Thermal Aging of Optically Clear Silicones

IMAPS–Device Packaging
Photonics Packaging

March 13, 2014

NuSil SILICONE TECHNOLOGY
Creative Partners in a Material World

NuSil Elements

- NuSil is one of the largest raw material silicone manufacturers in the world
- Serving Healthcare, Aerospace and Defense and Electronics for over 30 years
- 600+ employee–owners
- Located in Santa Barbara County, CA (2 hrs north of Los Angeles)
- Vertically integrated with multiple manufacturing facilities
- Global Sales Offices (USA, Europe and Asia)
- Wide variety of Specialty Chemicals

Yellow Silicone

- Chemical and Physical degradation
  - AKA "Yellowing"
- Consequences
  - Reducing lumen output
  - Changes in CIE and color
  - Signal decrease or loss
- Industry Demands
  - Material level testing for silicone encapsulants
  - No set standard conditions
  - No standard test module – multiple scenarios for packaging
  - Difficult to compare silicones due to multiple testing variables
  - Data needs to be consistent for relative comparison

Overview

- Goal: Better understanding of process to obtain %Transmittance data over time after heat aging of select silicones
  - Applications for Clear Silicone
  - Key Silicone Properties
  - Silicone Formulations
  - Silicone is not perfect
    - Themo-oxidative and thermo-optic effects
  - Variables of test and how we control
  - Demonstration of test results

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High Temperature Applications

- Silicone acts as a photon coupler between air and light
- **Light Emitting Diodes**
  - High Power LED (>1 W)
  - Super High Power LED (> 5W)
  - UVLEDs (DUV and UV)
- **Solar**
  - Encapsulants between cell and cover glass
  - Silicone on Glass (SOG) for Concentrated Photovoltaic as primary lens

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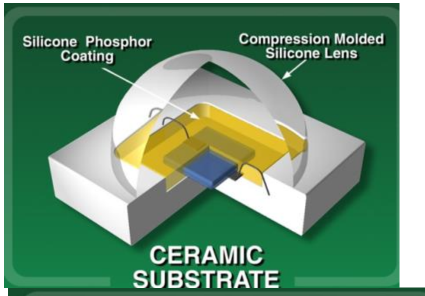
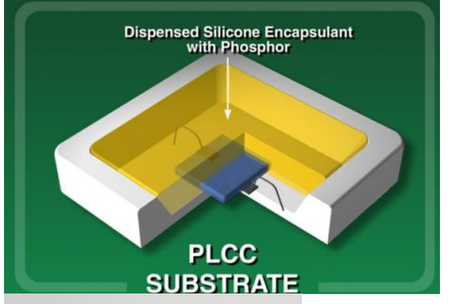
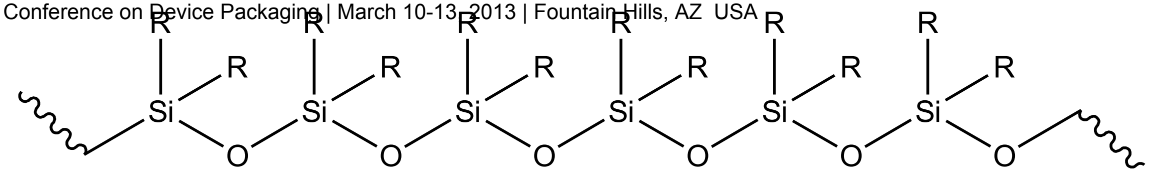
Applications for Silicone Encapsulants

- Silicone Uses for LEDs
  - Phosphor Coatings for white LEDs
  - Remote Phosphor carrier
  - Optical Lenses for Light guides
    - Light pipes, lenses, etc
    - Component or Luminaire
- Challenges
  - Temperature
    - HPLED $T_{junction}$ > 85˚C
    - Getting hotter (SHP LED)
  - Wavelength
    - Blue or violet LED ~400nm−465nm
    - Getting lower (DUVLED)





Why Silicone?



- Low Modulus – absorb stress during thermal cycling (1–5 MPa)
- Low Moisture Absorption (0.02 – 0.20 @ 85˚C/85% RH/ 168 hrs)
- Optimize for Refractive index (Fluoro (1.38), Methyl (1.41), Phenyl > 1.42))
- Optimize for low volatility (1% weight loss maximum 1 hr at 275 C)
- Optically Clear and in various form factors
    - Casting, molding and dispensing based on viscosity
- By Adding Filler
    - Reinforcing Silicone for high mechanical strength
    - Thermally Conductive
    - Electrically Conductive

