Lehigh University
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Effect of the Thermal Cycling on the Behavior of the Optoelectronic Packages

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Abstract

Advance optoelectronic packaging is heavily dependent on the fundamental understanding of the constituent material behavior during manufacturing and thermal cycling. Such understanding will allow increasing yield and performance of hermetic packages while decreasing their cost. The combination of issues such as dimensional stability, thermal management, electrical connections, and optical access are not well understood.

Dimensional stability of the optoelectronic package was studied by in-plane moiré interferometry. The grating was transferred on the test vehicle before it was subjected to the thermal cycling. The effect of the temperature cycling on the test vehicle integrity was analyzed by studying the relative deformation of the components. It was found that ten cycles in the range of 0° C – 100° C resulted in permanent deformation at the corner of the brass post and the quartz plate. The obtained results can be used in the reliability studies of the optoelectronic packages.

Introduction

Novel packaging concepts for highly integrated and compact optoelectronic devices are a prime area for innovation. Integrating component technologies to provide a system solution that will address system performance and cost considerations is of foremost importance for successful development of new optoelectronic devices.

Technology for more effective manufacturing (such as high throughput optical alignment methods), are lacking, and major breakthroughs are needed. The combination of issues such as dimensional stability, thermal management, electrical connections, and optical access are not well understood. Therefore, it is important to study the kinetics of cure of optoelectronic adhesives and the resulting mechanical behavior of adhesive joints. Thermally cured and UV-cured adhesives have to be evaluated.

The behavior the adhesive is studied by using a generic test vehicle, with the emphasis on a viscoelastic characterization of the mechanical behavior for dimensional stability purposes. The example of the optoelectronic package is shown in Figure 1.

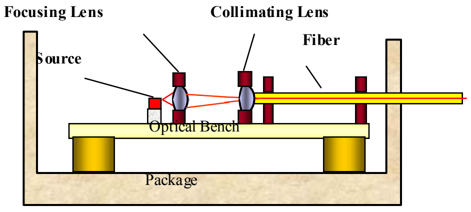

Figure 1. A generic optoelectronic package.

The "optical bench" is attached to the base by adhesive and the whole assembly is subjected to the temperature cycling during the device's life time.

Approach

In order to better understand the adhesive performance under cyclic thermal loading the simulated test vehicle was designed (Figure 2). It consisted of a brass base to which the simulated optical bench (1.18 mm thick quartz plate) was adhered by an epoxy adhesive. Thickness of the adhesive was under 20 microns. The goal was to study the relaxation of the adhesive, if any, due to thermal cycling between 0^0 C and 100^0 C. During each cycle the sample was exposed to the extreme temperature for 30 minutes. Analysis of the optical bench deformation due to the cycling may help to understand the applicability of the adhesive to the particular package.

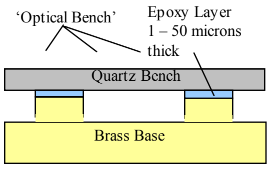

Figure 2. Schematic of the test vehicle.

Experimental Approach

The test vehicle was assembled and moiré grating was transferred onto the surface (shown in Figure 2) using the standard replication technique described elsewhere [1]. The test vehicle was placed into the moiré interferometer and well defined moiré pattern was observed by introducing carrier fringe. This test allowed checking the quality of the transferred grating. The sample was placed into the environmental chamber and subjected to ten cycles of the 0^o C to $+100^o$ C, the cycling time was about 60 minutes per cycle.

After the exposure to the thermal loading, the sample was placed again in the moiré interferometer and resulting moiré pattern was studied. It should be mentioned that the removal of the sample and returning it after ten cycles (i.e. about 24 hours later) did not allow using exactly the same setting of the carrier fringe patterns as was used to observe the pre-cycled sample.

Results and Discussions

The observation of the initial moiré pattern (Figure 3a) reveals continuous fringe crossing the boundary between the quartz (top layer) and brass (bottom layer). The boundary is shown by the dashed line; only the left post of the sample is shown. The same area is shown in Figure 3b after the completion of the thermal cycling. The line boundary line now is clearly visible. This fact suggested possibility of large deformations in this area due to the thermal cycling. This should be expected due to the large difference between the coefficients of thermal expansion of the brass (20.0 ppm/° C) and quartz (0.5 ppm/° C). However, the most important question – was there any permanent deformation due to the cycling?

