High Temperature Photovoltaics Silicone Adhesives for Venus Surface

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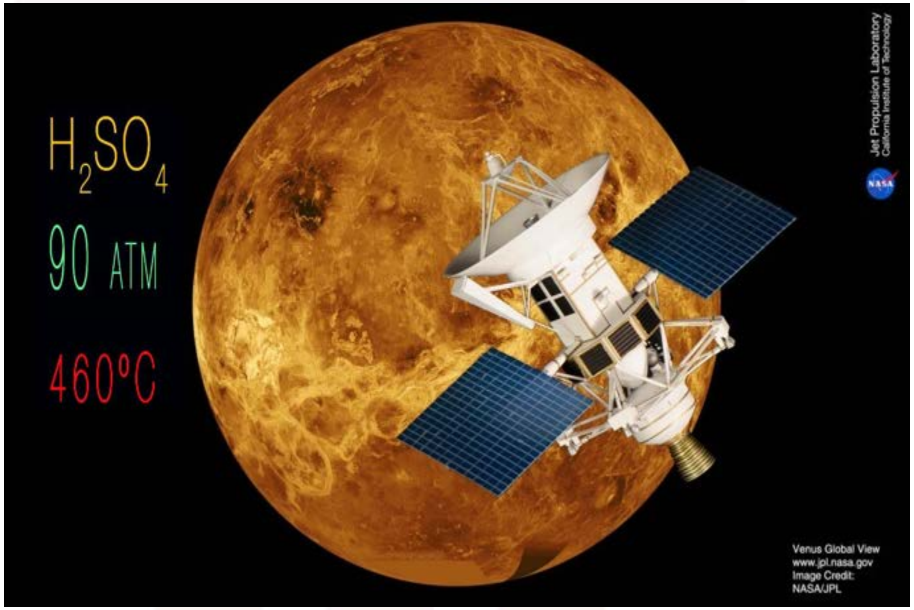
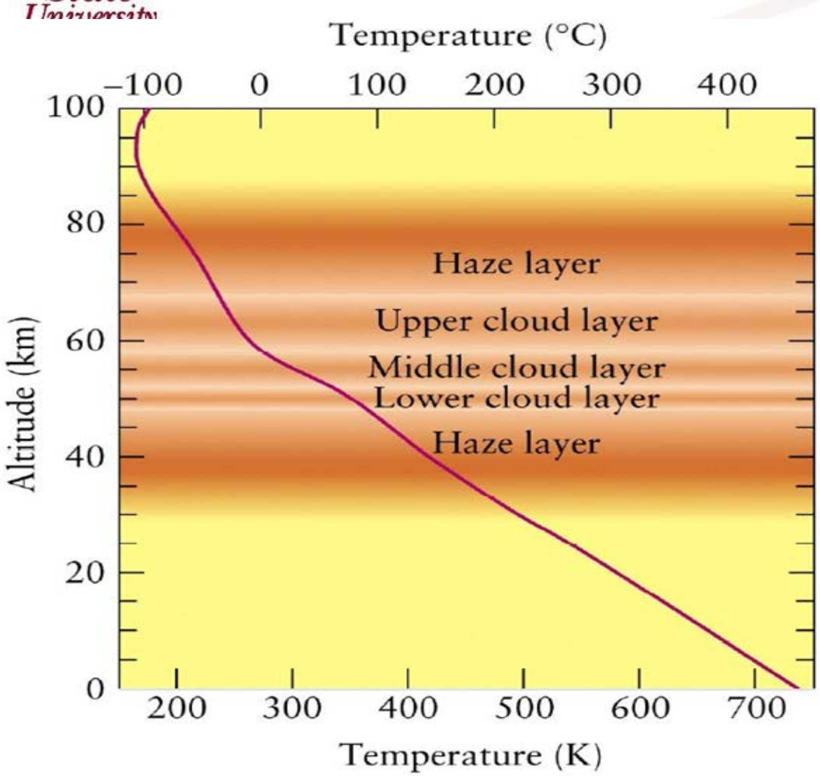
BACKGROUND

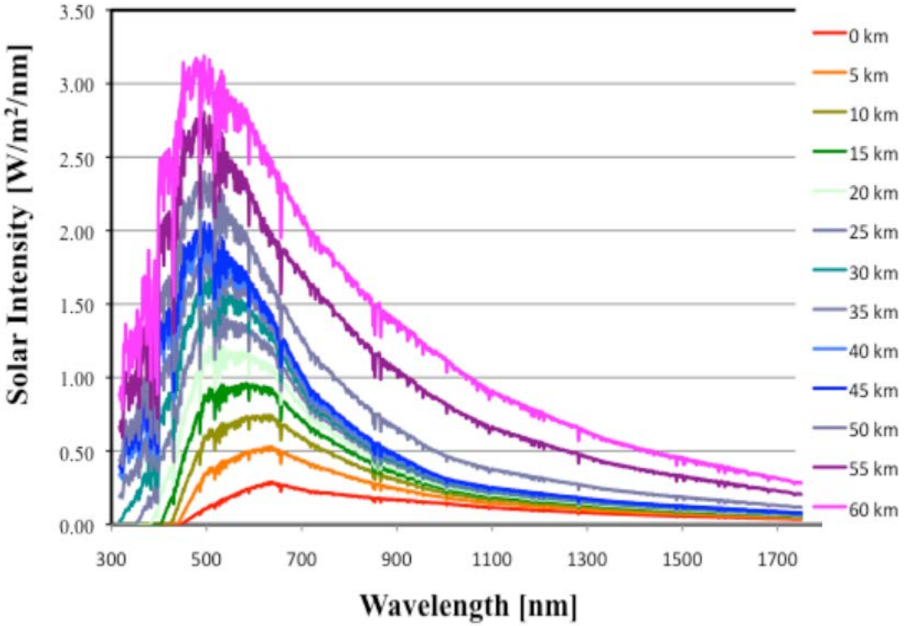
1. The environment at the surface of Venus is HARSH- high temperatures, and a corrosive acid environment

2. For the design of photovoltaic power generation for future missions to Venus, we need solar arrays that can function for a long lifetime without degradation.



