Optical Testing of Layered Microstructures with and without Underlying Vias

SAND2006-5270C

Justin R. Serrano and Leslie M. Phinney

Engineering Sciences Center, Sandia National Laboratories, Albuquerque New Mexico USA

Abstract

The response of microsystem components to laser irradiation is relevant for laser processing, optical diagnostics, and optical microelectromechanical systems (MEMS) device design and performance. The dimensions of MEMS are on the same order as infrared laser wavelengths which results in interference phenomena when the parts are partially transparent. Four distinct polycrystalline silicon structures were designed and irradiated with 808 nm laser light to determine the effect of a substrate via and multiple layers on the laser power threshold for damage. A substrate via resulted in lower damage thresholds, and a single layer structure had the highest damage threshold which is attributed to interference phenomena.

Test Structures

Four polycrystalline silicon (polysilicon) structures were fabricated from the SUMMiT V process for this study. The square part of the plate is 250 µm by 250 µm and suspended between rails. The gap between the P12 and P3 layer is 3.5 µm; whereas, the one between the P3 and P4 layer is 2.0 µm. The gaps between the P1 and P3 layers and the substrate is 0.3 µm and 4.8 µm, respectively. The layer and gap thicknesses are nominal values and can vary by up to 5%. The P3, P123, and P34 test structures have the same rail designs but not all of the layers in the plate.

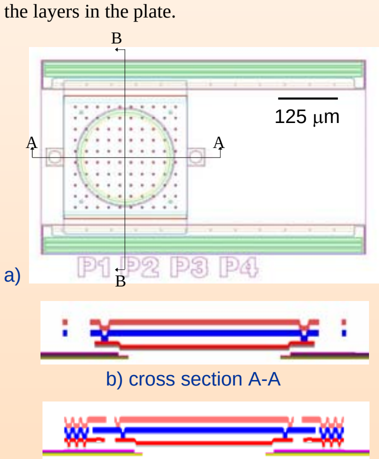

Fig. 1. Schematic of the test structure design for a P1234 plate. a) top view of the plate b) cross section A-A showing the plate and tabs, and c) cross section B-B with the plate and rails. The circular marks under the plate in (a) indicate the location and size of the via. The scale bar applies to the schematic in (a). The vertical scales in (b) and (c) are expanded so that the vertical layers are apparent.

SUMMiT V™

The polysilicon MEMS plates were fabricated using Sandia's SUMMiT-V™ process that uses four structural polysilicon layers and a polysilicon base plane, with each layer separated by a sacrificial oxide layer.

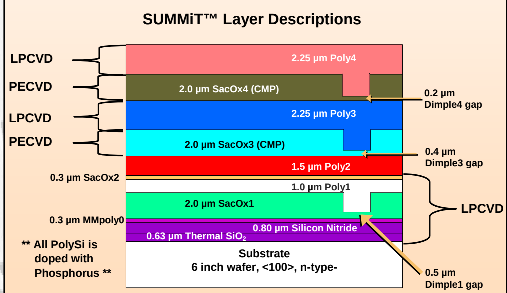

Fig. 2. SUMMiT V process.
© 2003 Sandia National Laboratories

Experimental Results

An important parameter is the threshold for damage which is determined from the damage fraction as a function of laser power data. Decreasing laser power results in decreasing damage and by extrapolating the damage fraction to zero damage, a threshold power for damage is estimated [1]. Fig. 3 shows before and after images of P1234 plates over a via irradiated with 722 mW. The damaged region of the plate is in the center of the plate. Aside from the size of the damaged region, the damage is similar in appearance for all the plate designs. In Fig. 4, the damage fraction as a function of laser power is plotted for the P1234 plate.

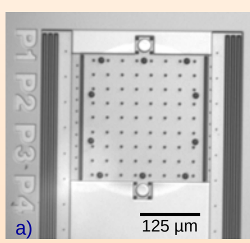

Fig. 3. Before (a) and after (b) images of P1234 plates irradiated with an 808 nm laser at a power of 722 mW over a via.

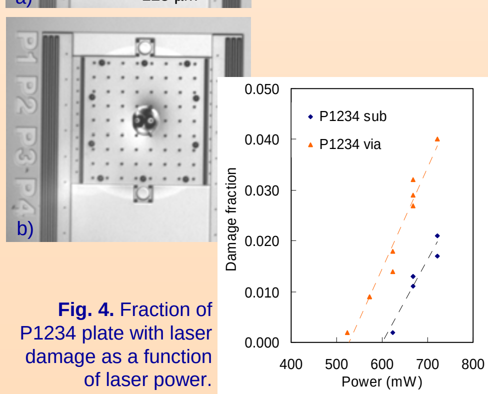

Fig. 4. Fraction of P1234 plate with laser damage as a function of laser power.

Damage Thresholds

Figure 5 shows the laser damage thresholds for all the plate designs over a via and over an area in which the substrate was intact.

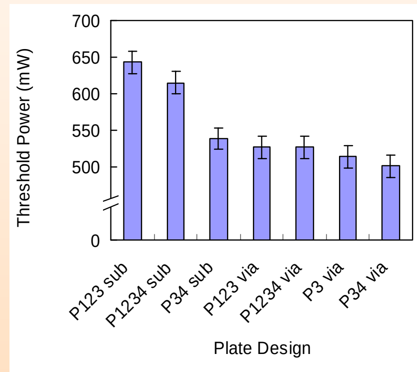

Fig. 5. Extrapolated threshold powers for different polysilicon plate designs irradiated over a substrate via and over an intact substrate. Not listed is the P3 only plate irradiated over the substrate which did not damage during the tests up to 760 mW. Error bars indicate the error in the threshold power estimation.

Conclusions

The likelihood of damage was experimentally determined for layered micromachined polysilicon structures when irradiated by a CW 808 nm laser. The structures consisted of P3, P34, P123, and P1234 plates. The laser threshold power increased when the plates were located over the substrate allowing for improved heat removal from the irradiated area. The impact of interference on the absorption properties of the plate was dramatically demonstrated by the P3 being the only plate that was not damaged at laser powers up to 760 mW, the maximum possible with the system, when over the substrate due to reduced absorption. The P34, P1234, and P123 plates were damaged at laser powers of 534 mW, 600 mW, and 631 mW, respectively, when positioned over the substrate.

References

[1] L. M Phinney and J. R. Serrano, "Influence of Target Design on the Damage Threshold for Optically Powered MEMS Thermal Actuators," *Sensors and Actuators A*, in press (2006).

Acknowledgements

- Katie Francis and Rosemarie Renn with their assistance in designing the test structures.
- MDL staff for device fabrication.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a LockheedMartin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.