Optically Clear Addition Cure Silicone

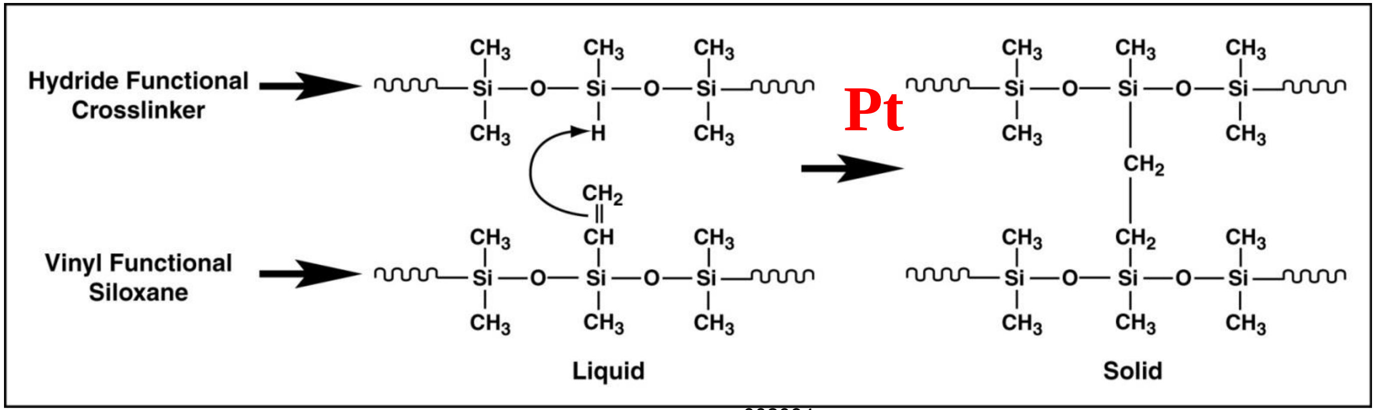
2 Component

Part A
Silicone Polymer
+ Pt Catalyst +
Reinforcing
component

Part B
Silicone Polymer
+ XL +
Reinforcing
component

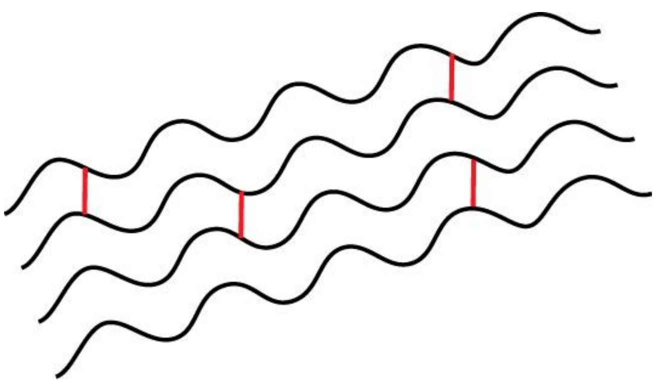
POSITIVE:
No leaving groups
Minimal Shrinkage
Heat accelerated

NEGATIVE:
Inhibition
Mixing Properly
Ensure fully cured

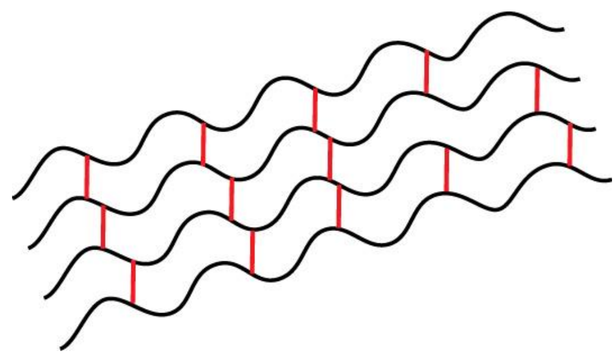


Polymer Chain Length & Crosslink Density

- The amount of vinyl and hydride groups on the polymers controls crosslink density.
- Crosslink density influences the durometer, or hardness, of a material.