PROFILE OF VENUS ENVIRONMENT

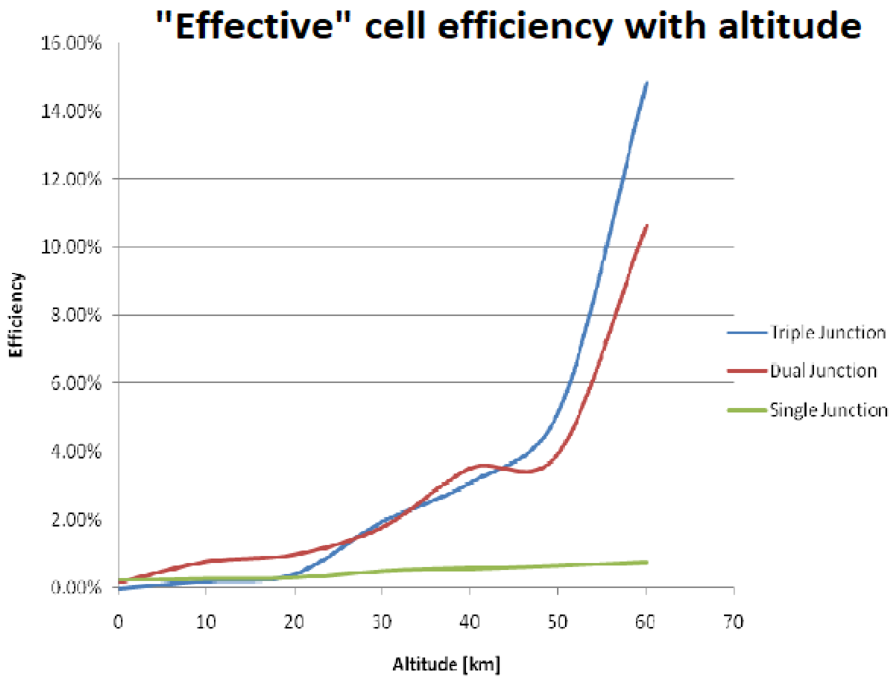


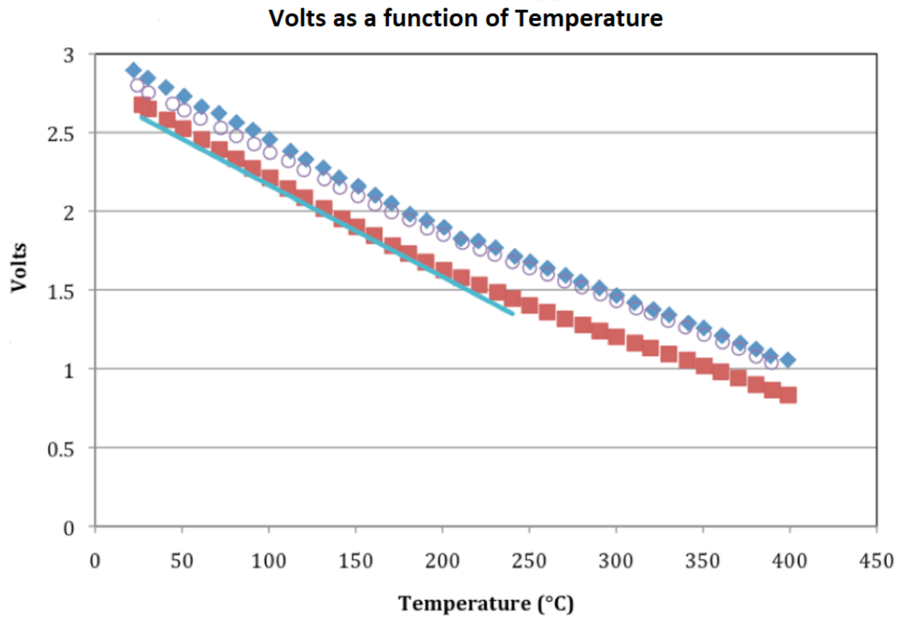


•Temperature Increases with Decrease in Altitude
•Layers of Corrosive chemicals

•Lower Solar Intensity with Decreasing Altitude

Challenges for use of Photovoltaics



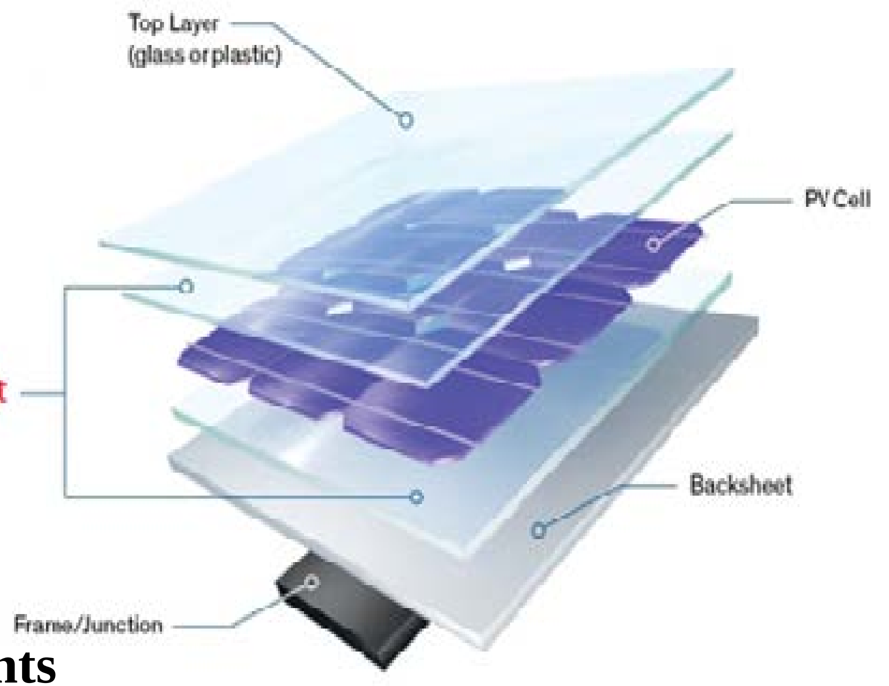


Experimental values of the effect of temperature on open-circuit voltage of commercially available triple-junction cells

- Efficiency decreases with decrease in altitude
- Voltage decreases with increase in temperature

"effective" efficiency is defined as power output divided by exoatmospheric intensity (that it, it incorporates the atmospheric opacity as a loss of efficiency)

The use of Cover Glass



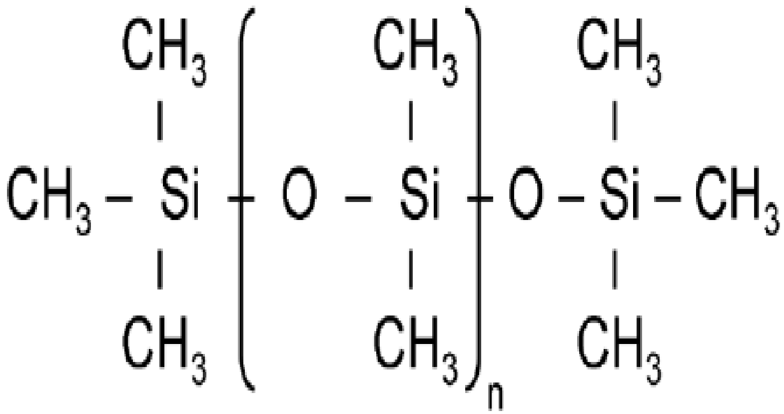
a. Encapsulant Material (ADHESIVE/FILM) Requirements

