Thermal Stress Relief In Beam Lead Diode Assembly

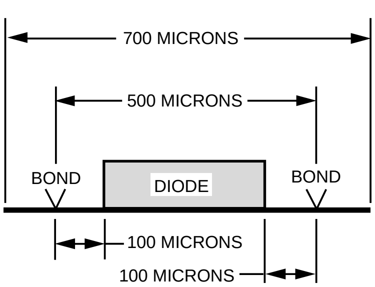
Application Note 993-1

Introduction

Unless specific precautions are taken in the mounting of beam lead diodes on soft substrates (e.g., Teflon/glass), a strong potential exists for lead failure during exposure to elevated temperatures. Soft substrate materials have a high thermal coefficient of expansion and can easily exert enough tensile force on any beam lead diode to pull it apart. Some stress relief, or "bugging", must be provided to insure mechanical reliability.

Stress Calculation

Calculation of lead stress due to thermal expansion of substrate (worst case - assumes no stress relief in leads) follows:



With a spacing of 500 microns between the points of beam attachment, the thermal expansion of a PTFE/glass substrate (elevated to 150 deg C) is:

Delta length = Coefficient of Thermal Expansion *length
= (15 E-6 /deg C)* (500 micron)* (150 - 25 deg C)
= 0.94 micron

The lead elongation (or strain) of the free lead length is:

Elongation = Delta/Length = Strain
Strain = 0.94 micron/ 200 micron
= 0.0047

The stress in the lead is:

Stress = Elastic Modulus* Strain
= (7.3 grams/sq. micron) *(0.0047)
= 0.034 g/sq. micron

The tensile force acting on a typical lead with a cross section of 10 x 110 microns is:

Force = Area * Stress
= (10 micron X 110 micron)* (0.034 g/sq. micron)
= 37.4 grams

With a minimum beam lead strength of 4 grams (typical maximum ≈ 10 grams), the leads would fail before the force of 37.4 grams could be exerted. The failure mode is usually a lateral separation of the lead near the body of the diode (weakest point of lead).

Assembly Methods

Resistance welding is the preferred method of assembly. Conductive epoxy or solder is also used but can reduce the free length of lead available to absorb substrate thermal expansion. This can occur when too much epoxy/ solder is used, in which case the epoxy or solder "wicks" up the lead. The same is true when the solder or epoxy dots are placed too close together. Thermosonic bonding is also used.

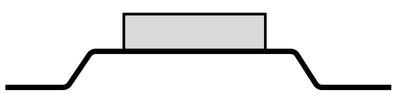
Note: The leads of some beam lead devices may exhibit a visual appearance of "cracking" on the "top" side of the leads (side opposite the junction – usually on top of the diode when assembled.) These cracks occur in the relatively thin surface layer of platinum which covers this side of the beam leads. The platinum is much less ductile than the gold lead material and subsequently cracks when the leads are bent. This condition is normal and is cosmetic only.

Possible Solutions

The problem of providing thermal stress relief for beam lead diodes on soft substrates can be addressed by the following methods:

A. Pre-form beam leads prior to assembly.

GULL WING:

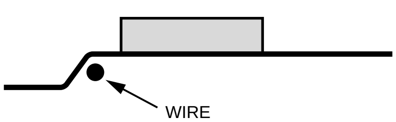


HALF GULL WING:

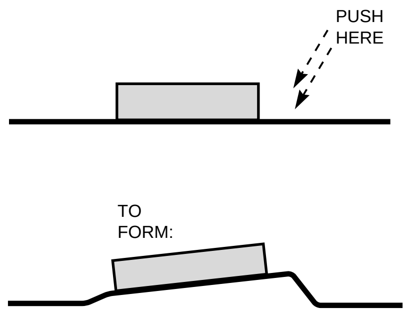
(Can be a difficult, manual procedure; also adds an additional handling step)

B. Bug leads during assembly.

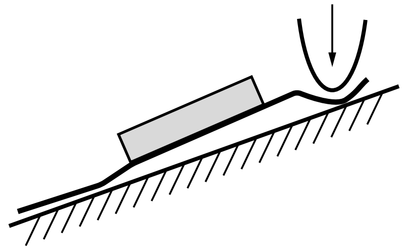
1. Attach one end of diode; bend lead over fine wire; attach other end of diode.



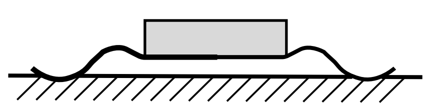
2. Attach one end of diode; push opposite end with a tool to bug lead; attach second end.



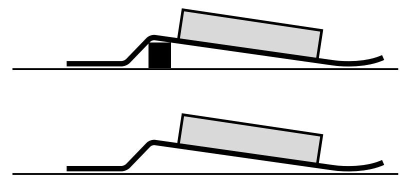
3. Attach one end of diode in usual way; attach other end with substrate at an angle (~20 degree) to bug lead.



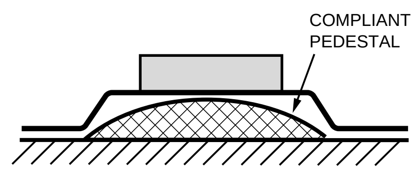
4. Some combinations of tool shape and pressure will crater the lead into the soft substrate in such a way as to form a natural bugging effect. Too much pressure can, however, have the opposite effect as well as damage the lead.



C. Assemble diode over soluble ridge; dissolve ridge material with suitable solvent after diode assembly.
(paper solution – unverified)

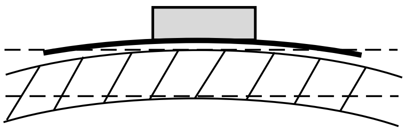


D. Mount diode on top of a compliant pedestal. Suitable pedestal materials must be somewhat elastic as well as electrically and chemically inert, e.g., silicone junction coating materials for semiconductors.

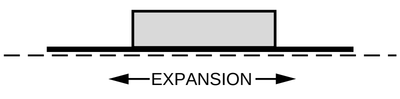


E. Pre-stress substrate during diode attachment.

1. Mechanical - Bend substrate over curved surface to put top surface in tension while diode is attached.



2. Thermal – Heat substrate to ~175 deg C during diode attachment. (Easiest if diode is located and one end mounted at room temperature prior to attaching second lead on heated substrate.)



SUBSTRATE AT +175°C

Notes:

1) Coefficient of thermal expansion of PTFE/glass:

15 E-6 /deg C for thickness of $\leq$ 0.010 inch

10 E-6 /deg C for thickness of $\geq$ 0.010 inch

2) Coefficient of thermal expansion of Copper = 16.5 E-6 /deg C (conductor material on substrate; ~ same as substrate)

3) Elastic Modulus of Gold = 7300 kg/sq. mm

Additional References:

Hewlett-Packard Application Note 993, *Beam Lead Bonding to Soft Substrates*

Hewlett-Packard Application Note 992, *Beam Lead Attachment Methods*

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