Karlsruhe Institute of Technology

Wire Bond Encapsulation Studies at KIT

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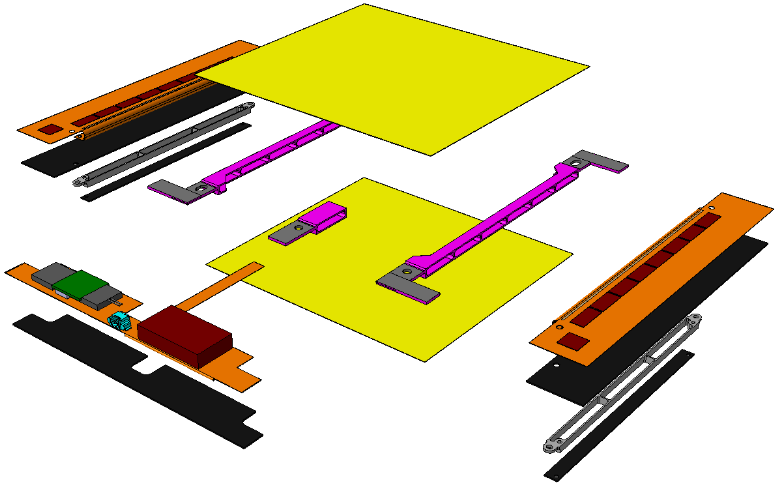
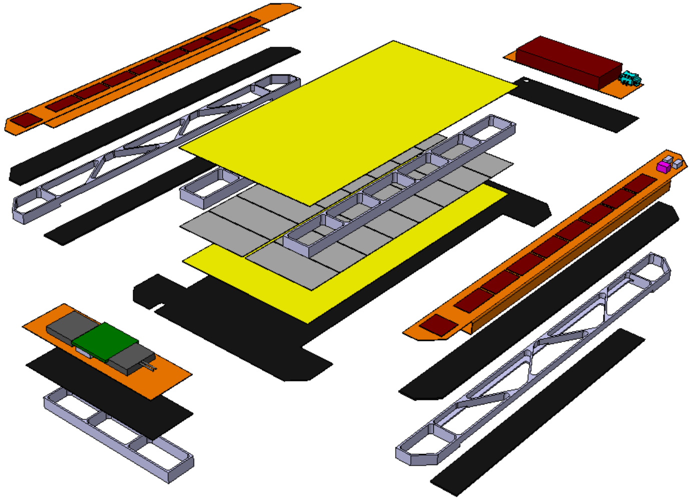
Tobias Barvich, Felix Bögelspacher, Alexander Dierlamm, ●Stefan Maier, Pia Steck