- ✓ Optical Clarity/ Transparent
- ✓ Optical stability
- ✓ Chemical corrosion resistance
- ✓ High Temperature Performance
  - o Mechanical Stability- no loss in adhesion properties
  - o Zero to low outgassing

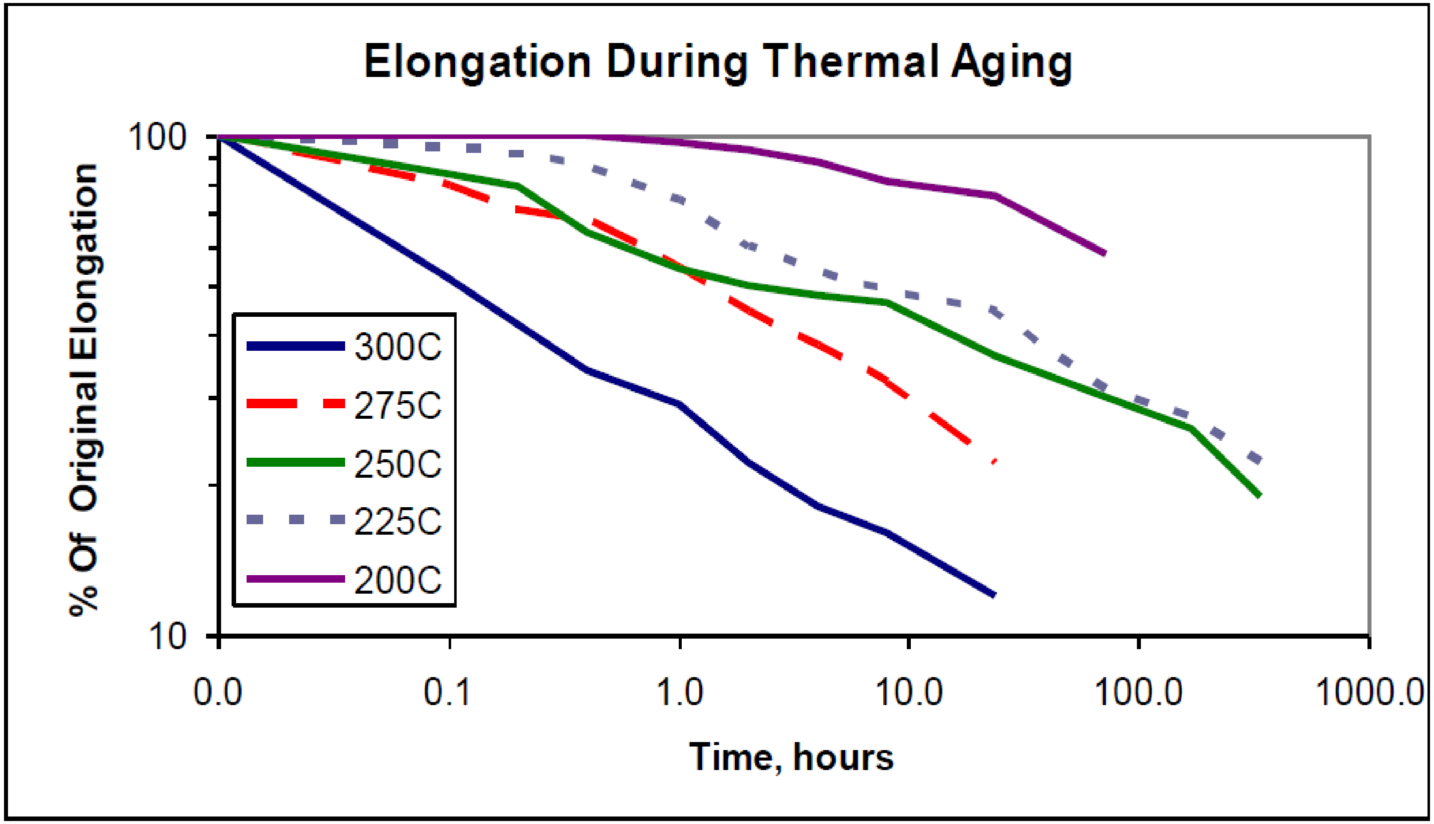
- **The behavior of such MATERIAL at Venus environment is not known**

It is the goal of this paper to review the Degradation mechanism of silicone adhesives when exposed to Venus environment as a way to provide valuable guidance in the transparent adhesive affixing the coverglass to the cells

Exploring the reliability of Silicone Polymers as Adhesives.

