Liquid Crystal Polymer MEMS Packaging

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Abstract

The military is concerned about the long term survivability and reliability of MEMS devices, particularly when subjected to high-G shock such as when munitions are fired from cannons. Researchers agree that package related failure mechanisms dominate all failure modes. Furthermore, packages degrade during long periods of storage. Dominant package related failure modes at high-g's include:

- **Movement of loose debris generating during processing.**
- **Cracking of ceramic packages**
- **Separation of lid and substrate**
- **Lid/substrate seal and wire bond degradation during storage due to non-hermetic package.**

Linden Photonics, Inc. is developing wafer and chip level packaging to mitigate these failure modes. Linden Photonics has know-how and proprietary technology related to near hermetic and radhard packaging of microelectronics and opto-electronics. Linden has developed Strong Torpedo Fiber Optic Cable (STFOC) for the Navy. Data and measurements showing progress will be presented.

1. Near Hermetic Packaging of Optoelectronic and MEMS Components

Linden's LCP jacketed optical fiber has great potential in the area of packaging for electro-optic devices. One of the major challenges facing the packaging engineer is that of creating the hermetic seal around the optical input and output ports. Such a seal is typically created by stripping and metalizing the end of the fiber, and then soldering it into a metalized glass sleeve. Finally the sleeve is soldered into the metal housing of the device. Stripping and metalizing the fiber is an expensive, labor intensive operation. Handling bare, metalized fiber is also problematic and fiber breakage during the packaging process is common.

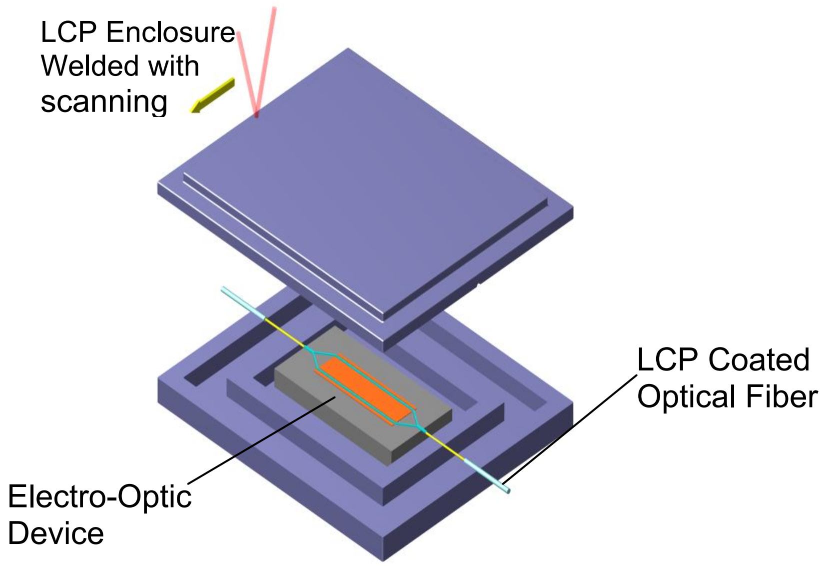

Figure 1. Packaged opto-electronic device with hermetically sealed optical ports

With Linden's technology, it is possible to use LCP both for the hermetic packaging, and the fiber jacket (Figure 1). This monolithic approach to the packaging problem has the advantage that no special preparation of the fiber is required, and expensive metalized pigtail can be replaced by a short length of LCP jacketed fiber which is inherently more robust and easier to handle.

2. LCP Buffered Optical Cable (Patent Pending)

To this end we have used a conventional cross-head extruder to buffered SMF28 optical fiber with a layer of LCP. As is well known the tensile strength of LCP increases with decreasing wall thickness because of increased alignment of polymer chains along extrusion direction. Transverse modulus, however, remains unchanged. This is illustrated by data published by Ticona and shown in Figure 2.Ticona published data

We extruded thin layers of LCP to form cables with diameters of 0.014" .016" and .020" diameter and demonstrated that the strength of the LCP material increases as the thickness is reduced. We also extruded thin monofilaments of LCP with nominal diameters of .002", .005" and .01" and measured the tensile strength of each. The results for these measurements are shown in 0 2 together with those from the thin walled cable, and data from the Vectra product sheet for thin walled molded parts.

As can be seen from the chart, there is a very significant increase in the strength of the material as the thickness is reduced below .01", and the UTS of the thinnest (.002") filament is over 4 times that of a molded .05" thick sample. The strength also varies with the process, and there is some overlap between the extruded tube and filament. We suspect that the large surface area to volume ratio of the thin walled tube most probably gives rise to the greatest shear force, resulting in highly aligned material.

