# Encapsulation of wirebonds

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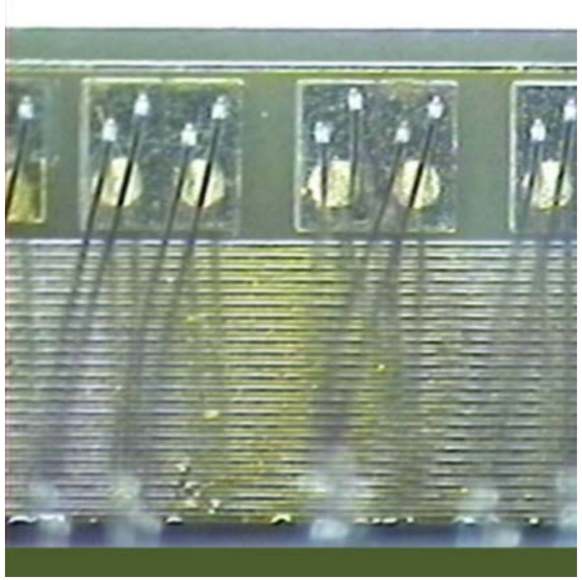
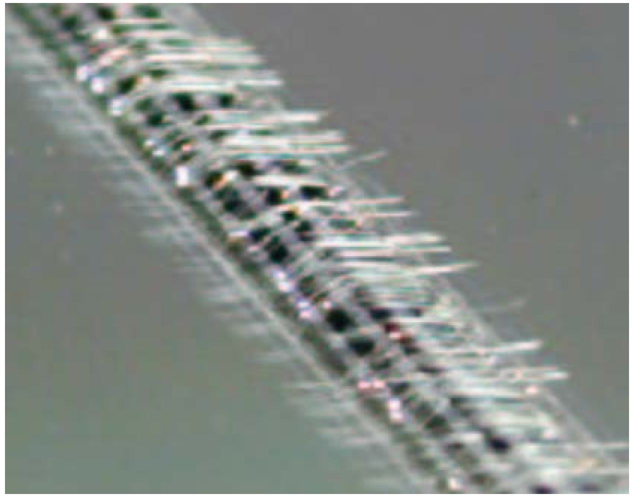
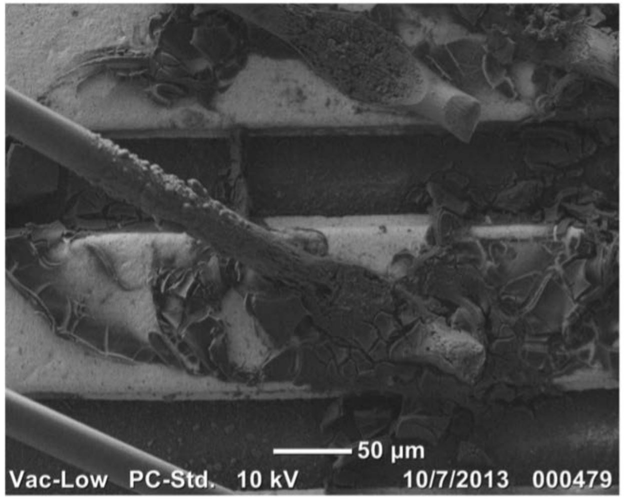
# Motivation for wirebond protection

- Severe damage to wirebonds was experienced by CDF, ATLAS, CMS.

  - Resonant vibrations due to Lorentz force (CDF SVX-II, ATLAS IBL)
  - Vibrations or shock during transport (CMS Silicon-Strips)
  - Chemical damage: corrosion, shorts (ATLAS IBL, CMS BPIX)