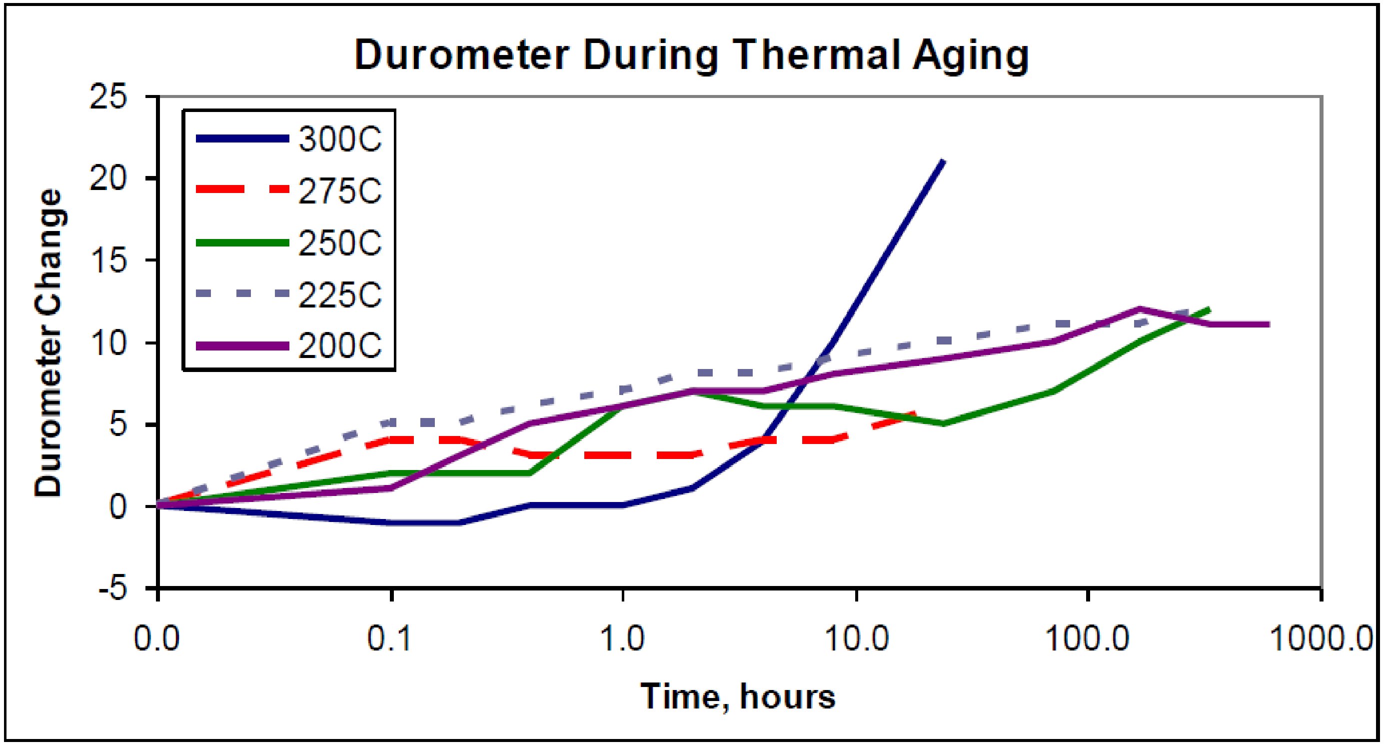


Siloxanes, or polysiloxanes, with polydimethylsiloxane (PDMS) as the most common member



Change in Elongation During Thermal Aging

- Elongation (Polymer Chain) decreases with increase in temperature



Change in Durometer During Thermal Aging

- Polymer becomes hard and brittle with increase in temperature

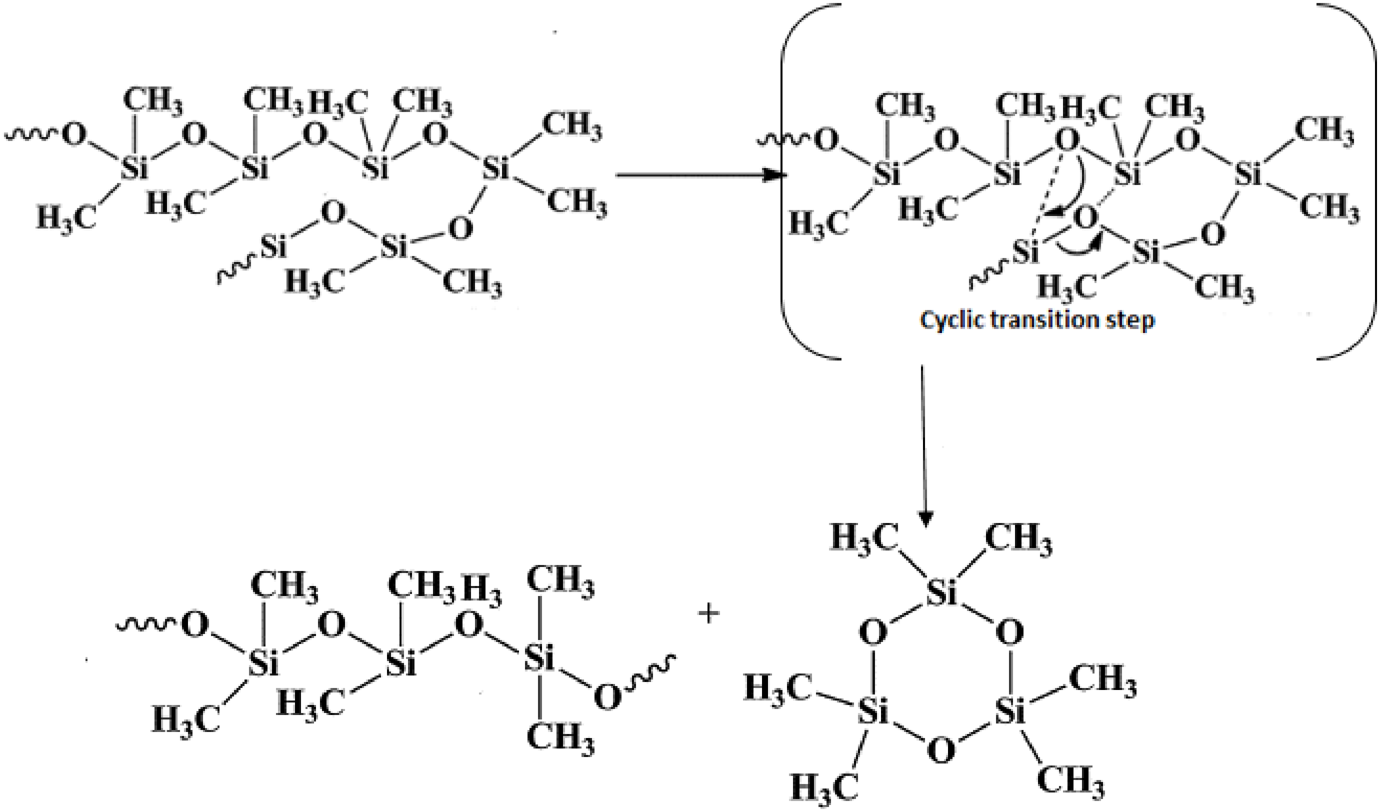
Understanding the Degradation Mechanisms

The following mechanisms were studied:

1. **Thermal Degradation**
   - **Effect of high temperature**
2. **Thermal oxidative degradation**
   - **Effect of oxidants in the atmosphere of venus**
3. **Degradation by Hydrolysis**
   - **Effects of acids/water vapor**
4. **Photochemical Degradation**
   - **UV degradation**

UNDERSTANDING Thermal Degradation

Si–O bond (108 kcal/mol) cleavage instead of **C–Si bond (78 kcal/mol) to form a mixture of** cyclic products and shorter chain siloxanes- loss of adhesive elasticity and an increase in brittleness

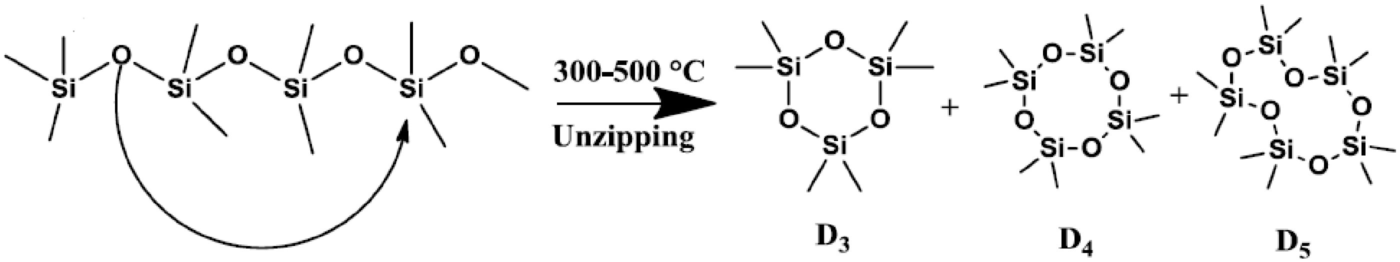


Molecular Deploymerization Mechanism

Degradation Mechanism: occurs through two competing mechanisms:

