanning electron micrograph (SEM) of the XYZ stage with an integrated micro-Fresnel lens. The microlens has a vertical optical axis, and has been elevated by 250 μm from the Si surface. Such movable microlens is particularly useful for optical interconnect applications. A two-dimensional array of individually moveable microlens array can be formed. Dynamic focusing and tracking can be achieved by driving the actuators through a feedback loop. Potentially, the movable microlens can be integrated with active devices such as vertical cavity surface-emitting lasers using epitaxial liftoff or wafer fusion technique. The micro-XYZ stage can also be integrated with vertical micro-Fresnel lenses using microhinges. The vertical height of the XYZ stage versus the lateral displacement of the SDA is shown in Fig. 3. A maximum height of 250 μm is achieved when the SDA moves by 110 μm. Figure 3 also shows that there is significant displacement amplification at small height. For the initial 20 mm movement of the SDA, the movement in the Z direction is more than 100 μm.

In summary, a fully actuated micro-XYZ stage with bi-directional scratch drive actuator array has been demonstrated for the first time. This fabrication process of this micro-XYZ is fully compatible with the free-space micro-optical bench technology [1]. This allows high performance free-space optical systems to be monolithically integrated on a chip.

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References

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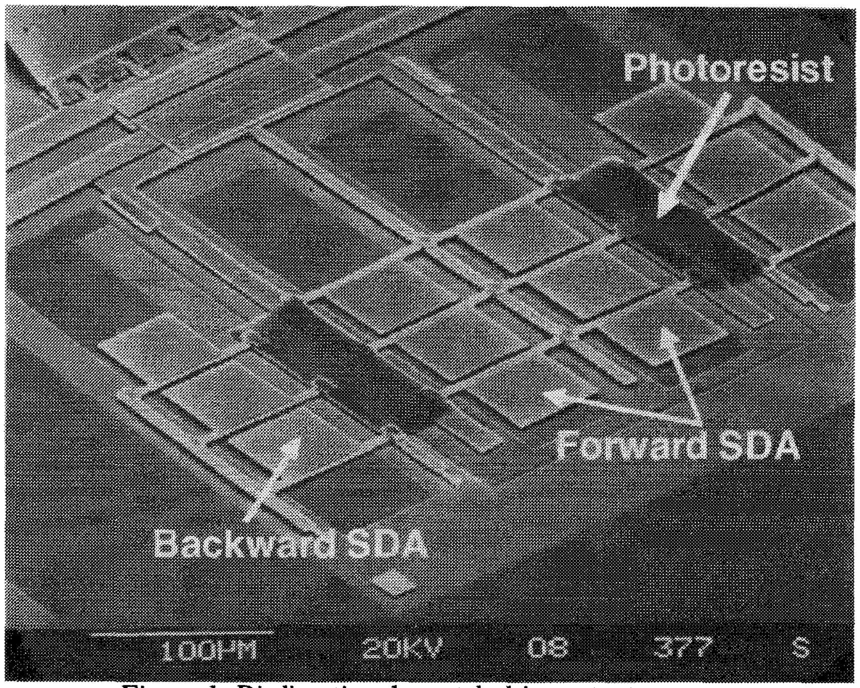

Figure 1: Bi-directional scratch drive actuator array.

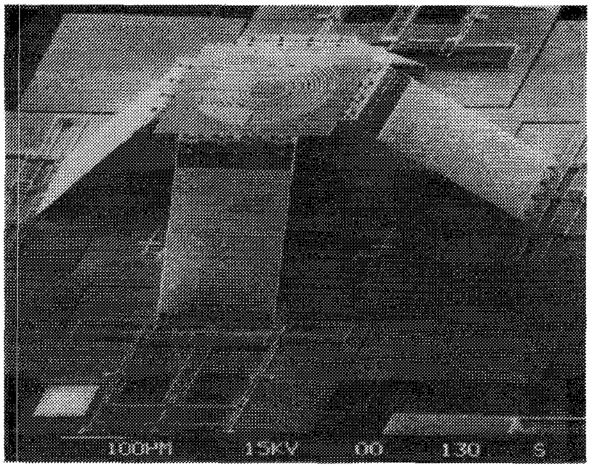

Figure 2: The scanning electron micrograph (SEM) of the XYZ stage with an integrated micro-Fresnel lens.

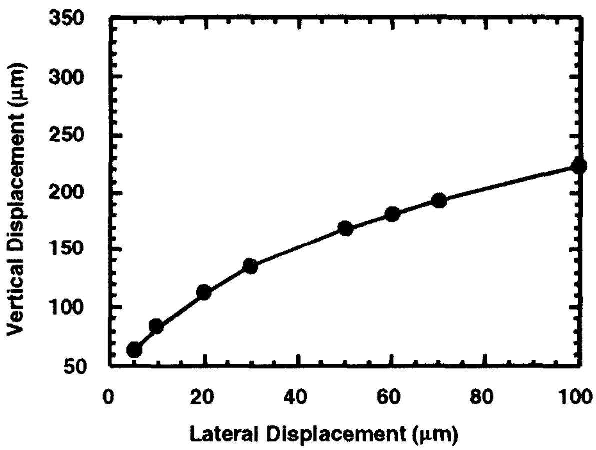

Figure 3: The vertical height of the XYZ stage versus the lateral displacement of the SDA.