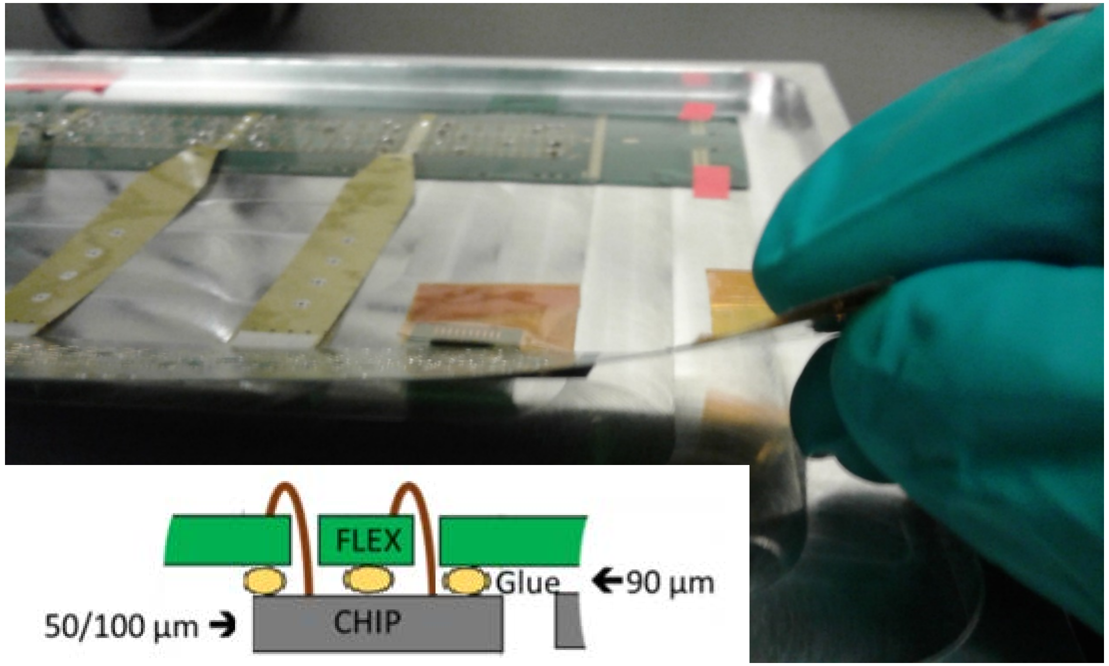




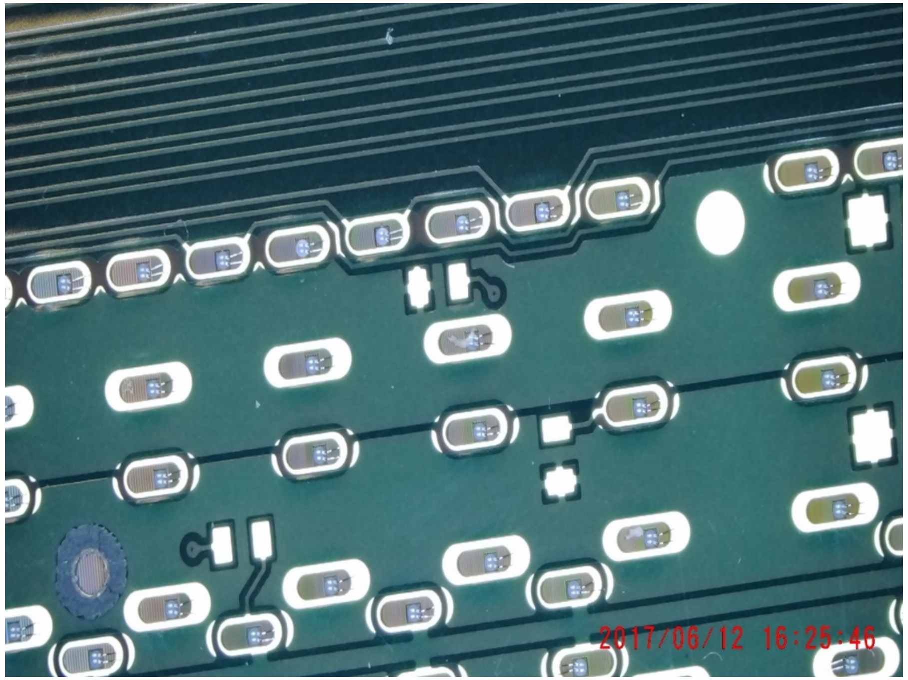



*Figures from Refs[1,2,3]*

# Protecting against mechanical damage




*Cartoon from [7]*




- Wirebond loop-height over the FPC is low and module is very thin.
  So, wirebond might break due to bending, vibration, or manipulation during stave assembly.
- Encapsulant could make the FPC—sensor joint more robust and damp oscillations.