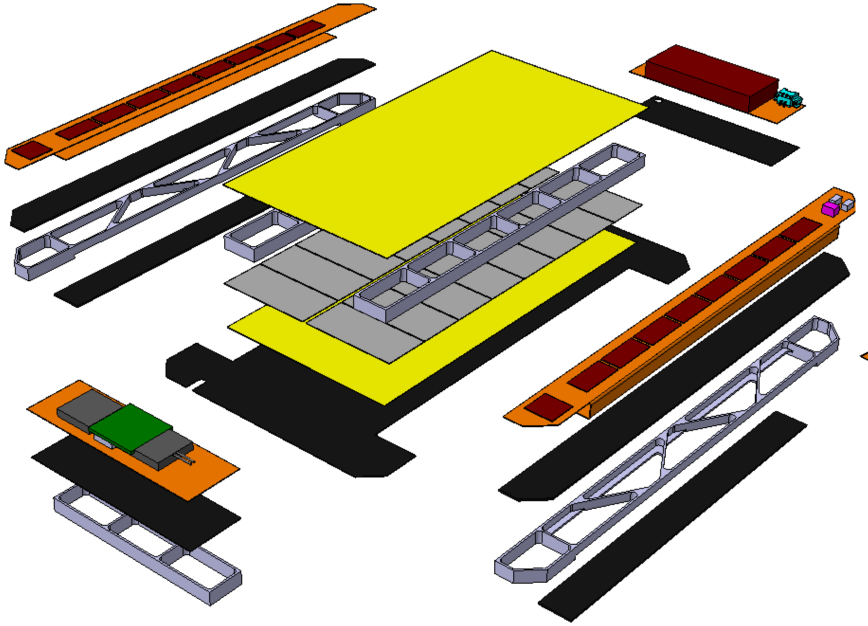
Institut für Experimentelle Kernphysik



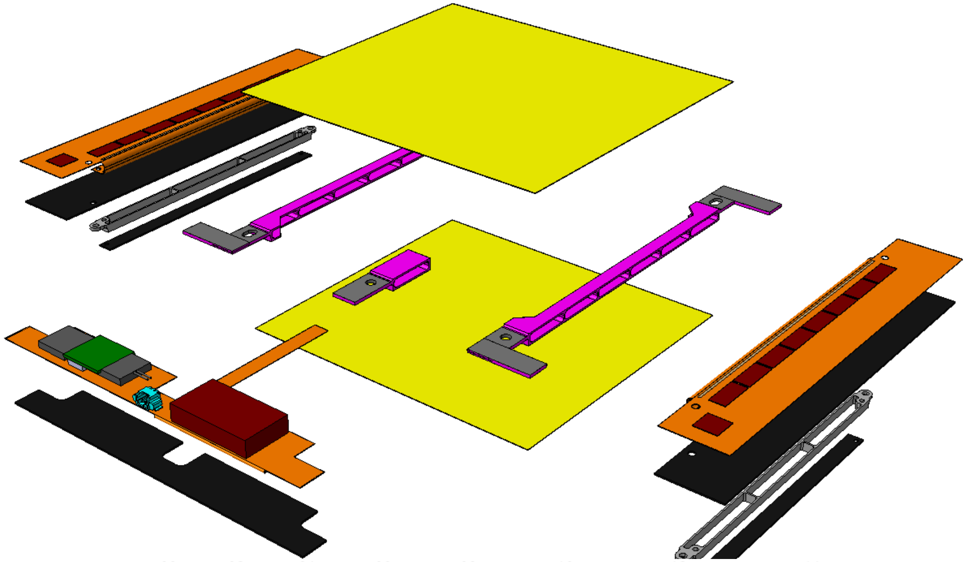


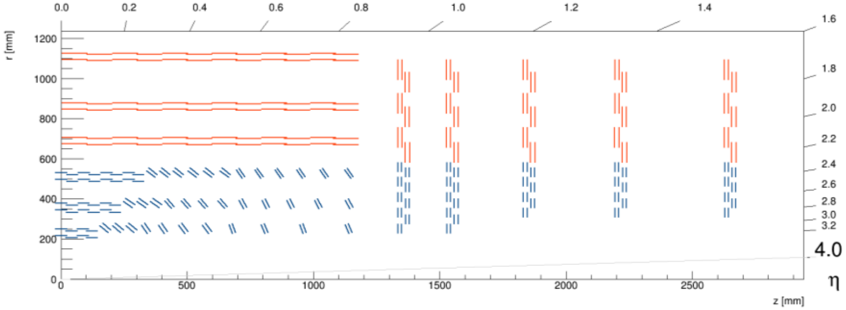
CMS Phase II Upgrade – 2S- and PS-Module