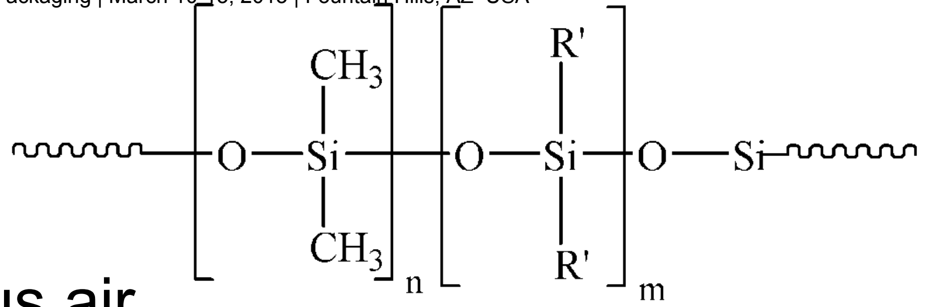


Soft Gel

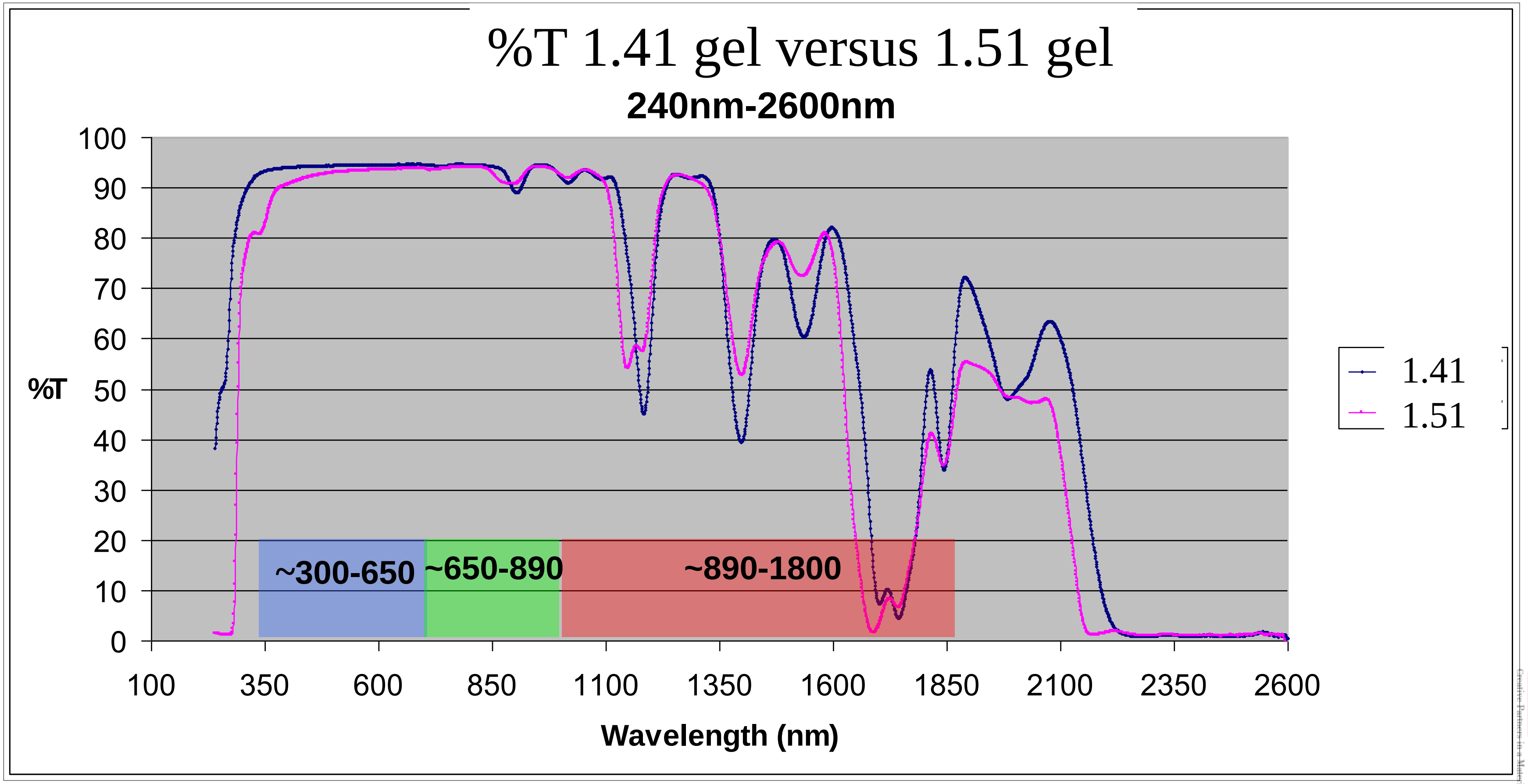


Resin reinforced elastomer

Optically Clear

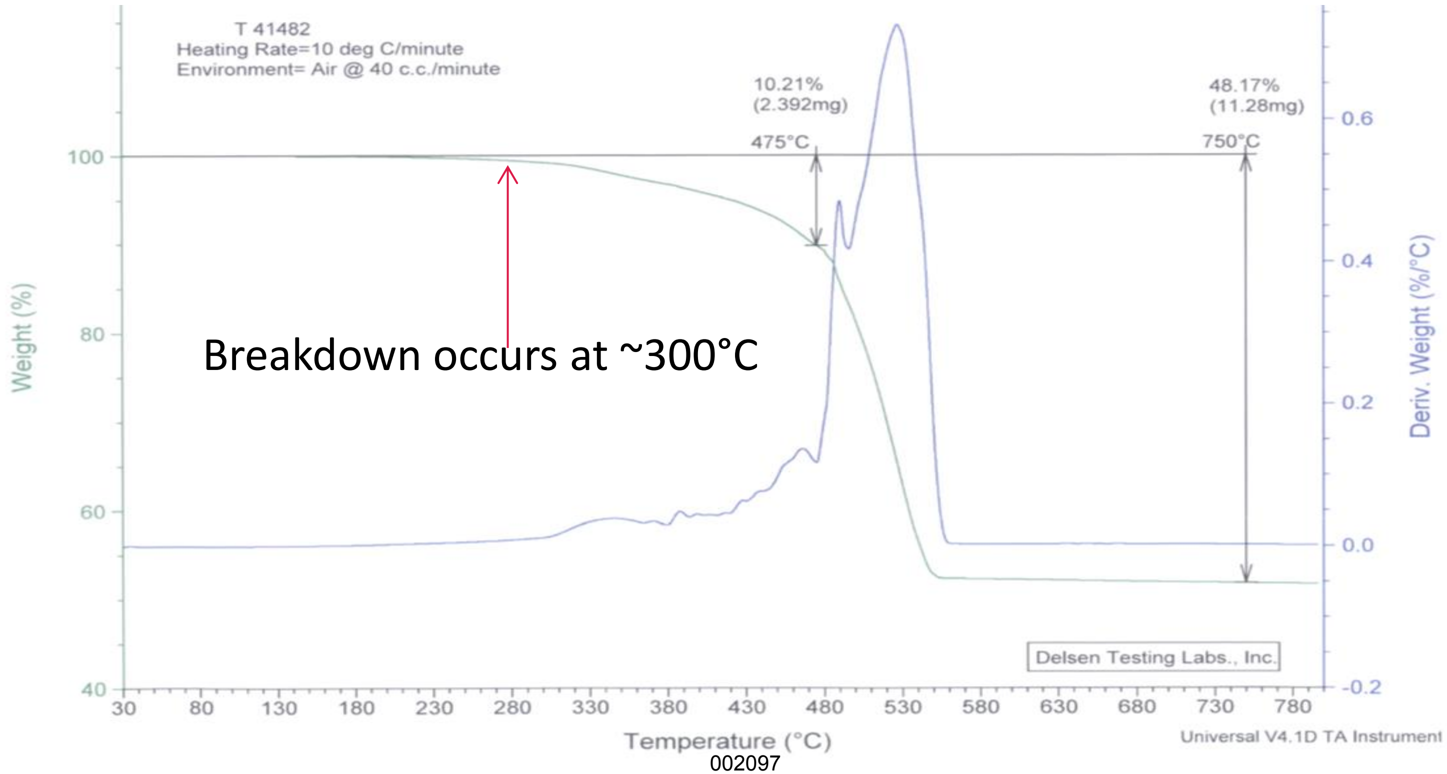


%T at 1 cm path length versus air



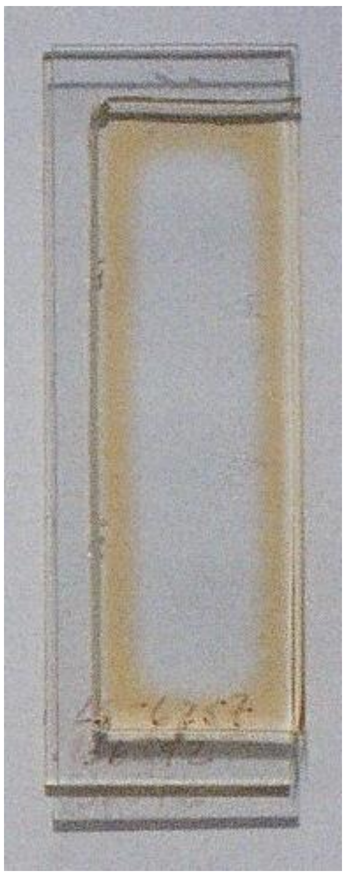
Other Properties of Silicone