# Encapsulants tried

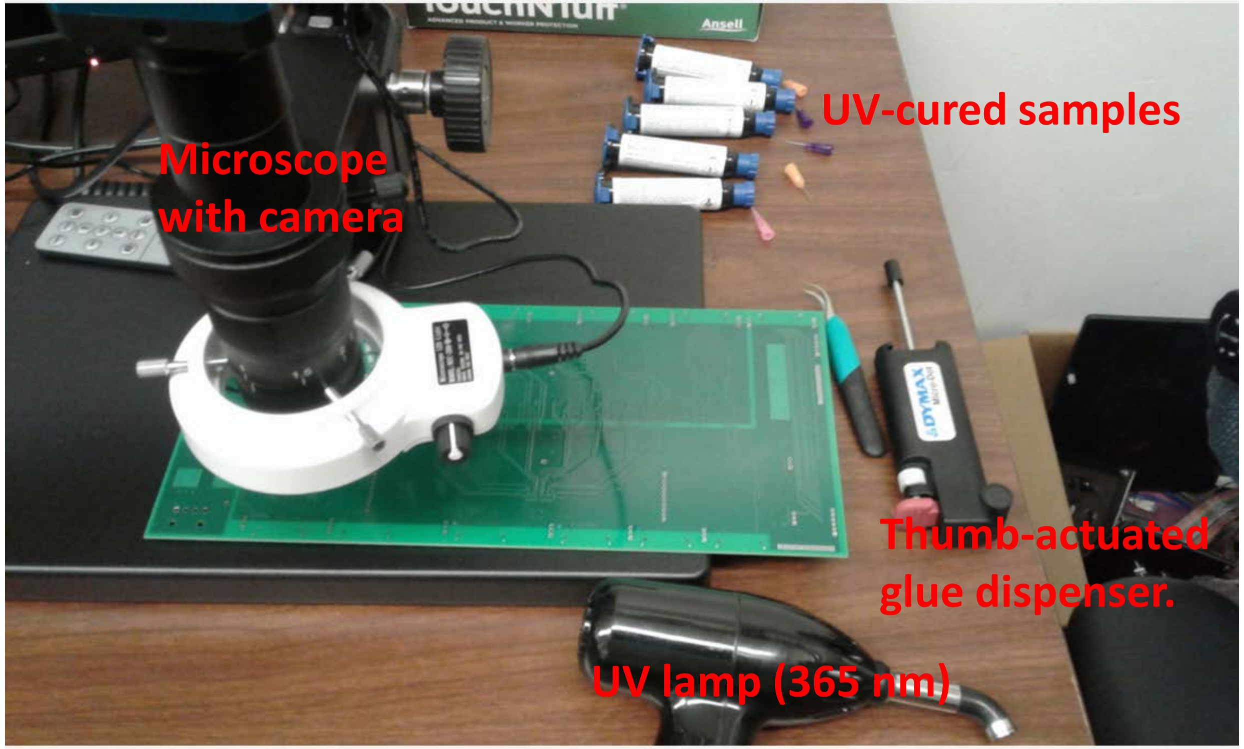
- We probed an ample range of viscosity.
- Various UV-cured with short curing time, and two traditional “two-part” encapsulants with long curing time

