

# CHARACTERIZATION AND REMOVAL OF LASER SLAG VIA CHEMICAL CLEANING

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## INTRODUCTION:

The most common substrate currently used in the electronic packaging industry is alumina ( $\text{Al}_2\text{O}_3$ ). However, as the size of the products decreases, there is a need for a substrate material that has a higher thermal conductivity. One material that is being used is beryllia ( $\text{BeO}$ ). However, processing and recycling of  $\text{BeO}$  is an issue because of the carcinogenic nature of the material. Many extra safe guards are necessary to process  $\text{BeO}$ , and once used, the presence of  $\text{BeO}$  in the product causes difficulties with disposal or reuse of the product. An alternative substrate material is aluminum nitride ( $\text{AlN}$ ).  $\text{AlN}$  has a slightly lower room temperature thermal conductivity relative to  $\text{BeO}$  but is much more environmentally friendly. The major problem faced when using  $\text{AlN}$  is the material's reactivity with water. The product formed can result in an inconsistent metallization of the substrate and decrease the electrical performance of the substrate.

Another reaction that takes place during the processing of the  $\text{AlN}$  is the formation of laser slag. The laser slag leaves the surface of the substrate discolored and increases the roughness of the substrate surface. Current laser slag removal methods tend to be time consuming and expensive as they mainly rely on manual mechanical removal.

Little work has been done in the determination of the composition of the laser slag or on how it is formed. The purpose of this study is the initial characterization of the laser slag product and development of a cleaning process suitable for an industrial setting.

## METHODS:

Hi-Therm™ annealed and lapped AlN substrates were supplied by Saint Gobain (Sanborn, NY). Scribe lines and drilled holes, prepared via laser processing, were completed by Laser Processing Technologies (Portland, OR), using a CO2 laser and a proprietary shroud gas composition [3].

The substrates were broken along scribe lines so that two square sections, each with two laser drilled holes, separated with a laser scribe line were included in the sample.

### Test variables:

Temperature:  $25^{\circ}\text{C}\pm 5^{\circ}$ ,  $60^{\circ}\text{C}\pm 5^{\circ}$  or  $80^{\circ}\text{C}\pm 5^{\circ}$

Acid (pH=2):  $\text{HNO}_3$ ,  $\text{HCl}$  or  $\text{H}_2\text{SO}_4$

Time: 1, 2, 4, 8 or 12 hours

Vibration: no vibration, stir 300 rpm or ultrasonic

The samples were treated under the conditions shown above. Analysis of the samples included observation by optical microscope and scanning electron microscope (SEM), and characterization using energy dispersive spectroscopy (EDS).

## RESULTS:

Observation by optical microscope indicated that the acids all had similar effects and that all of the treatments broke down the laser slag. The samples at room temperature did not show much degradation of the slag; however the samples treated on a hot plate with a stir bar showed a decrease in the slag. The color of the slag went from black, seen in as received samples, through brown, yellow and white. Samples treated in the ultrasonic bath showed a different pattern of slag lost than those treated on the hot plate. In the samples treated on the hot plate there appeared to be an even removal of the slag while in those treated in the ultrasonic cleaner appeared to lose slag first at the bottom of the hole. The SEM showed that the slag layer was coming off in pieces. The slag layer was completely gone between 8 and 12 hours in the  $\text{HNO}_3$  at  $80^{\circ}\text{C}$ . EDS analysis shows that the slag layer contains aluminum, yttrium, and oxygen. Semi-quantitative EDS analysis shows that over time the yttrium content decreases. None of the ratios between the elements in the laser slag are consistent with any single phase seen in the AlN- $\text{Al}_2\text{O}_3$ - $\text{Y}_2\text{O}_3$  phase diagram, indicating that the laser slag is actually a solid solution. The decreasing yttrium content in the slag coincides with the color change in the slag, indicating a possible color center effect.

## CONCLUSIONS:

- Increasing the temperature and vibration increases the laser slag removal rate.
- Complete removal of the laser slag layer still required 8-12 hours for test conditions.
- A visual color change occurred prior to laser slag removal. Therefore visual inspection of slag removal can be misleading.
- Color change was correlated with loss of  $\text{Y}_2\text{O}_3$  from slag layer.

**WORK IN PROGRESS:**

The SEM study, as well as the EDS analysis, is still in progress.

**REFERENCES:**

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