- Thermally Stable
- Dielectric Strength; > 500 V/mil (20 kV/mm)
- Electrically Insulating; > 10^{12} Ω•cm
- Thermal Conductivity 0.2 W/mK

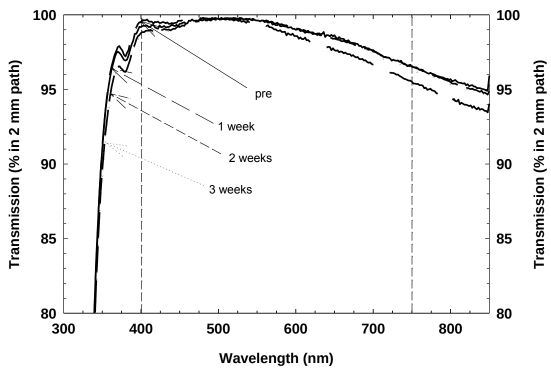


Air Exposure

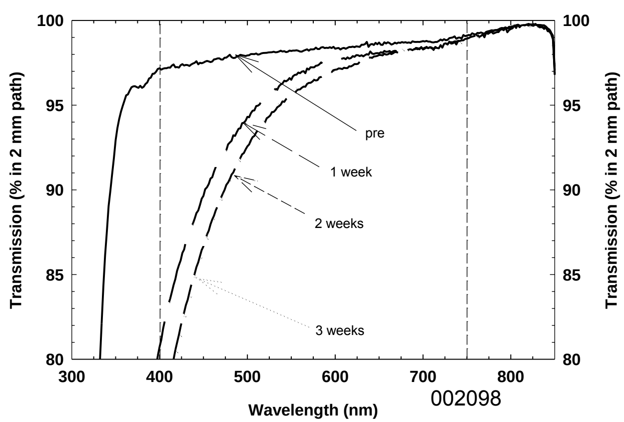
- Oxygen (Thermo-oxidative)
  - Oxygen can accelerate degradation