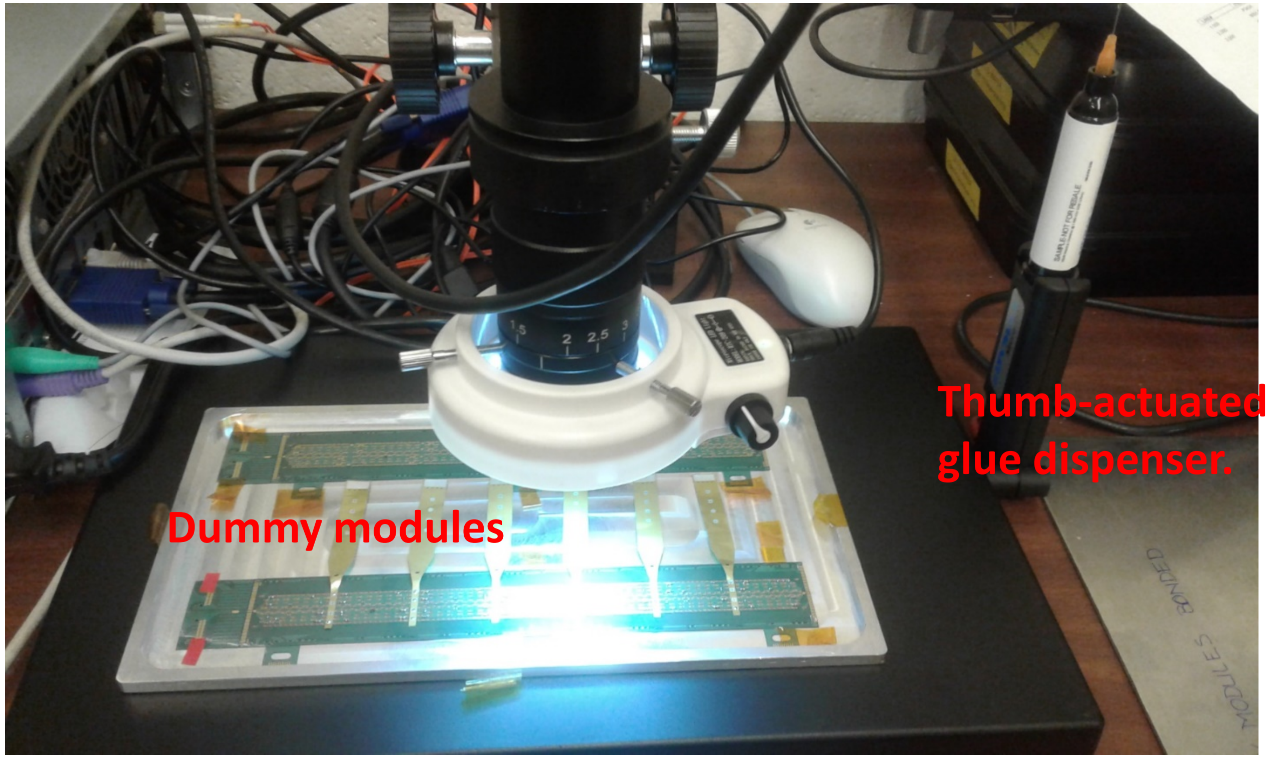
| Name | Viscosity (cP) | Curing time |
|---|---|---|
| 9001-E-v3.0 | 400 | 30 s with UV 365 nm |
| 921 | 750 | 30 s with UV 365 nm |
| 921-T | 3500 | 30 s with UV 365 nm |
| RTV615 | 4000 | More than 24 hours at RT |
| 9001-E-v3.1 | 4500 | 30 s with UV 365 nm |
| 9001-E-v3.5 | 17000 | < 30 s with UV 365 nm |
| 9-20588-REV-A | 20000 | 30 s with UV 365 nm |
| Sylgard 186 | 66000 | More than 24 hours at RT |

→ Stefania’s suggestion (RTV615)

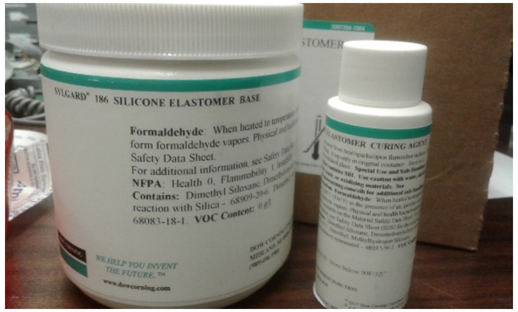
→ **Used by ATLAS Pixel and STAR HFT** (9001-E-v3.1)