PS-Module



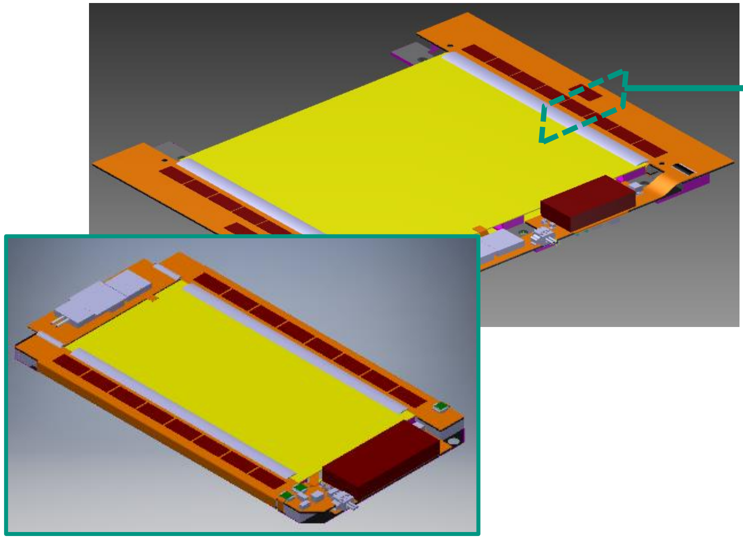
2S-Module

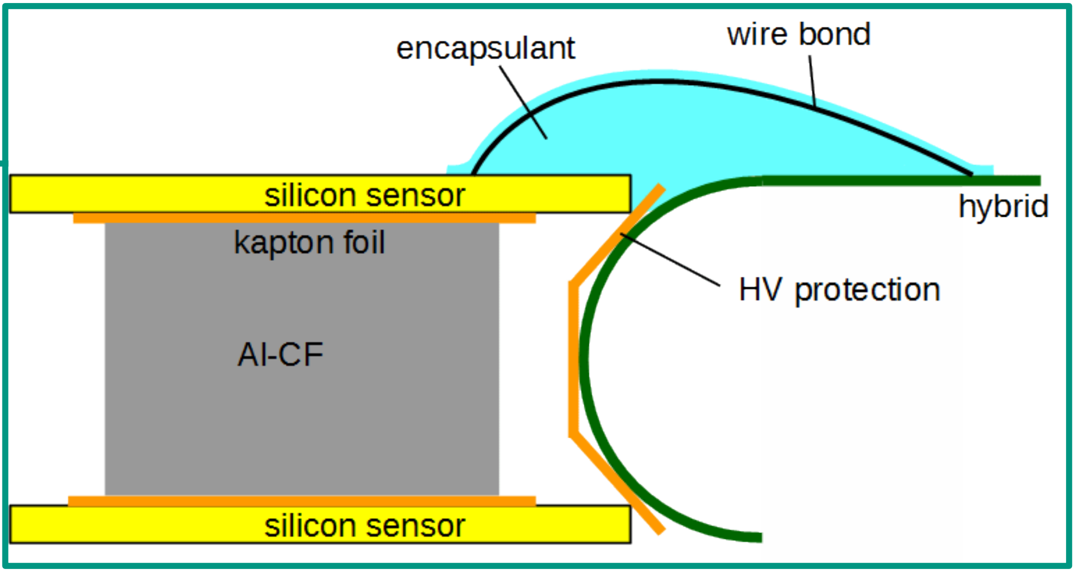




- New CMS Tracker consist of
  ~8200 2S- and ~5300 PS-Modules
- Two silicon sensors placed on Al-CF spacers
- Sensors surrounded by service and readout hybrids

CMS Phase II Upgrade – 2S- and PS-Module





- ~4000 wire bonds connect the silicon sensors (2S-Module) with readout hybrids, encapsulation required
  - Mechanical damage: touching (cables)
  - Chemical damage: (electrochemical) corrosion
  - Keep bond feet from lifting from the bond pad