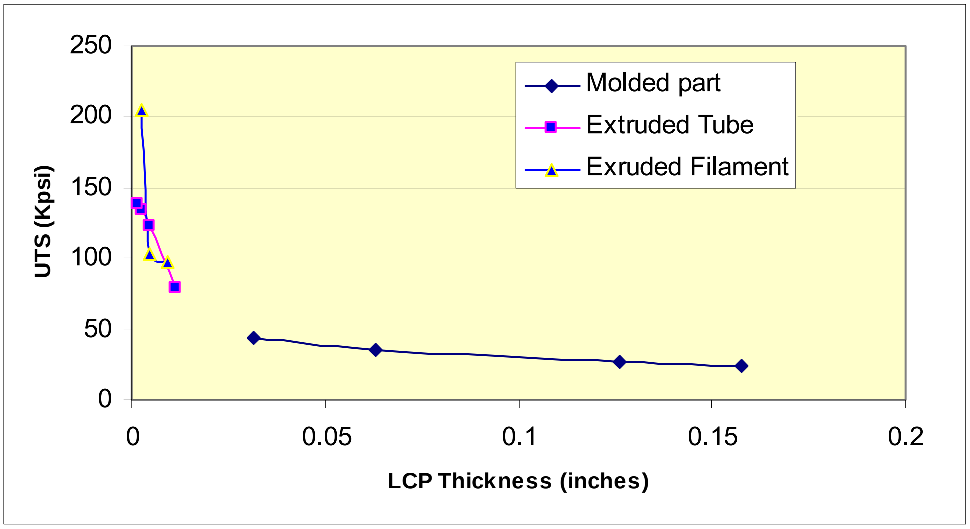

Figure 2. UTS of LCP as a function of material thickness

3. Moisture Absorption in LCP Buffered SMF28e Cable

LCP buffer of varying thickness was extruded on SMF28e fiber. A customized procedure was used to measure moisture absorption in these cables. We have earlier measured the moisture absorption of SMF28e and A950 separately. Thus by measuring the moisture absorption in LCP buffered SMF28e cable it was hoped that one could subtract the absorption in the LCP buffer so that what was left would be moisture transmitted by LCP and absorbed in the SMF28e. At temperatures below 70^0 C we know that the moisture absorption of SMF28e is at least a factor of 10 higher than the LCP so that the SMF28e acts effectively as a moisture getter. By doing these measurements at different temperatures and for three different thicknesses of LCP buffer we hoped to extract the moisture transmission through LCP buffer as a function of temperature and thickness, information that is critical but not found in the literature.

Table 1 shows moisture absorption of 5 m sections of SMF28 fiber with 5 mil thick LCP so that the OD of the final structure was 20 mil (Cable is referred to as 20/10). Measurements are at 70^0 C and 85^0 C. Moisture absorption data for 5 m of 20/10 cable and SMF28e is shown in Figure 3. This shows dramatically that if a 5m length of SMF28e is exposed to moisture, within 30 mins. it absorbs 2.3 mg of moisture at room temperature. When it is protected by 5 mil thick LCP buffer it is still unsaturated after 340 hr. at 70^0 C (Figure 3)

Table 1. Moisture absorption of 20/10 LCP buffered SMF28e cable.

Test Sample	Weight before exposure (mg)	Exposure temperature (^{0}C)	Moisture exposure time (hr.)	Wt. Increase (mg)
A950 LCP buffered SMF28e; LCP thickness 5 mil on 10 mil SMF28e, Cable OD 20 mil, Linden part no. 20/10 LCP Cable	1277.968	70	12	2.29
		70	24	2.61
		70	72	3.80
		70	168	5.05
		70	336	5.76
		70	504	5.96