# Setup




Non-UV cured

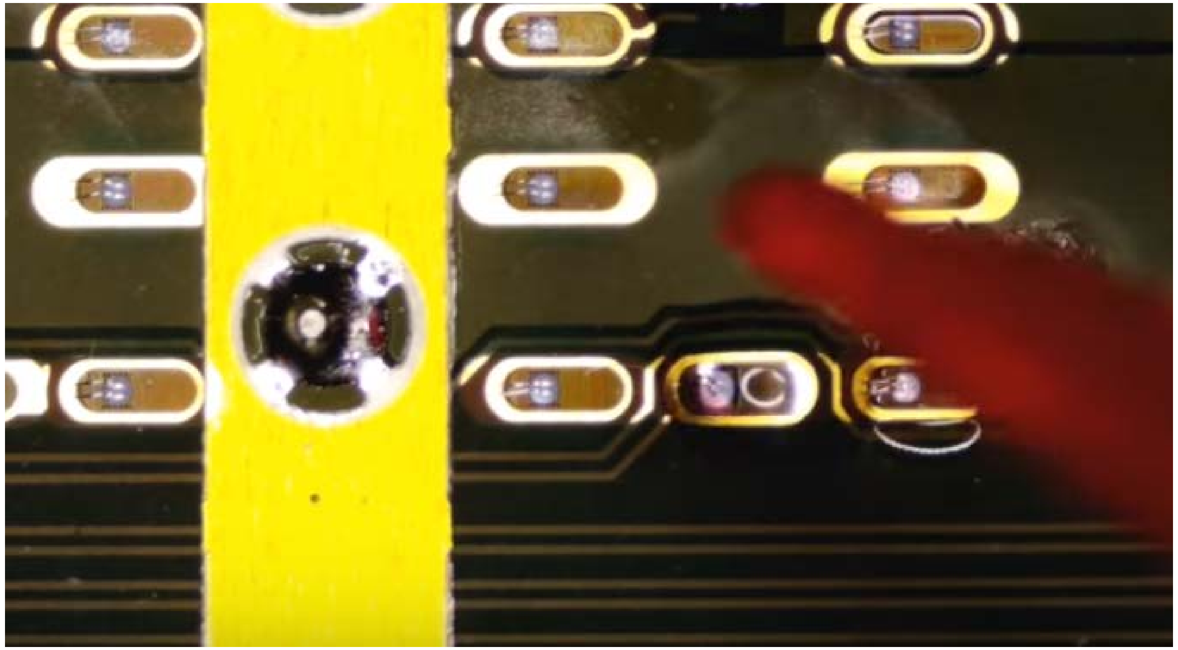




UV cured

# RTV615

Used by previous CERN experiments, so is rad-hard, etc.

https://www.youtube.com/watch?v=IVpMwxBOQXs



- The glue flows
  from one via to the next.
  **Its viscosity (4000 cP)**
  **is too low for our application**

# 9001-v3.1

## Used by ATLAS and STAR, so is rad-hard, etc.

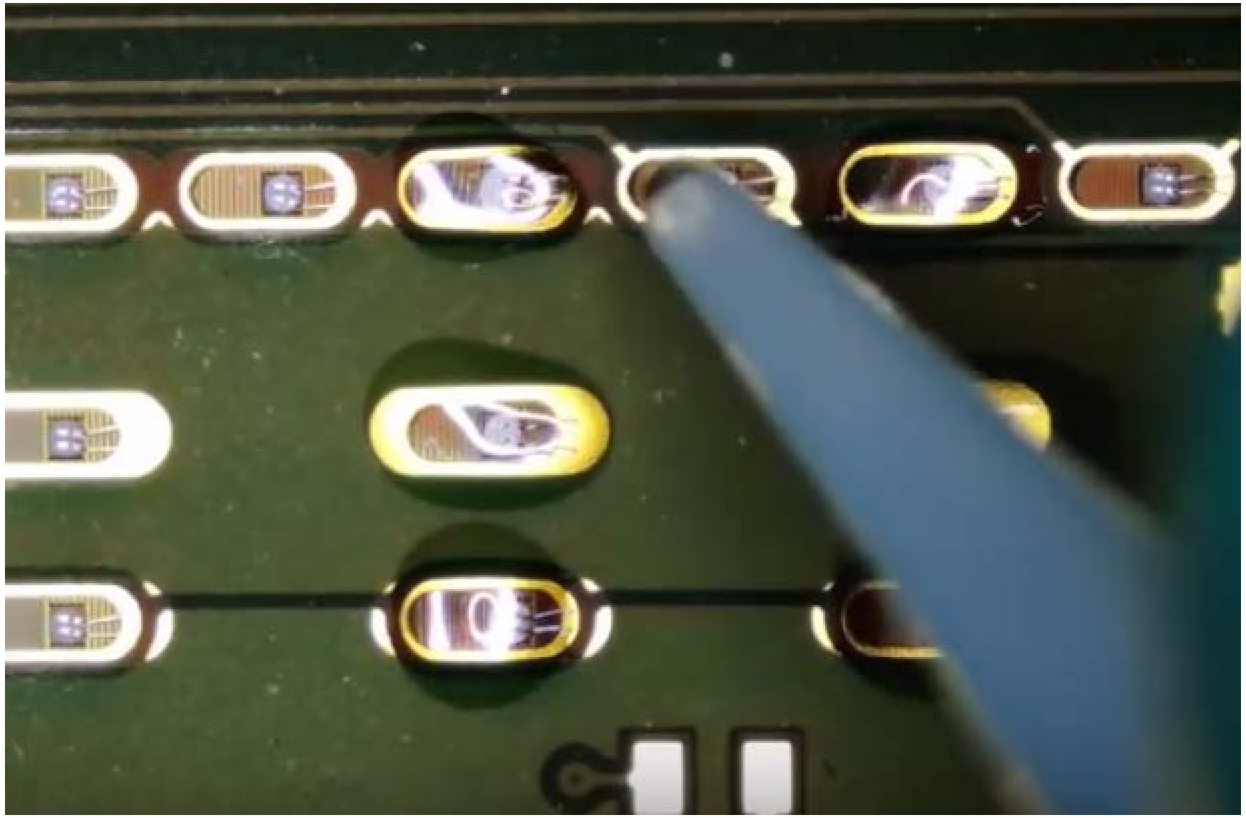
https://www.youtube.com/watch?v=CthveNcI8EE&list=PLOtoW8B04ModFzZYTQa67_lr19zm-4Eq0&index=8