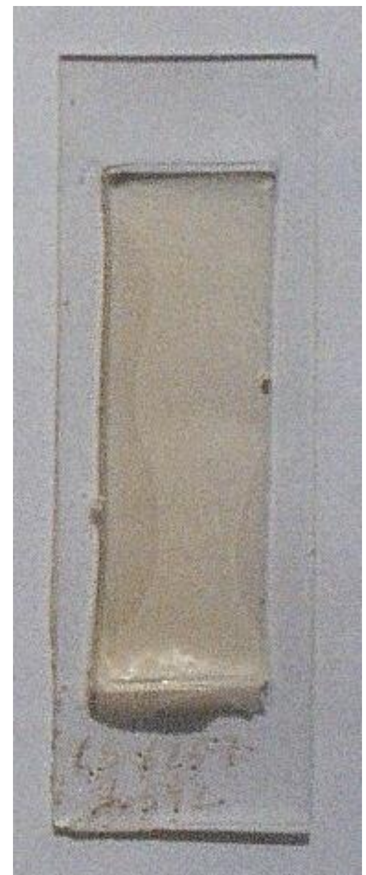


Optical Transmission vs. Wavelength
LS-6257, Lot# 36592
closed sample, gasket removed, before and after 150C exposure



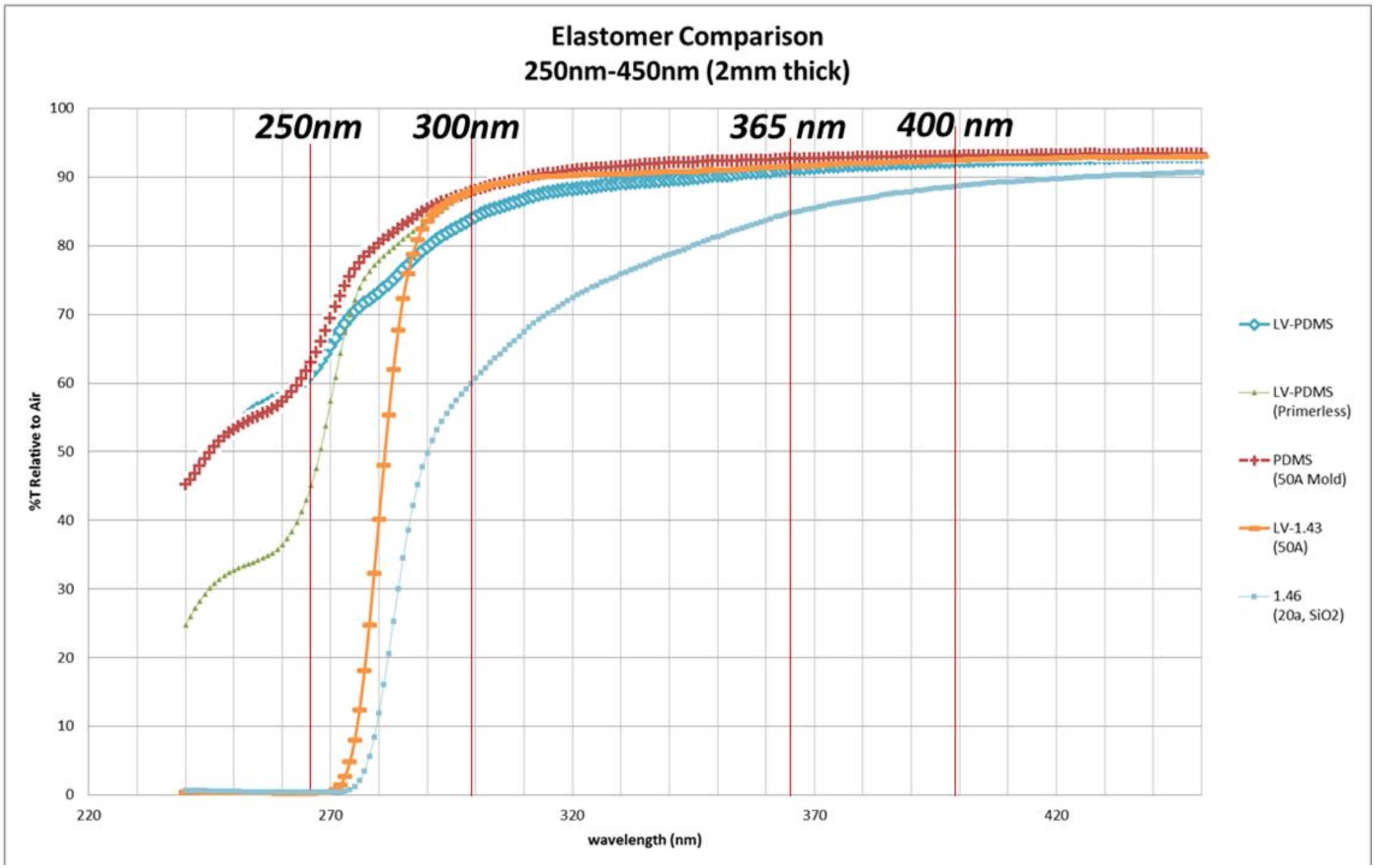
Optical Transmission vs. Wavelength
LS-6257, Lot# 36592
open sample, gasket removed, before and after 150C exposure