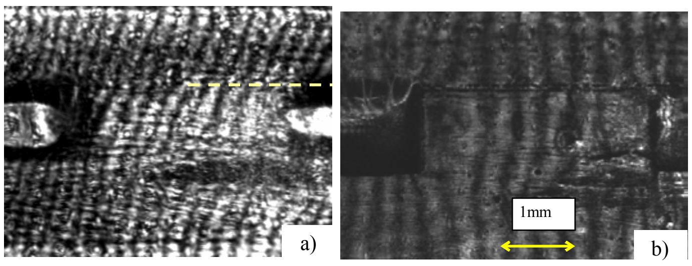

Figure 3 Moire pattern of the test vehicle (scale is shown)
a) before thermal cycling b) after 10 cycles of thermal loading

To answer this question a displacement analysis was performed on the sample subjected to the thermal cycling. The moiré patterns just above and below the boundary line in the near vicinity of the corner (scan length of 600μ) were acquired and analyzed. The raw data includes the effect of the unknown carrier fringe. Observation of the displacement data suggests that the strain patterns should be different near the corner. The linear fit to the data was used to remove the effect of the carrier fringe. However, it is absolute value could not be detected from the available data, thus only relative strain in the quartz part versus the brass part can be estimated. Since there is a discontinuity in the fringe pattern at the very corner (Figure 3b), it was assumed that the permanent slip occurred in this area and the strain in the brass corner was released. Assuming that the strain was released completely, the effect of the carrier fringe may be removed and the strain in the quartz can be extracted (Figure 4).

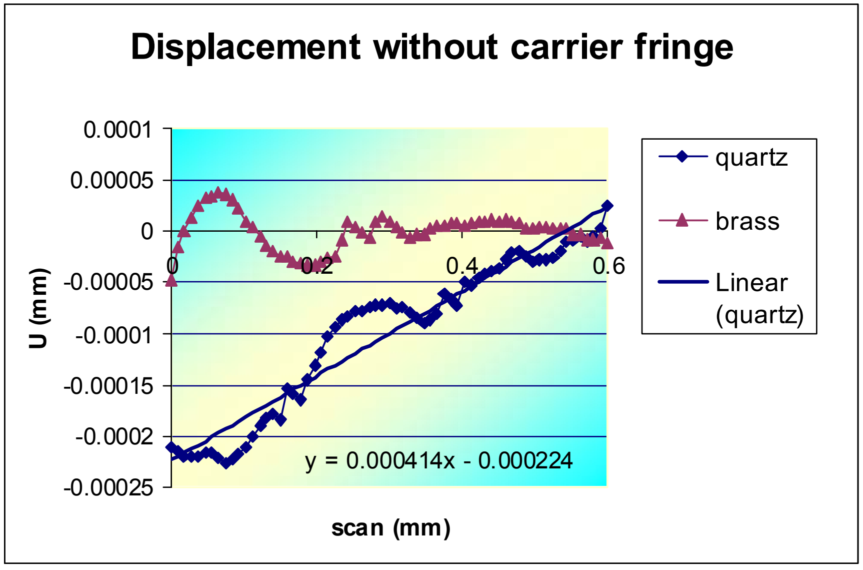

Figure 4. Displacement near the boundary between the quartz and brass after removing the effect of the carrier fringe. The linear fit and the related equation to the quartz data are shown.

Comparison of the average strain along the whole length of the brass post and corresponding portion of the quartz layer show small difference under 60 µstrain. Linear fit to the quartz data (Figure 4) shows the average strain of 400 µstrain. Similar stain magnitude was obtained from the boundary at the second post.

Conclusions

Thus, the obtained results suggest that during thermal cycling there was an irreversible deformation or slip at the corner of the brass post on the boundary with the quartz plate.

The presented here methodology may be used for analysis of the various adhesives under cyclic thermal loading. It will be very useful information for the design of the optoelectronic package, since it will allow for prediction of the possible misalignment.

Acknowledgement

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[1] D. Post, "Moiré Interferometry," Ch. 7, Handbook of Experimental Mechanics, A. S. Kobayashi, Editor, Prentice-Hall, Englewood, Cliffs, NJ, pp. 314-487, 1987