- The glue flows from one via to the next.
  **Its viscosity (4500 cP) is too low for our application.**

# 9001-v3.5

High-viscosity version of 9001-v3.1

https://www.youtube.com/watch?v=OWVmIee8UuA

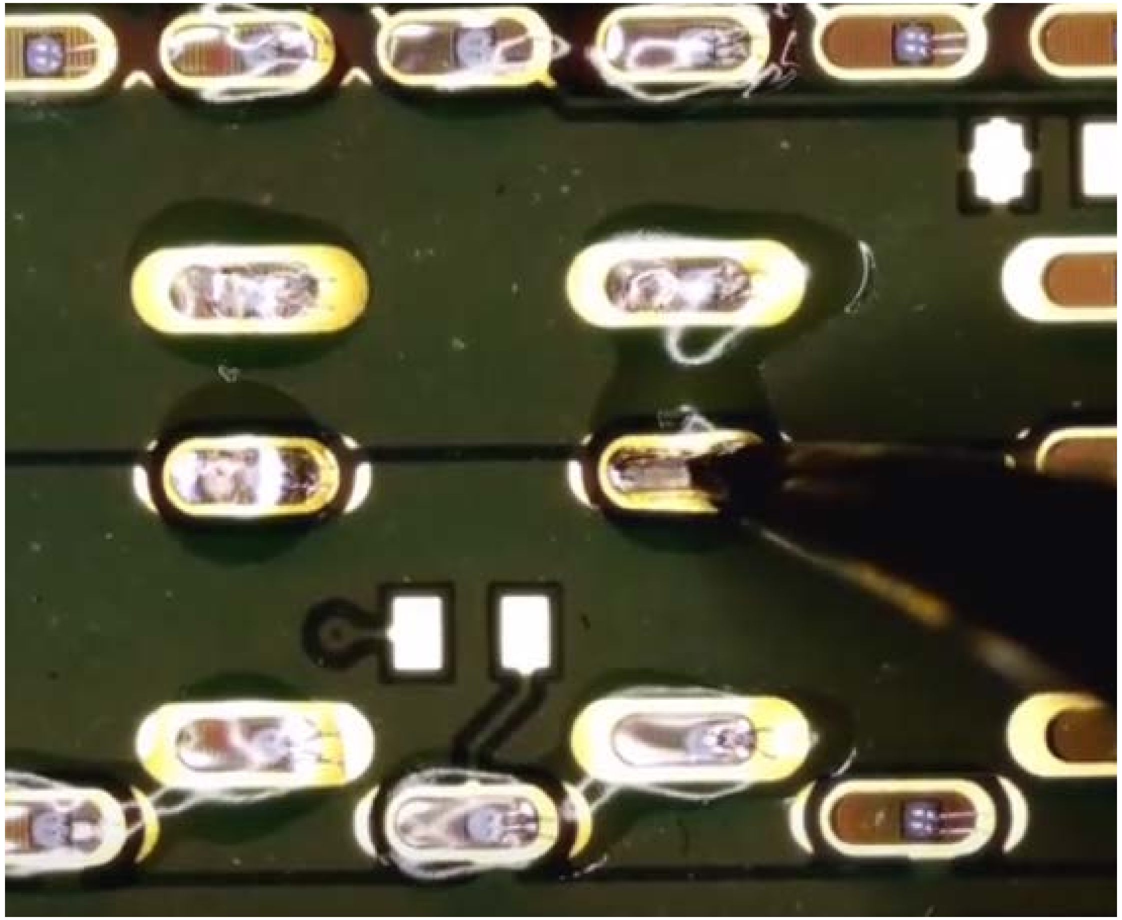


- Glue fills volume of the via and it does not flow out of it.
- Its viscosity (17000 cP) is adequate for our application