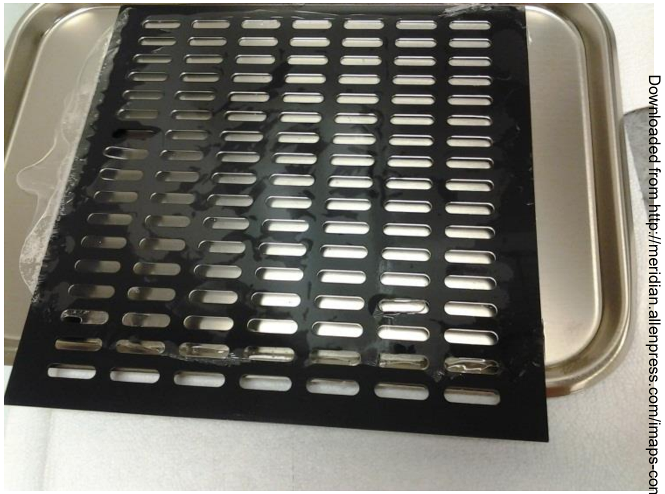


Thermo-Optic Effects of Silicone

- Wavelength effects



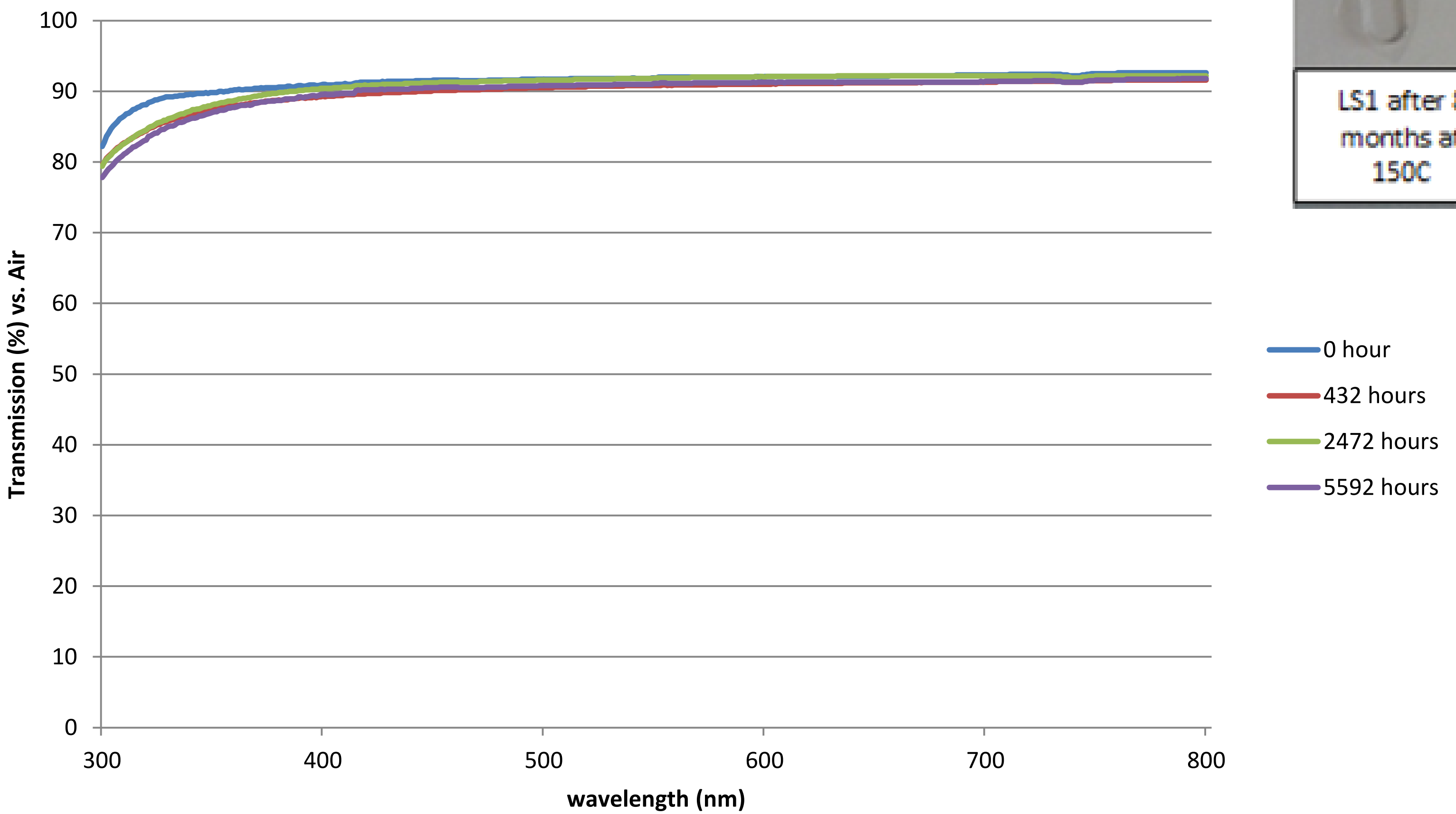
Heat Aging Test

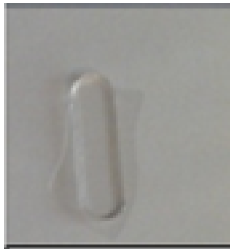


- Material Test conditions
  - Maximize exposure of heat and air
  - 150˚C
  - Testing interval
- Measuring %T over Time
  - Spectrophotometer (direct or integrated sphere)
  - Blank on air
  - Specimen thickness (2mm)
  - Measure test specimen direct on air
    - Glass slides were varied in %T within lot
    - Avoid trapped air
    - Result in lower overall %T due to Fresnel losses

