

February 17, 2000

Ms. Helen Armandula  
LIGO Livingston Observatory  
19100 Ligo Lane  
Livingston, LA 70754

Re: Failure Analysis of Aluminum Dumbbell  
LIGO Account No 5F518, SEAL Job No 1086

Dear Ms. Armandula:

Two aluminum dumbbell assemblies which were glued to a glass surface were sent to SEAL Laboratories to determine why the adhesive failed.

### **ANALYTICAL PROCEDURES**

The aluminum and adhesive bonding surfaces were examined in a Scanning Electron Microscope (SEM) to determine the failure mode. The surfaces were then analyzed using Electron Spectroscopy for Chemical Analysis (ESCA) a surface analysis technique, to identify any surface contaminants which could lead to failure.

### **SUMMARY AND CONCLUSIONS**

The SEM images of both the aluminum dumbbell bonding surface and the mating adhesive surface, are presented below:

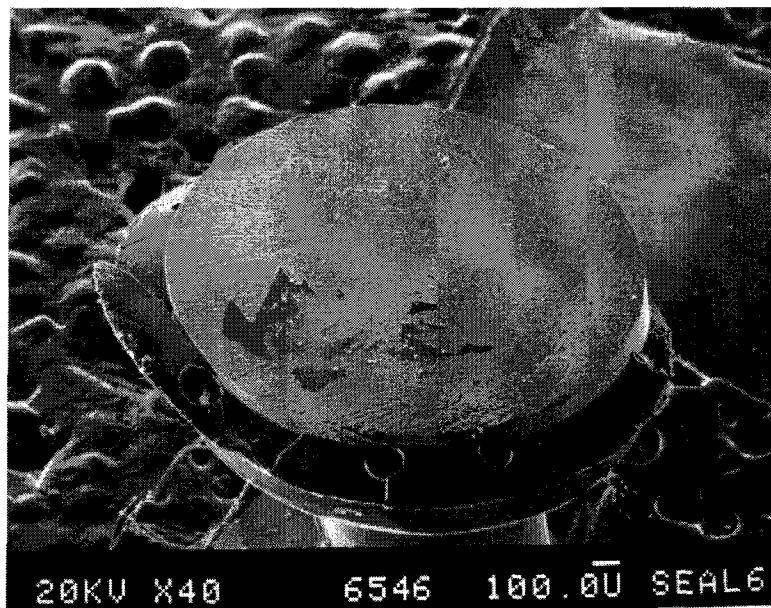


Figure 1. 40X SEM Image of Aluminum Dumbbell Bonding Surface

cc: M. Barton  
D. Cook  
J. Kern  
J. Romie  
D. Shoemaker  
S. Whitcomb



Figure 2. 200X SEM Image of Aluminum Dumbbell Bonding Surface

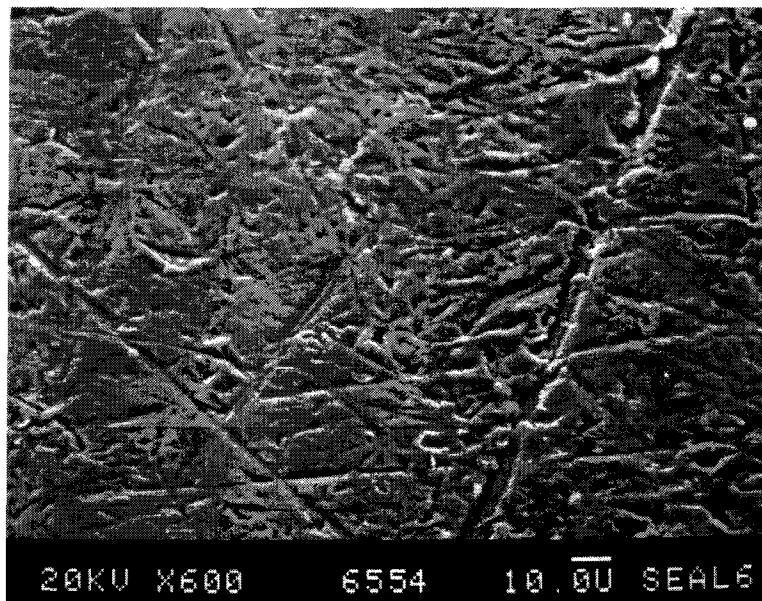


Figure 3. 600X SEM Image of Aluminum Dumbbell Bonding Surface

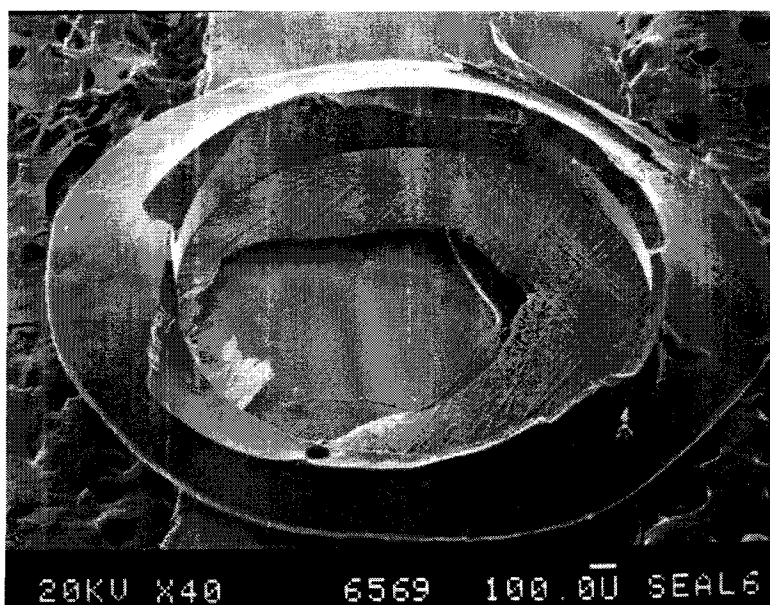


Figure 4. 40X SEM Image of Adhesive Bonding Surface

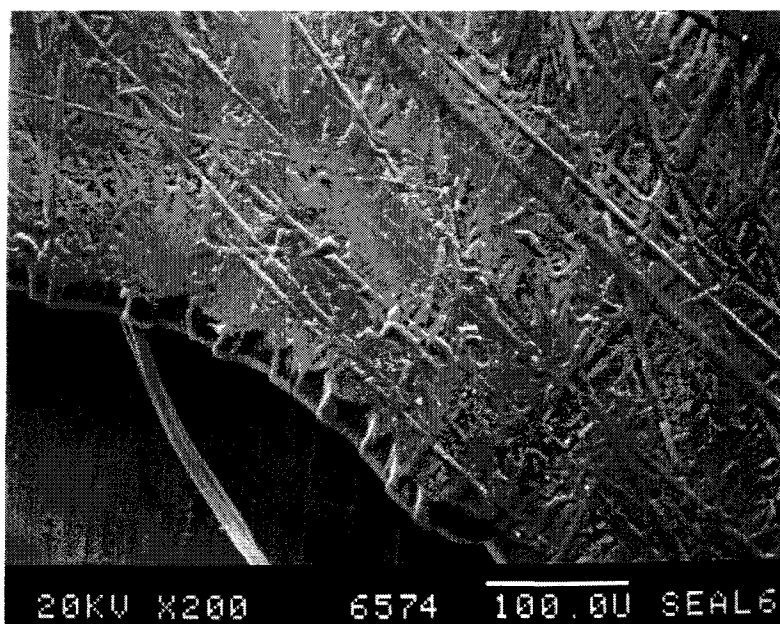


Figure 5. 200X SEM Image of Adhesive Bonding Surface

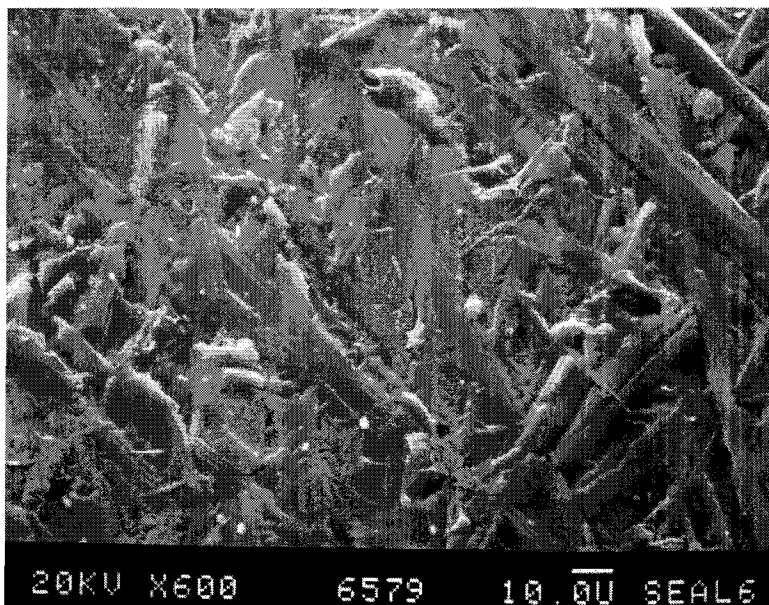


Figure 6. 600X SEM Image of Adhesive Bonding Surface