Molecular mechanism:

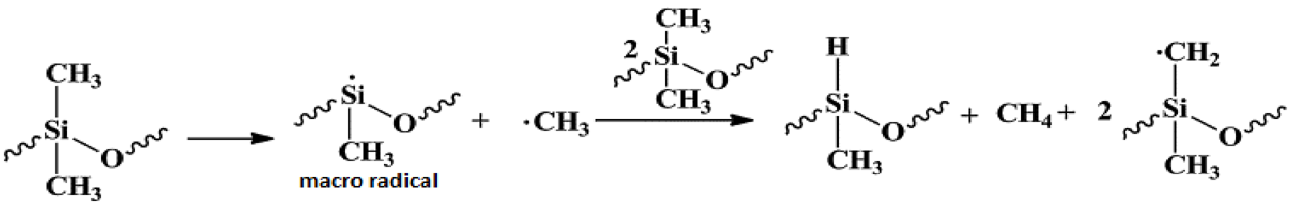
- ✓ Governed mainly by the molecular structure and kinetic consideration, and not by bond energies.
- ✓ Cyclic transition state requiring only an activation energy of about **40 kcal /mol** as the rate-determining step in PDMS thermal degradation.
- ✓ The above cyclic oligomers splitting process from PDMS chains will proceed until the residual linear structure is too short too cyclize and/or the evaporation of the shortened chain fragments favorably competes with cyclization.



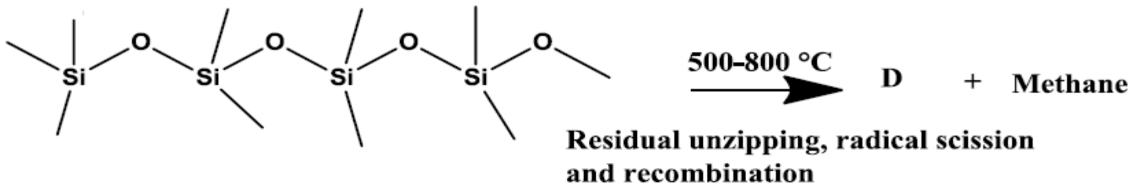
Depending on the chain length of the siloxanes, various ring sizes can be formed as shown in the scheme

UNDERSTANDING Thermal Degradation

Radical mechanism: At temperature ranges between above 500C, radical mechanism through homolytic Si-CH_3 bond scission prevails and leads to methane through hydrogen abstraction,



The macro radicals can cross-link with each other to decrease the flexibility of the adhesive and hinders the further splitting of the cyclic oligomers of the type D (3-5etc). The thermal stability of the material can further be increased and bond rearrangements can occur to form ceramic silicon oxycarbide,



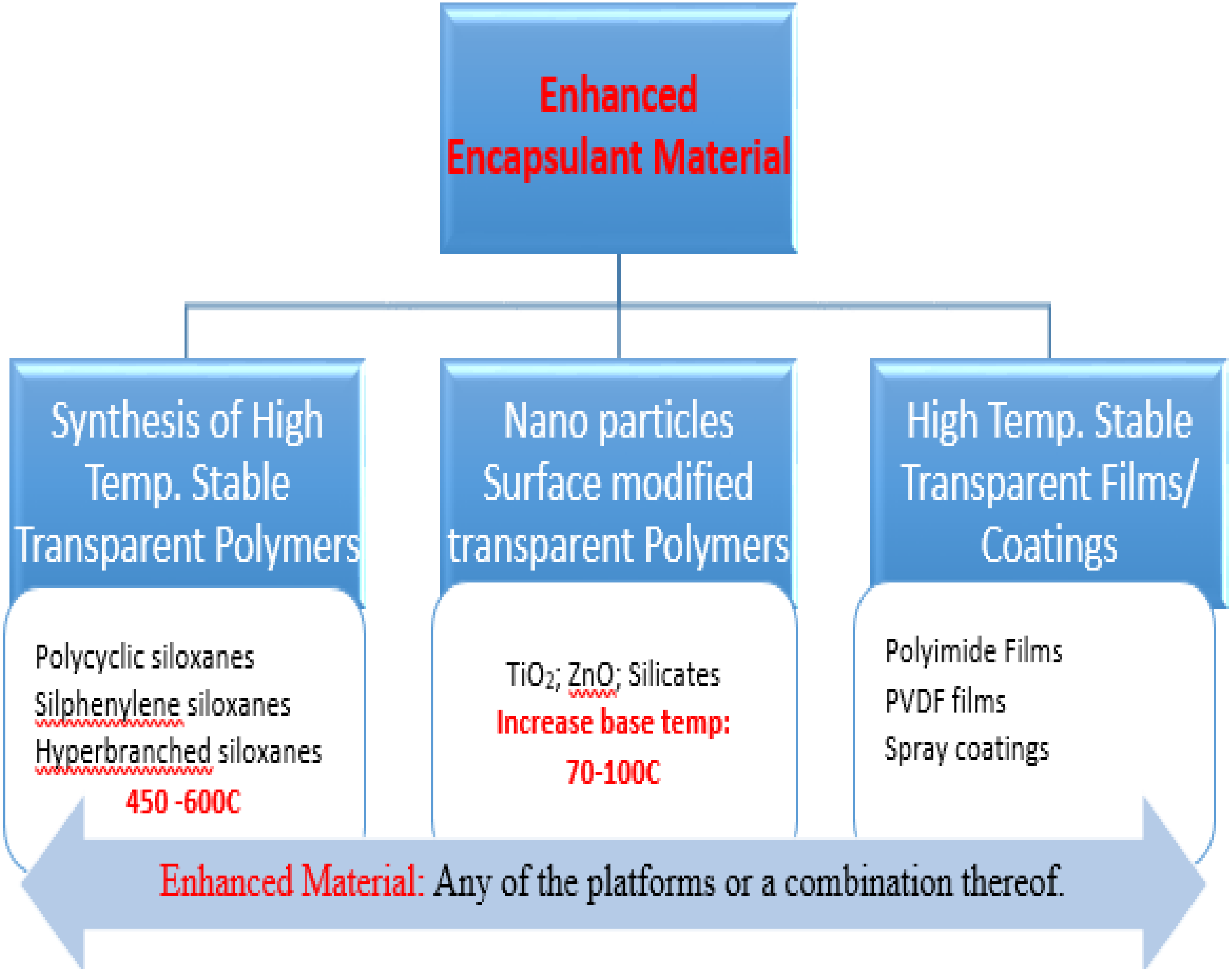
The test panel with all the sample configurations for 460C/1hr testing