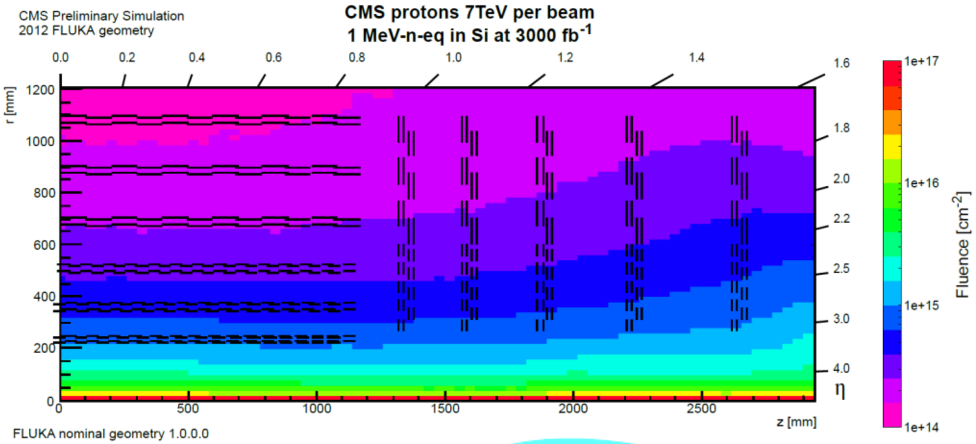
Requirements on encapsulation material

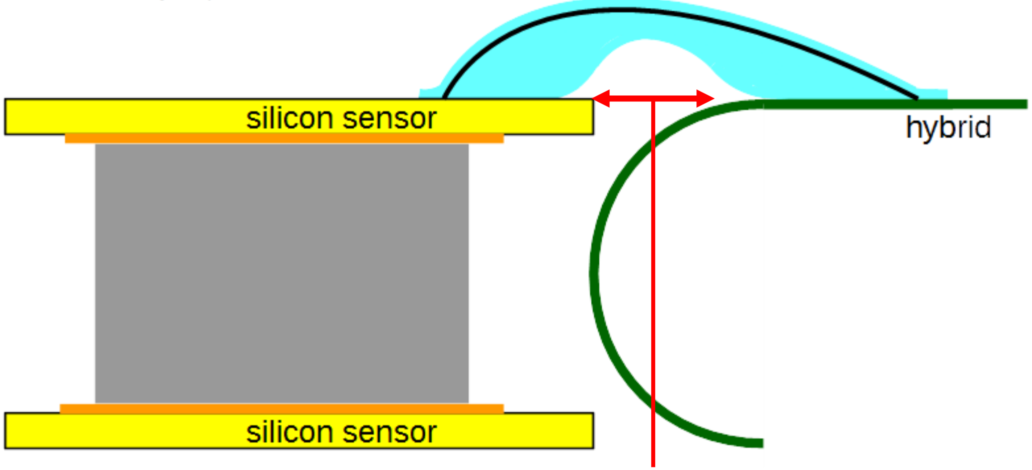
- Radiation hardness

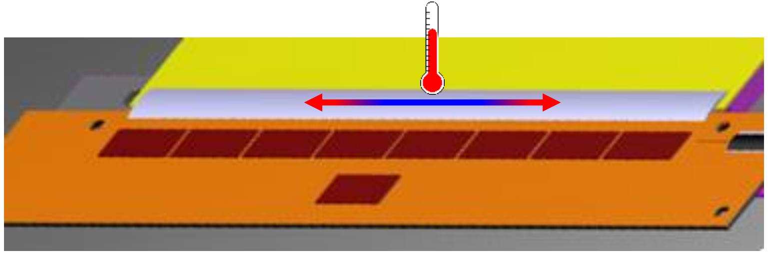
  (up to 10^{15} p/cm^2)

- Proper viscosity for easy application
  - Cover bonds completely
  - Keep other parts clean
  - If possible: stick solely to bonds

- No thermal stress on wire-bonds (ΔT=40K)







HV protection gap:
→ No Kapton foil necessary
→ Looser requirements on dimensions and positioning (sensor and hybrid)

Tested encapsulation materials

Material	Base	curing type	Viscosity η(t) (cP)	Volume resistivity (Ω cm)	CTE (10^{-6}/K)
Sylgard184	silicone	heat	3500	2.9E14	325
Sylgard186	silicone	heat	65000	8E14	330
1:1 Mixture (184/186)	silicone	heat	~35000		
Dymax9103	acrylated urethane	moisture / UV-Light	25000	2.62E13	81

- Silicone: flexible material
- Urethane: first flexible, very hard after few days

Application technique, test of η(t)