The above SEM images show nearly a complete adhesive failure. That is, the bond failed cleanly at the interface between the aluminum dumbbell and the adhesive. The 600X images of the aluminum dumbbell and the adhesive are mirrored, or replicate each other, showing that the adhesive cleanly failed at the interface with little bonding present.

Since this type of failure is often due to surface contaminants, ESCA surface analysis was performed on both the aluminum bonding surface of the dumbbell and the bonding surface of the adhesive. A spectrum was obtained of the surface of a cured sample of the adhesive for comparison. The ESCA results are presented below:

(Note: All data are in atomic percent)

Sample Area	O	N	C	Si	Al
Al Dumbbell	27.04	3.62	57.93	2.08	9.33
Failed Adhesive	17.47	-	75.75	6.78	-
New Adhesive	13.26	10.23	76.51	-	-

The ESCA analysis detected silicon at the bonding surface. The binding energy of the silicon peaks indicates that the silicon detected was organically bound, most likely as a silicone. Since pure silicone will have only 20-25% silicon on its surface (Silicone is empirically composed of approximately 50% carbon, 25% oxygen, and 25% silicon), the amounts detected above suggest that approximately 10% of the aluminum bonding surface was contaminated with silicone, and over 30% of the adhesive bonding surface was contaminated with silicone. Silicone contaminants at these levels can easily cause bond failures.

In conclusion, the aluminum dumbbells failed adhesively at the interface between the aluminum and the adhesive, most likely due to silicone contamination.

All data are included for your consideration. If any questions arise as you review these data, feel free to contact me at (310) 322-2011.

Sincerely,

Michael Altheim  
Senior Member Technical Staff  
SEAL Laboratories