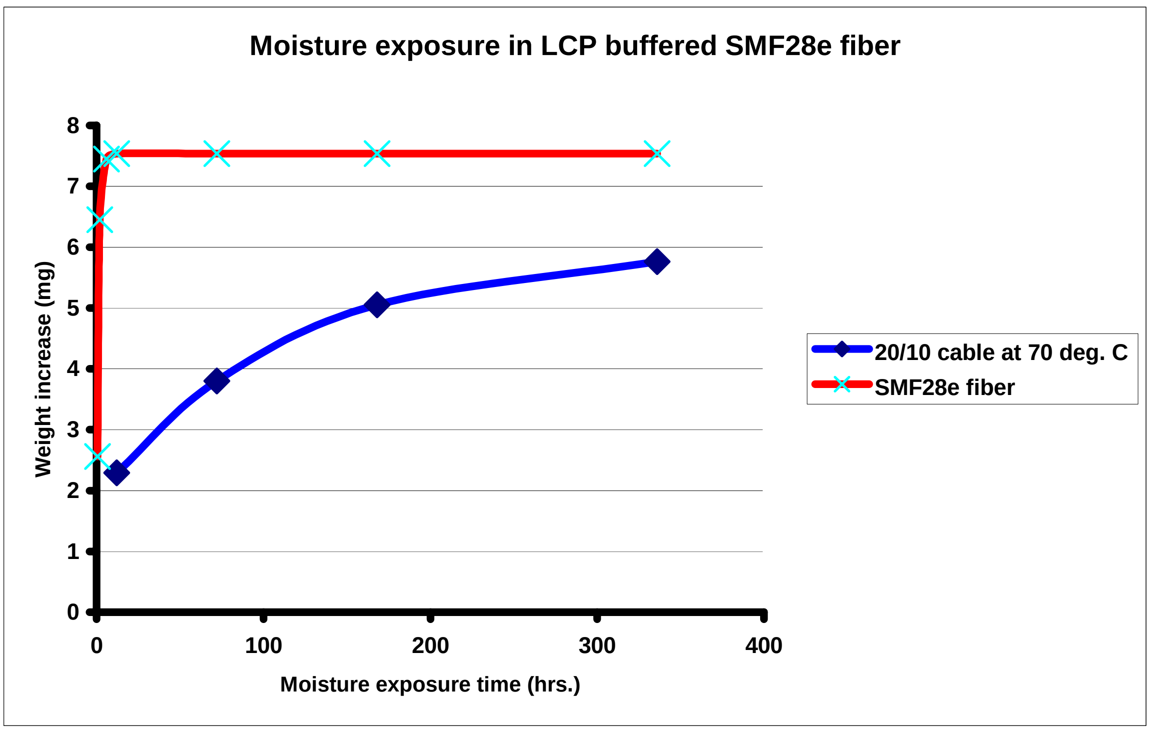

Figure 3. Moisture absorption vs. time in LCP buffered SMF28e fiber cable.

4.0 Moisture Transmission Rate Through Extruded LCP Buffers

The results of section 3 enable calculation of moisture transmission rate through thin extruded LCP tubes. We know from earlier work that the saturation moisture absorbed by 5 meters of 10 mil diameter extruded LCP rod and SMF28e, at 70^0 C, is 0.69 mg and 6.54 mg respectively. LCP buffered cable with 5 mil thick LCP extruded on SMF28e (20/10 cable) has three times the volume of LCP as 10 mil LCP rod per unit length. Therefore, we expect the LCP in 5 m of 20/10 cable to absorb three times as much moisture at 70^0 C (≈2.07 mg) as the LCP rod. Any moisture in excess of this is transmitted by the LCP and is absorbed by the SMF28e which acts like a getter. After sufficient time even the SMF28e will saturate with total weight increase of about 8.61 mg (= 2.07 mg + 6.54 mg) and no more moisture will be absorbed by the cable. We see from Figure 3 that the 20/10 cable after 340 hours moisture absorption at 70^0 C has absorbed about 6 mg of moisture. SMF28e itself would absorb 2.3 mg of moisture in about 30 minutes even at room temperature. Therefore, clearly the LCP acts as an excellent moisture barrier.

The calculated moisture transmission rate is shown in Table 2. The data suggests that the moisture transmission through extruded LCP is small even at 70^0 C.

Table 2: Moisture transmission through extruded LCP buffer

Temperature (^{0} C)	LCP Thickness (mil)	Moisture exposure time (hr.)	Moisture Transmission rate (gm.mil/100 in^2.day)	Moisture Transmission rate after subtracting absorption in LCP (gm.mil/100 in^2.day.atm.)
70	5	12	0.37	0.036
		24	0.21	0.044
		72	0.1	0.047
23 (from literature)	Unknown	Unknown		0.07
38 (from literature)	Unknown	Unknown		0.13
PET				2.0 – 3.0

5. Conclusion

We have demonstrated the fabrication of stron, LCP buffered optical fiber. We have also shown the reduced moisture absorptiona dn transmission through this buffer to the inside acrylate buffer. We are now conducting experiments to fabricate molded LCP enclosures and appropriate optical ports to enable near-hermetic packaging of optical MEMS and other optoelectronic components.