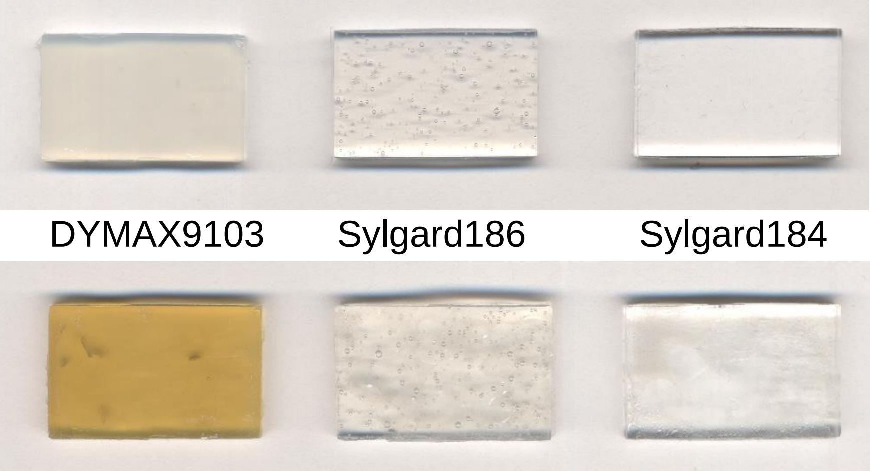
HV stability test

Effect of high CTEs on bond connections

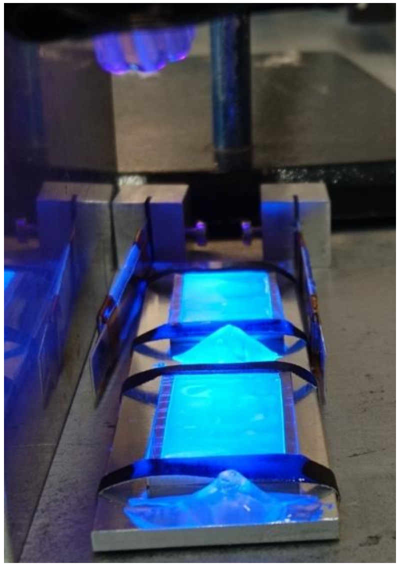
CTE (10^{-6}/K)		
	Si:	2.6
	Al-CF:	4
	Kapton:	20

Irradiation samples – blocks

- Samples were irradiated with 10^{15} protons/cm²
  - Before
  - After



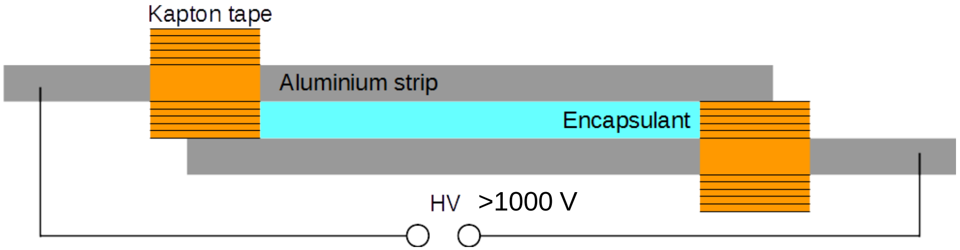
Dymax9103 cured with UV-LEDs

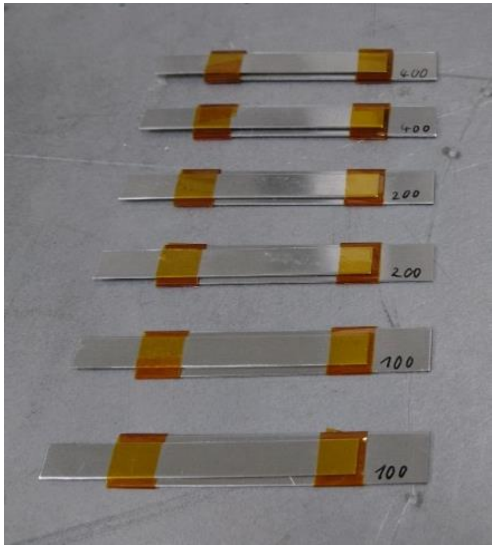


- Sylgard materials lost most of flexibility and became slight milky
- Small deformation of Sylgard186 block
- Hardness of DYMAX9103 increased and it became brownish (small cracks)
- No shrinkage