# 9001-v3.5

## High-viscosity version of 9001-v3.1

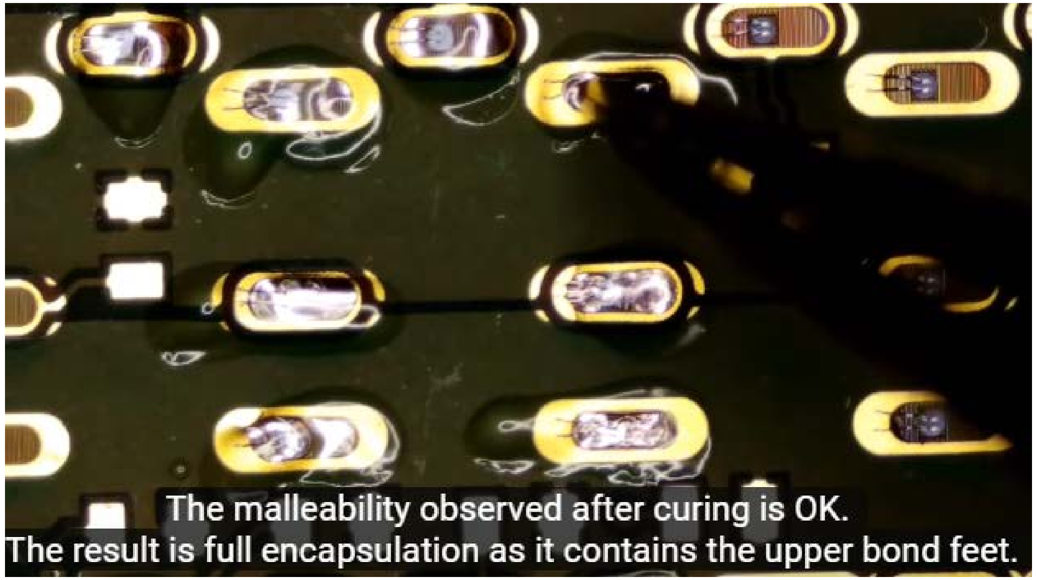
https://www.youtube.com/watch?v=VCn13Mw7esk



- After 30 seconds of curing, we achieved full encapsulation, i.e. both bond ends are encapsulated

# 9-20558

an alternative to 9001-v3.5


- Its viscosity (20000 cP) also works for our application.
- We achieved full encapsulation.

https://www.youtube.com/watch?v=xaZvDwxH1uk&index=1&list=PLOtoW8B04ModFzZYTQa67_lr19zm-4Eq0.
https://www.youtube.com/watch?v=Jz05lWKYq-c&list=PLOtoW8B04ModFzZYTQa67_lr19zm-4Eq0&index=2
https://www.youtube.com/watch?v=sCvLwGTBUNc&list=PLOtoW8B04ModFzZYTQa67_lr19zm-4Eq0&index=3
https://www.youtube.com/watch?v=9t2DY_NimQ0&list=PLOtoW8B04ModFzZYTQa67_lr19zm-4Eq0&index=4
https://www.youtube.com/watch?v=GHkKca8SJMA&list=PLOtoW8B04ModFzZYTQa67_lr19zm-4Eq0&index=5

# 9001-v3.1 vs 9001-v3.5

**CURED PROPERTIES (not specifications)**

| *PHYSICAL* | |
|---|---|
| Durometer Hardness | D45 (nominal) |
| Elongation at Break | 150% |
| Tensile at Break | 750 psi |
| Modulus of Elasticity | 2,500 psi |
| Water Absorption (24 h) | 1.0% |
| Boiling Water Absorption (2 h) | 2.6% |
| Thermal Limit | 150°C |
| Glass Transition, $T_g$ | 40°C |
| Coefficient of Thermal Expansion, $\alpha_1$ | $95 \times 10^{-6}$ in/in/°C |
| Coefficient of Thermal Expansion, $\alpha_2$ | $180 \times 10^{-6}$ in/in/°C |
| Linear Shrinkage | 2% |