460C LABORATORY EVALUATION OF DC93500

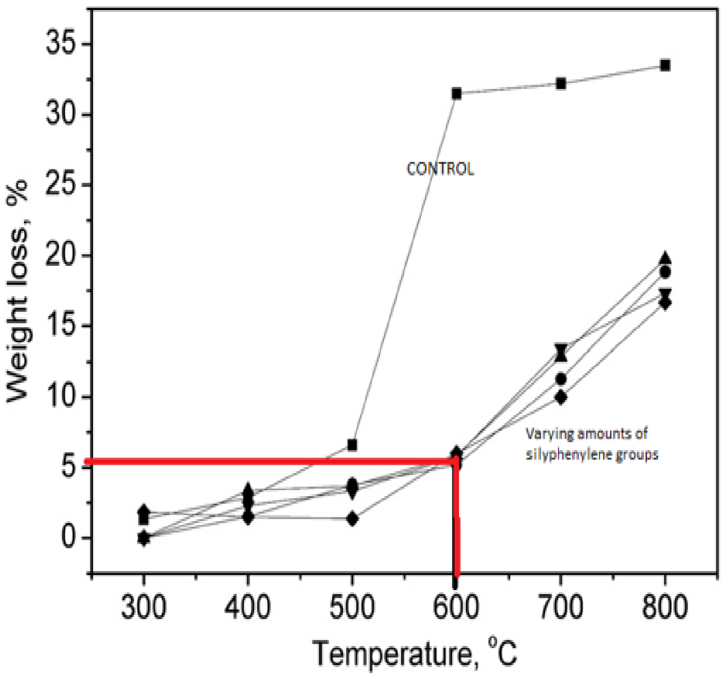
DC 93500, rt cured		rt.cured	160C/1hr cured no coverglass		160c/1hr cure with Coverglass

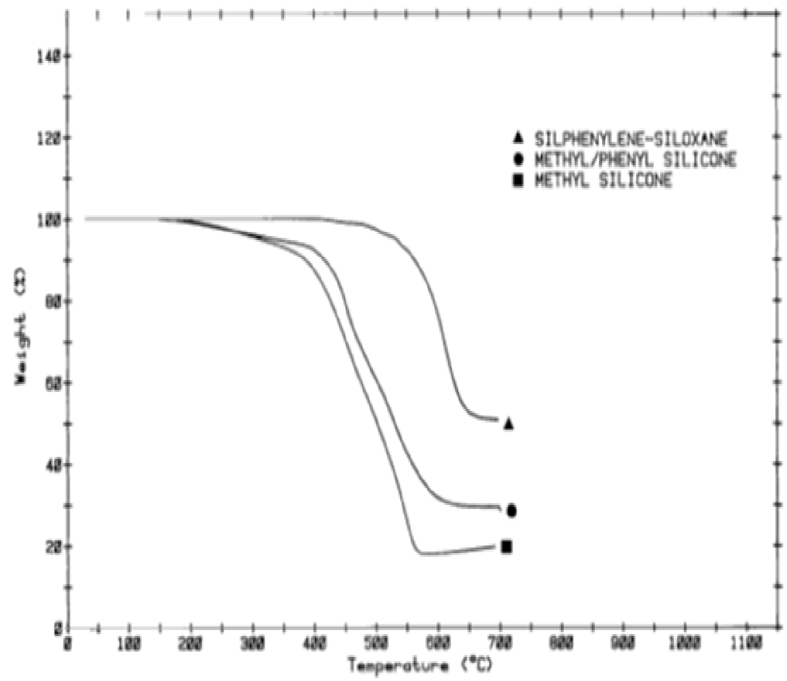
DC 93500 becomes brittle at 460C consistent with the degradation mechanism stipulated but interestingly did not yellow!

STRAGIC SOLUTION –DRIVEN APPROACH



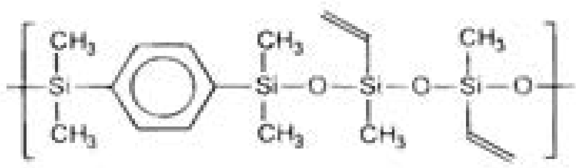
I. Evaluation of possible high temperature transparent polymer systems