Irradiation of HV samples

- Two flat aluminum pieces with different spacing (betw. 100 and 600 µm) are filled with encapsulant



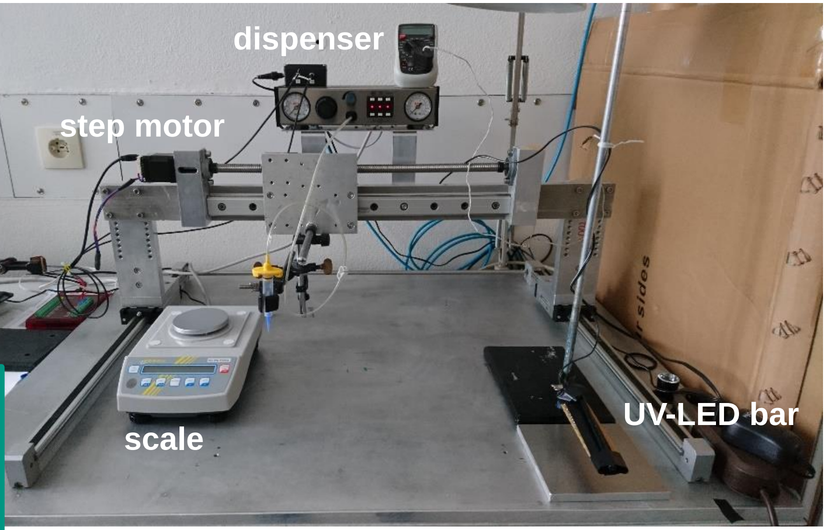


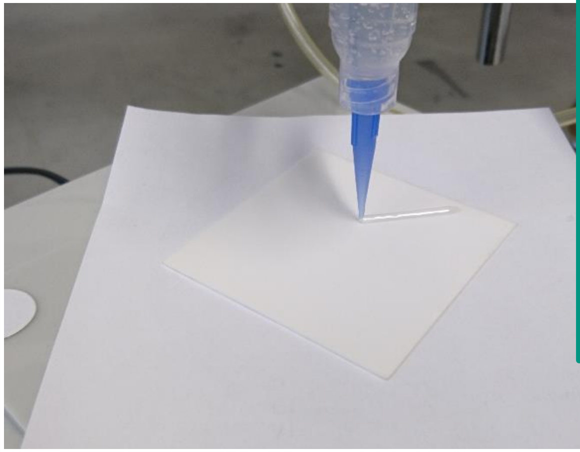
- With I(V) curves the volume resistivity can be estimated
  - Significant increase for Dymax9103
  - Thin (~ 100 µm) Sylgard samples broke down
  - Thick (> 100 µm) Sylgard samples showed an increased ρ

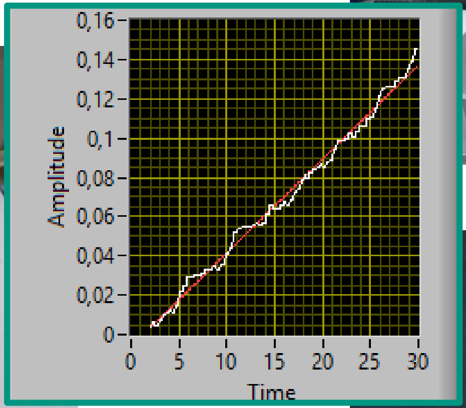
Material	**$\rho_{spec.}$ (Ω cm)**	**$\rho_{meas./\ unirr.}$ (Ω cm)**	**$\rho_{meas./\ irr.}$ (Ω cm)**
Sylgard184	2.9E14	1.5E14	2E14
Sylgard186	8E14	2.3E14	> 3E14
Dymax9103	2.62E13	6.5E10	> 3E14