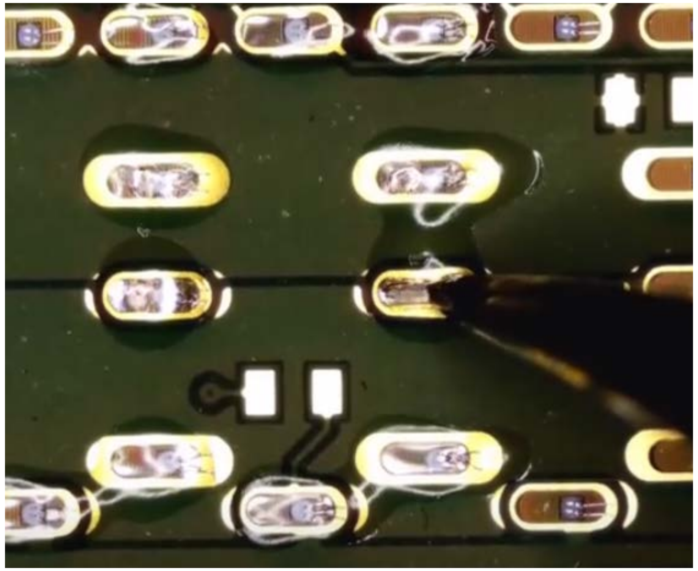
**CURED MECHANICAL PROPERTIES ***

| Property | Value |
|---|---|
| Durometer Hardness | D45 |
| Tensile at Break, MPa [psi] | 5 [750] |
| Elongation at Break, % | 150 |
| Modulus of Elasticity, MPa [psi] | 17 [2,500] |
| Glass Transition $T_g$, ˚C | 45 |
| CTE$\alpha_1$, µm/m/˚C | 95 |
| CTE$\alpha_2$, µm/m/˚C | 180 |
| Refractive Index (20˚C) | 1.51 |
| Boiling Water Absorption, % (2 h) | 2.6 |
| Water Absorption, % (25˚C, 24 h) | 1.0 |
| Linear Shrinkage, % | 2 |

- Properties listed in datasheets are identical (except viscosity).
- **9001-v3.1 already proven radhard, no issue with thermal cycle, etc., by ATLAS and STAR experiments.**

# Summary

- We have explored several encapsulation options and found a couple of UV-cured glues that work fast and well.
- One of them is the high-viscosity version of *Dymax 9001-v3.1* that was used by ATLAS and STAR.



# An automatic system would cost ~25 k

A quote we got:

| Part Number | Description | Price |
|---|---|---|
| **DPG3141** | **SmartDispenser™ Linear Dispensing System - Complete**<br>• Control Unit, power cord and foot pedal<br>• Pencil Gun and 3 and 5cc retaining rings<br>• keyboard, mouse, earpiece and wireless USB stick<br>• AirFree™ barrel and dispense tips sample kits | **$9000 ea.** |
| **D48D641** | **SmartDispenser® Table Mount** | **$640 ea.** |
| **JR2303N** | **Janome 3 Axis Robot 300mmX320mm** | **$14,220** |
| **JR9007N** | **Teaching Pendant** | **$1600** |
| **JR9008N** | **Additional IO1 Connector** | **$500** |
| | **Total Quote:** | **$25,960** |

http://www.fishmancorp.com/wp-content/uploads/2011/03/SSDAV-HT-BA7.pdf#pagemode=thumbs

# References


1) **CDF:** Wire-bond failures induced by resonant vibrations in the CDF silicon detector
http://www.sciencedirect.com/science/article/pii/S0168900203028158?via%3Dihub

2) **CMS:** Silicon Tracker Module Assembly at UCSB.
http://uscms.org/uscms_at_work/dmo/siTracker/Notes/note04_010.pdf

3) **ATLAS:** The ATLAS Insertable B-Layer: from construction to operation
https://arxiv.org/pdf/1610.01994.pdf

4) **ATLAS:** Studies of IBL wire bonds operation in an ATLAS-like magnetic field and evaluation of different protection strategies
http://ieeexplore.ieee.org/document/7581879/

5) **CMS:** Wire bond vibration of Forward Pixel Tracking Detector of CMS
http://lss.fnal.gov/archive/test-tm/2000/fermilab-tm-2363-e.pdf

6) Polyurethane spray coating of aluminum wire bonds to prevent corrosion and suppress resonant oscillations
http://iopscience.iop.org/article/10.1088/1748-0221/11/03/C03019/meta

7) A. Di Mauro, https://indico.cern.ch/event/662411/

# Datasheets

- http://www.dymax.com/images/pdf/pds/9-20558.pdf
- http://www.dymax.com/images/pdf/pds/921-t.pdf
- https://www.dymax.com/images/pdf/pds/9001-e-v30.pdf
- https://www.dymax.com/images/pdf/pds/9001-e-v31.pdf
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