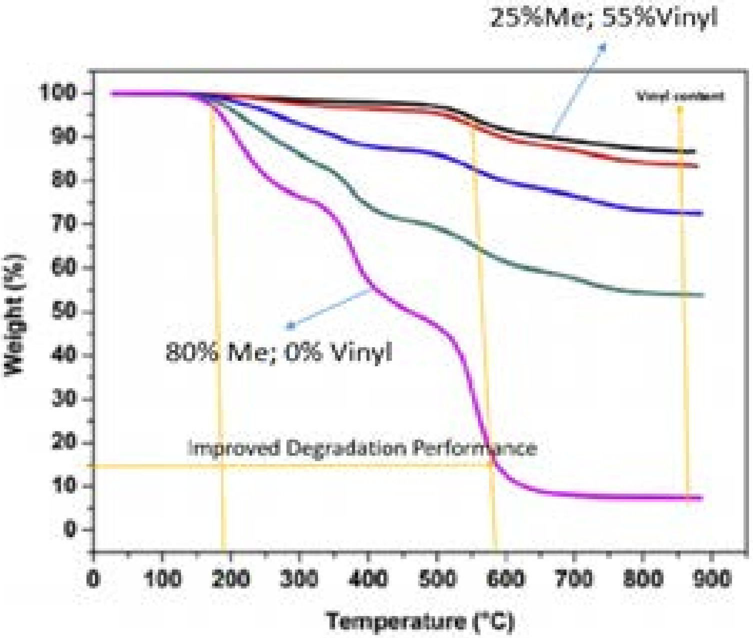




The mass loss of the silicone resins as a function of degradation

UNDERSTANDING Thermal Degradation

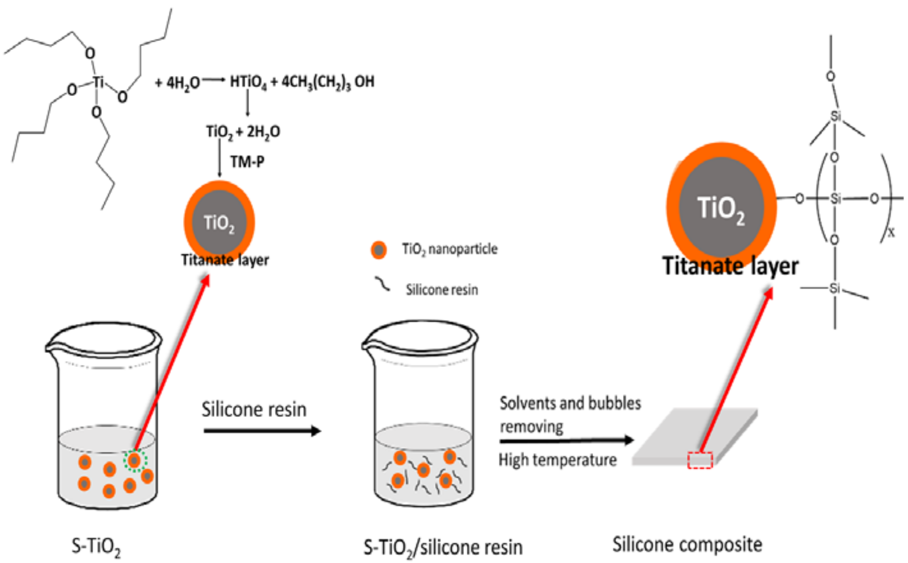


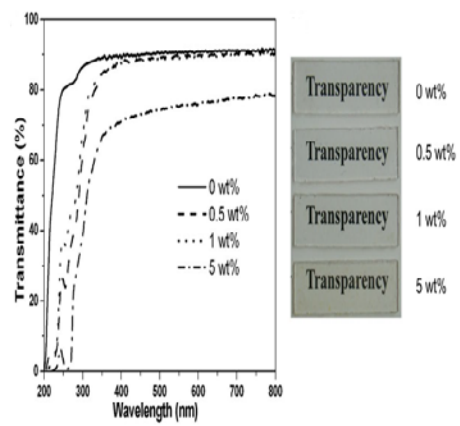


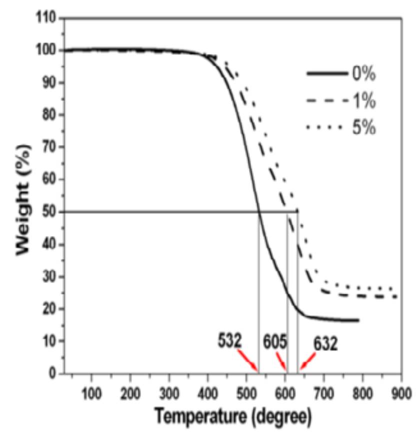
Nano particles surface modifications of adhesives- Enhanced Performance of inherent properties

Transparent Space Grade Silicone Adhesives → Nanoparticles surface modification chemistry → Enhanced Performance- Transparent Space Grade Silicone Adhesives

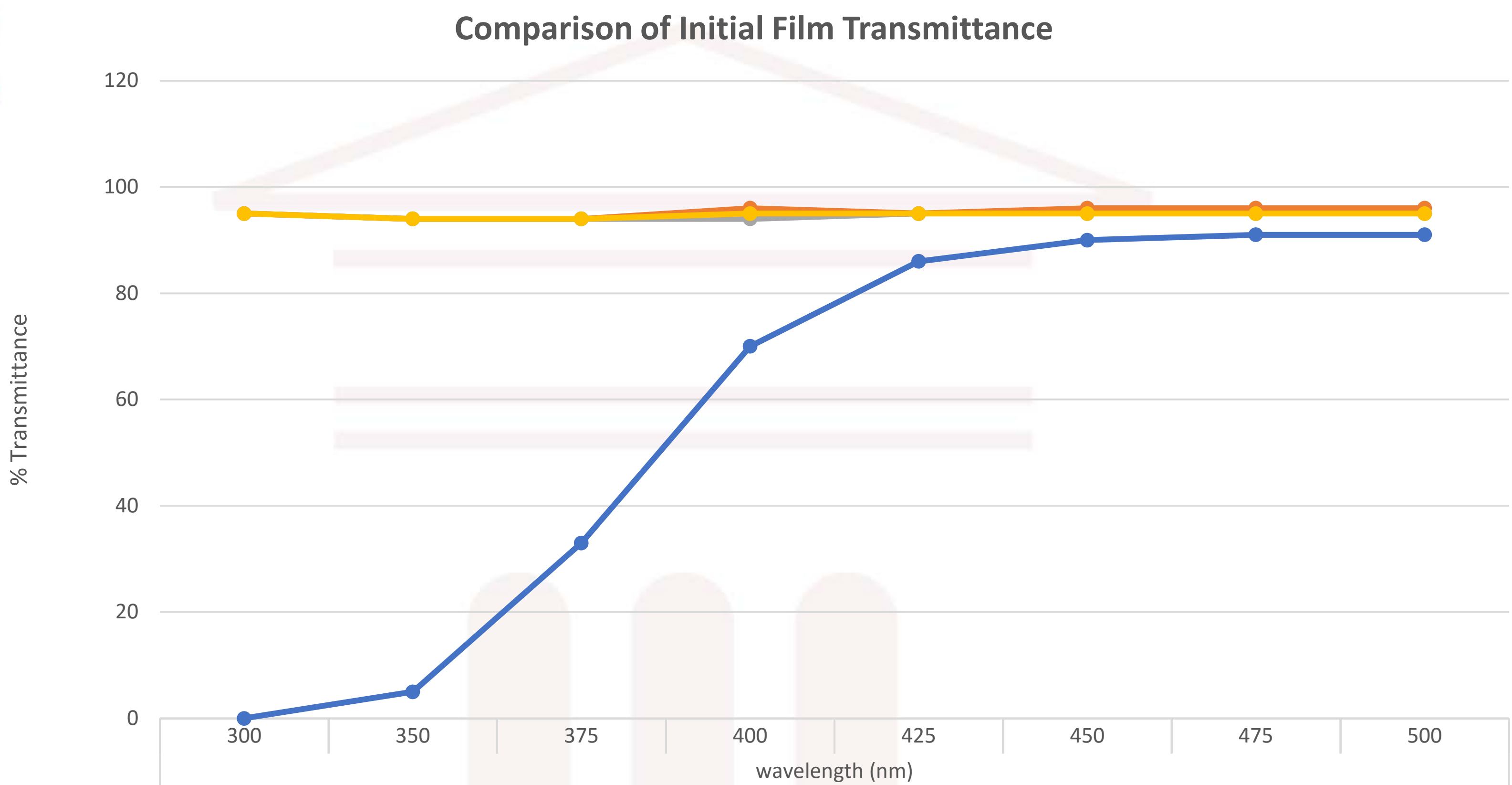
Inorganic/organic hybrid materials can combine the light weight and cost-effective features of the polymeric component, and high refractive index and UV shielding ability of the inorganic nanomaterials maintain high transparency with retention of adhesive elastic properties.