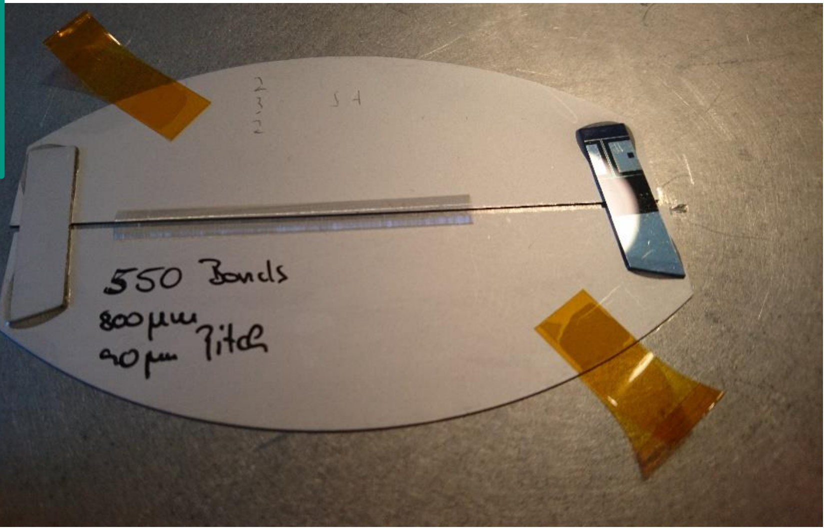
Dispensing machine

- Encapsulation done by a self made dispensing machine
- Before Sylgard application: Calibration of dm/dt with a scale







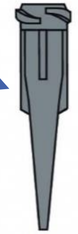


- UV-LED bar cures Dymax9103
- Simple samples to test different application techniques

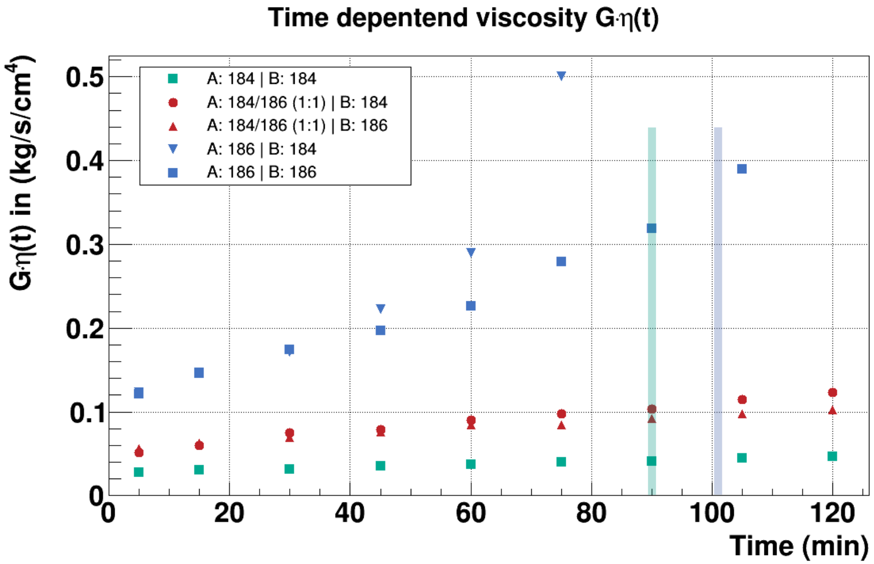
η(t) of Sylgard

- Sylgard 184, 186 (two-component material, base/hardener 10:1)
  - Curing starts after mixing
  - Change of viscosity and therefore of flux properties over time
- Determine $G\cdot\eta(T)$ by measuring m(t,T) with a scale
  - Hagen–Poiseuille equation: $\frac{dV}{dt} = \frac{\pi\, r^4}{8\,L}\frac{\Delta P}{\eta} \rightarrow \boxed{G\cdot\eta(T) = \frac{\Delta P\,\rho}{\dot{m}(T)}}$