Thermal Aging of Optical Silicones

LS1-6140 (2 mm) heat aged 150 C in air

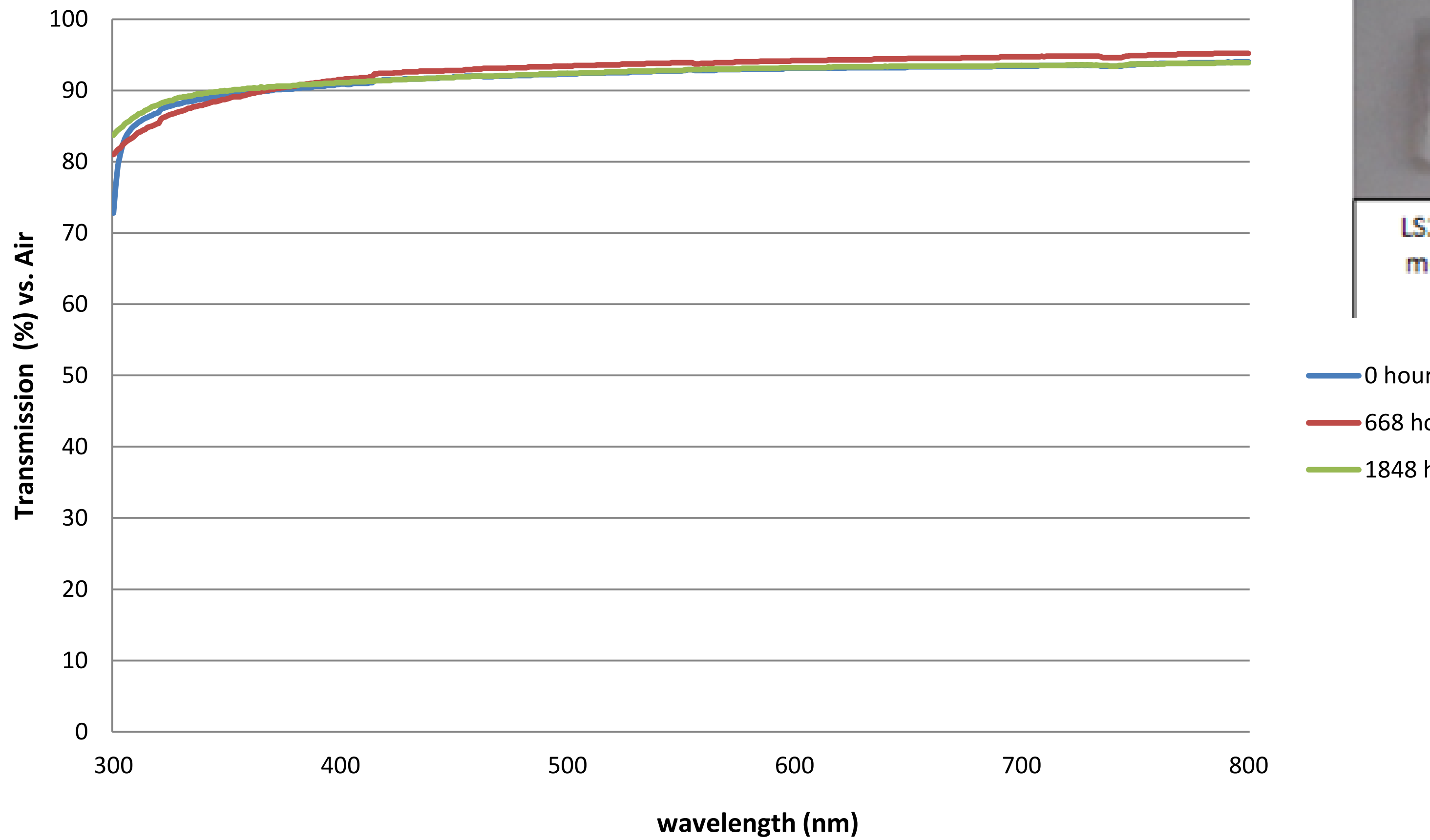




LS1 after 8 months at 150C

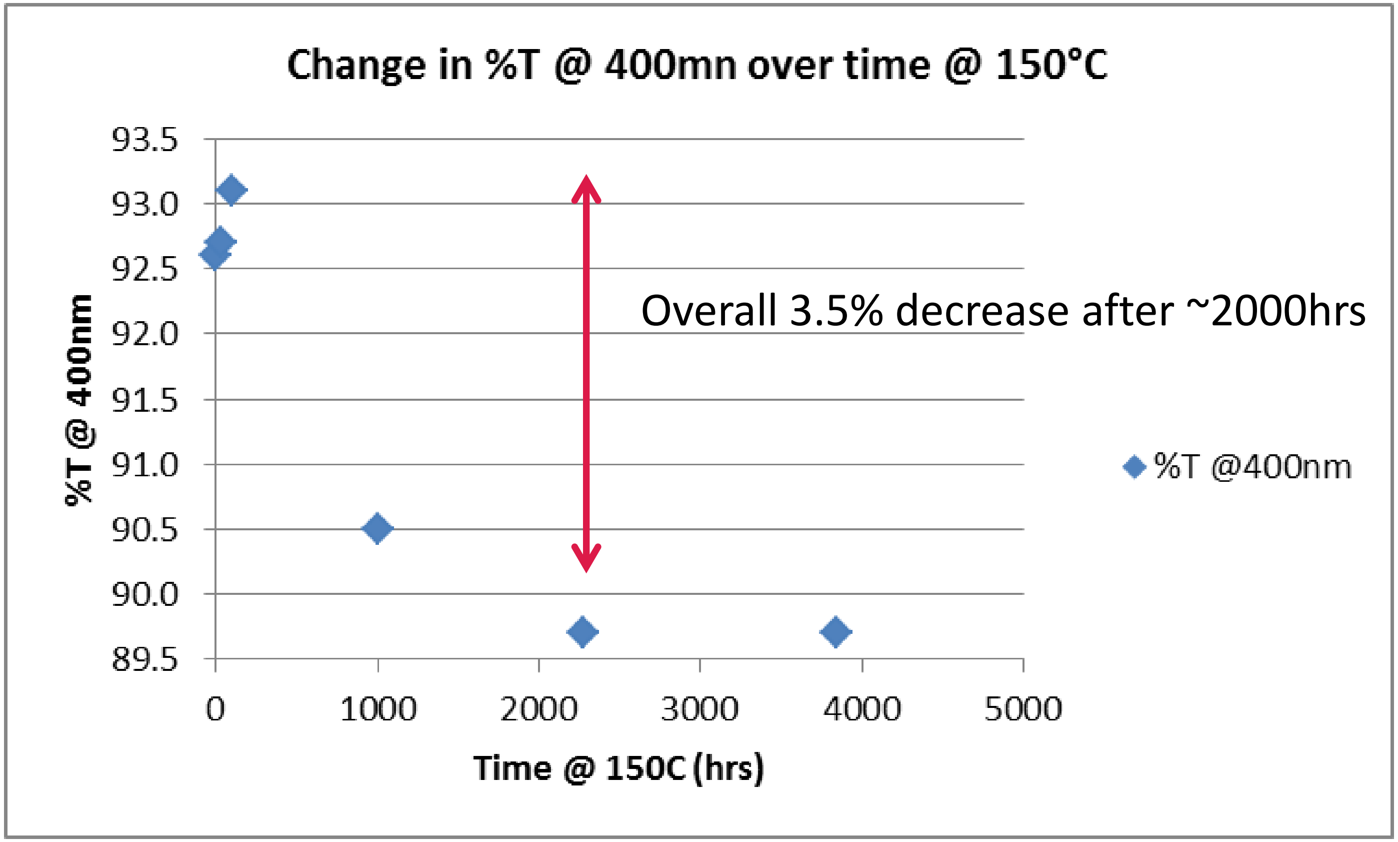
Thermal Aging of Optical Silicones

LS2-6140 (2 mm) heat aged 150 C in air



LS2 after 2 months at 150C

Wavelength


Change in %T @ 400mn over time @ 150°C
93.5
93.0
92.5
92.0
91.5
91.0
90.5
90.0
89.5
%T @ 400nm
0
1000
2000
3000
4000
5000
Time @ 150C (hrs)
Overall 3.5% decrease after ~2000hrs
%T @400nm

Conclusion

- Material Level Testing Standardization
  - Doesn't exist at this time (temperature, process and technique)
- Excellent for relative comparisons
- Best test is by end user
- Good thermal management will reduce stress on materials and give longer operation life