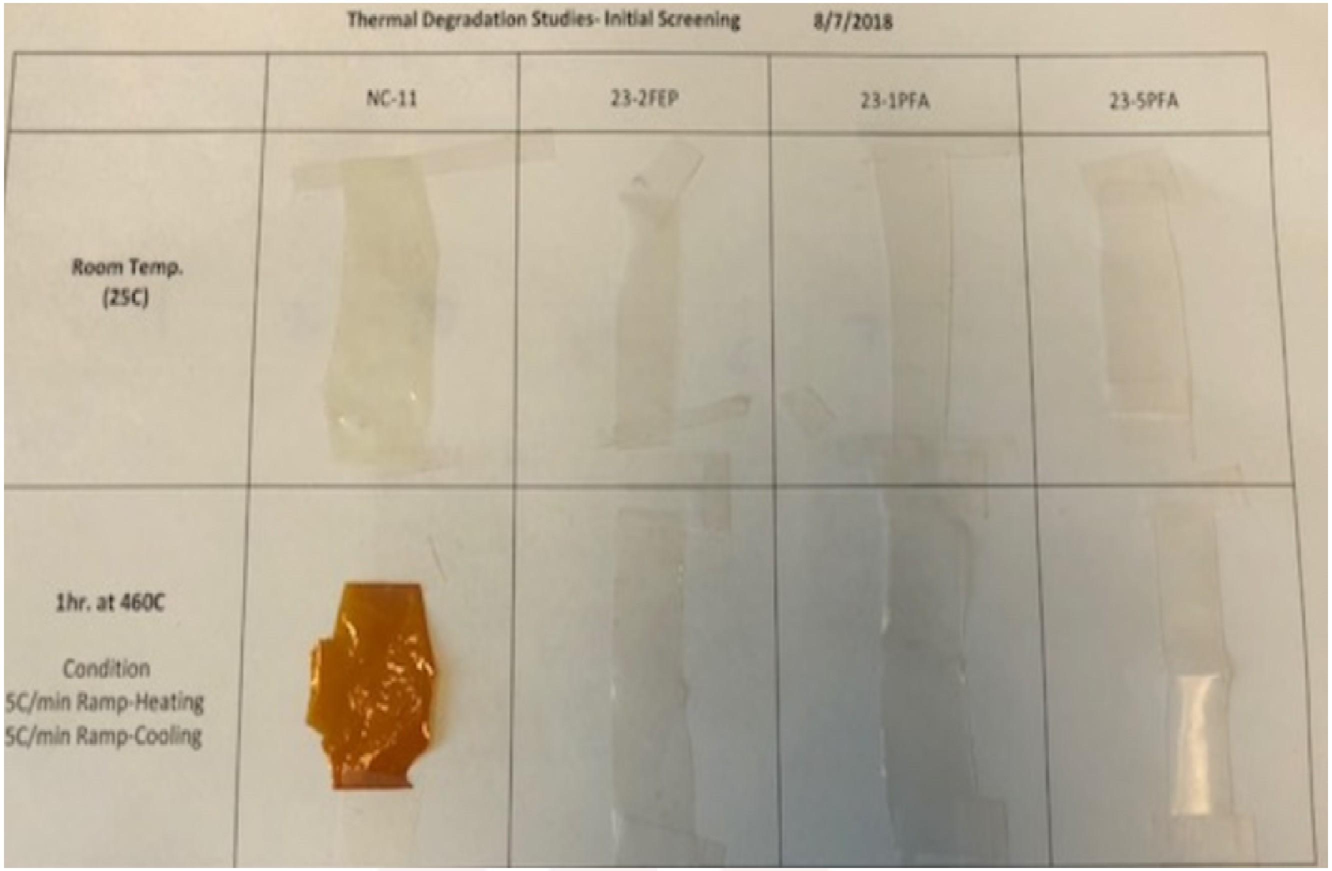


TRANSPARENT FILMS



	300	350	375	400	425	450	475	500
NC-11	0	5	33	70	86	90	91	91
23-2FEP	95	94	94	96	95	96	96	96
23-1PFA	95	94	94	94	95	95	95	95
23-5PFA	95	94	94	95	95	95	95	95

UNDERSTANDING Thermal Degradation



1. All the films except NC-11 did not appear to be affected by 460C/1hr condition

2. Even though NC-11 showed “visible coloration”, the % transmittance in the spectral bands of Venus sunlight was unchanged.

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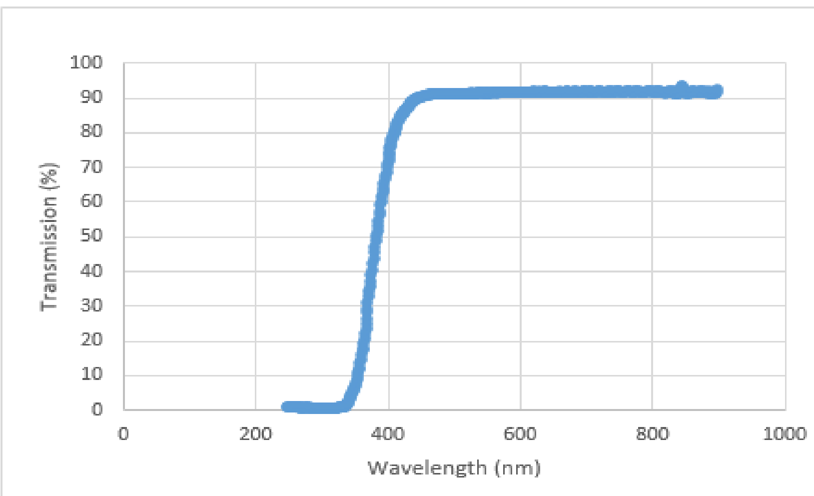
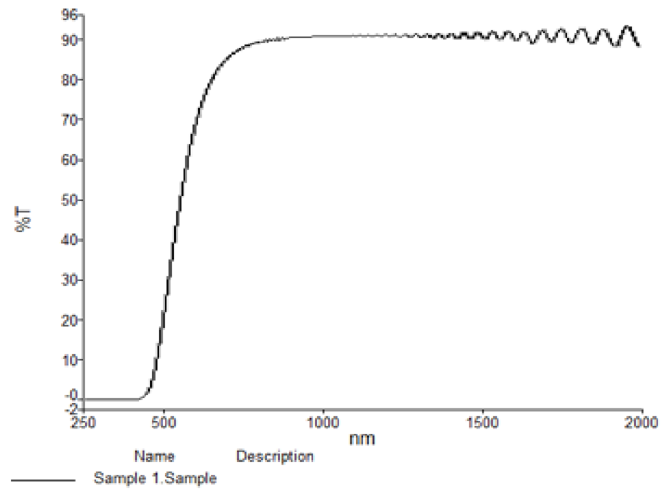
Effect of 460C on NC-11





NC-11 @ room Temperature

NC-11 1hr @460C

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