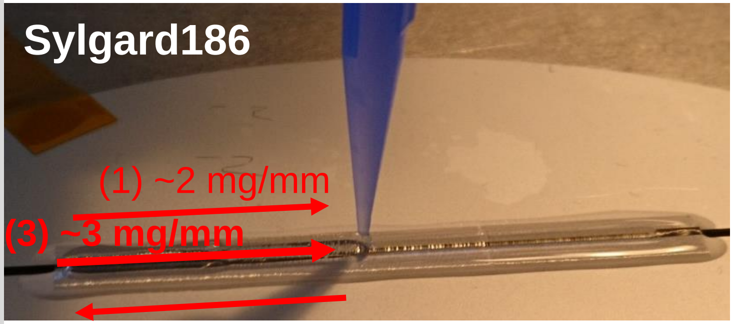
Geometry factor

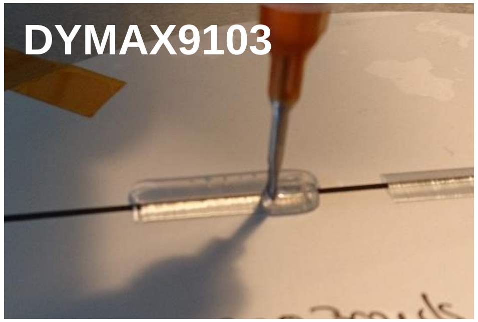


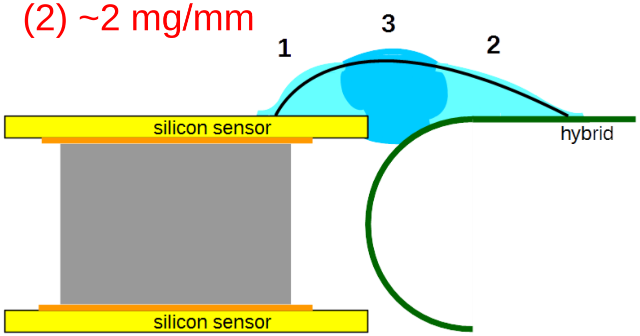
- Viscosity of Sylgard186 increases by a factor of 3 during pot life
- Sylgard184 and 1:1 mixture of 184 and 186 (part A) too liquid for useful application, viscosity does not significantly change during pot life

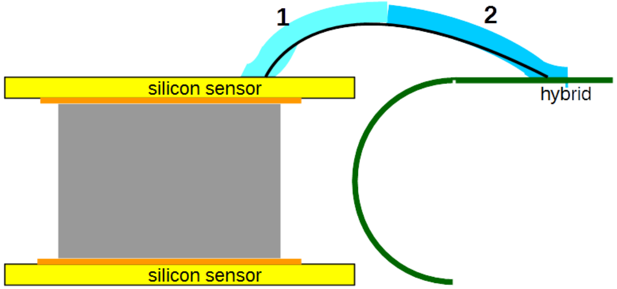


Application techniques









- With Sylgard186 an encapsulation in multiple steps is possible
  - First line 1 & 2 (low viscosity, cover bond feet)
  - after ~ 10 min line 3 (slightly increased viscosity) to seal gap
- Encapsulation with Dymax9103 manageable in two steps with oval tip (Wait 10 min before curing so all bond feet are covered)

Conclusion

- **2S Modules for the CMS Phase II Upgrade will have a wire-bond encapsulation**
- **Sylgard 184, 186 (silicone) and DYMAX9103 (urethan acrylate) were irradiated with 10^{15} protons/cm²**
  - **Thin layers (~100 µm) of Sylgard break down at high voltages after irradiation**
- **The viscosity of Sylgard 186 rapidly changes during curing time, which can be helpful to properly encapsulate the bonds over a gap**
- **A gap between sensors and hybrids could be implemented (HV protection)**

- **ToDo’s:**
  - **Effect of high CTE’s on bond connections**