

Relationship of Cure Temperature to Mechanical, Physical, and Dielectric Performance of PDMS/ Glass Composite for Electric Motor Insulation

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Abstract

Achieving NASA's aggressive fuel burn and emission reduction for N+3 aircraft will require hybrid electric propulsion system in which electric motors driven by either power generated from turbine or energy storage system will power the fan for propulsion. Motors designed for hybrid electric aircraft are expected to operate at medium to high voltages over long durations in a high altitude service environment. Such conditions have driven research toward the development of wire insulation with improved mechanical strength, thermal stability and increased breakdown voltage. The silicone class of materials has been considered for electric wire insulation due to its inherent thermal stability, dielectric strength and mechanical integrity. This paper evaluates the dependence of these properties on the cure conditions of a polydimethyl-siloxane (PDMS) elastomer; where both cure temperature and base-to-catalyst ratio were varied. The PDMS elastomer was evaluated as a bulk material and an impregnation matrix within a lightweight glass veil support. The E-glass support was selected for mechanical stiffness and dielectric strength. This work has shown a correlation between cure conditions and material physical properties. Tensile strength increased with cure temperature whereas breakdown voltage tended to be independent of process variations. The results will be used to direct material formulation based on specific insulation requirements.

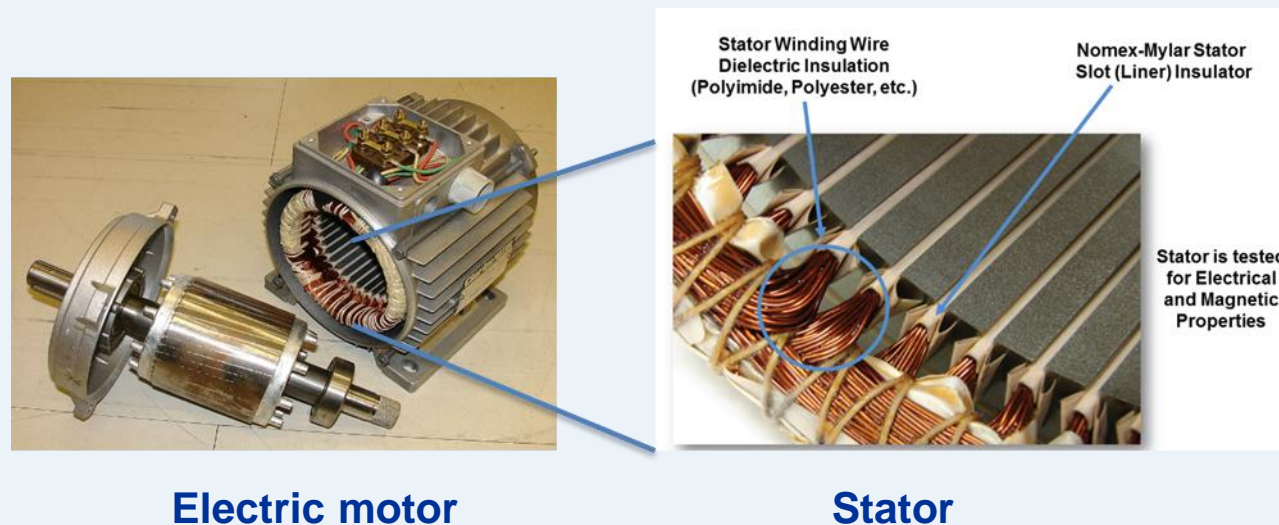
Introduction

Significance:

Dielectric breakdown and heat accumulation are design, size/mass, and life limiting properties for insulations used in electrical machine applications.

Goal:

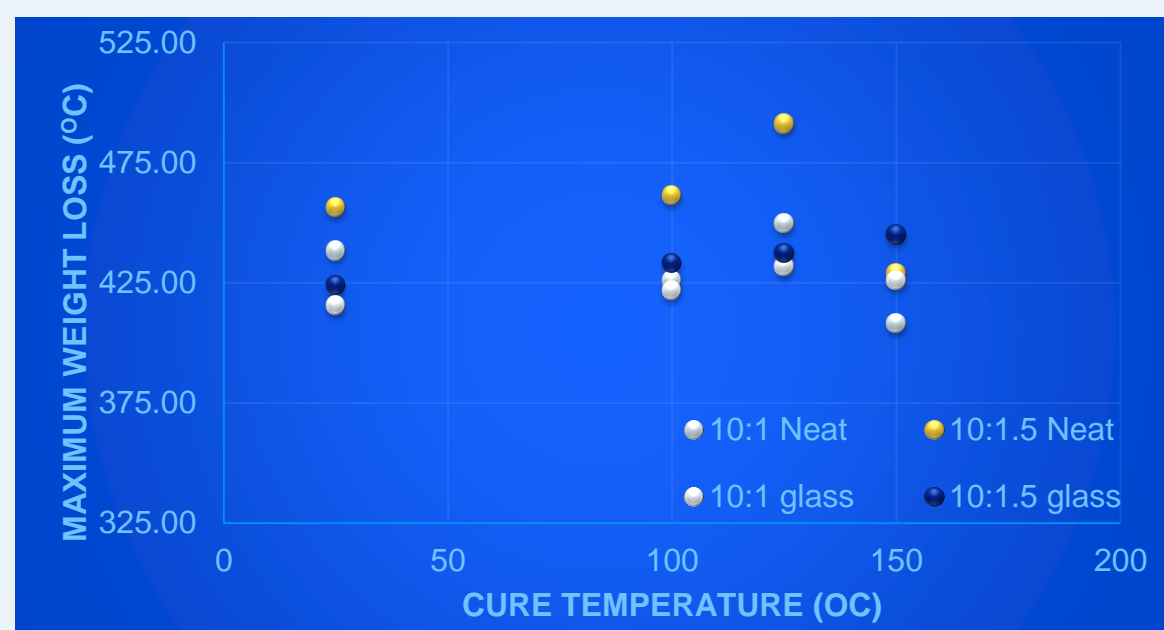
Develop polymer composite for electrical insulation that provides both higher dielectric strength and improved thermal conductivity over the state-of-the-art for the next generation commercial aircraft. Specifically this work evaluated the influence of Sylgard 184 cure conditions and base to catalyst ratio on the thermal stability, mechanical strength, and dielectric breakdown voltage of the elastomer.



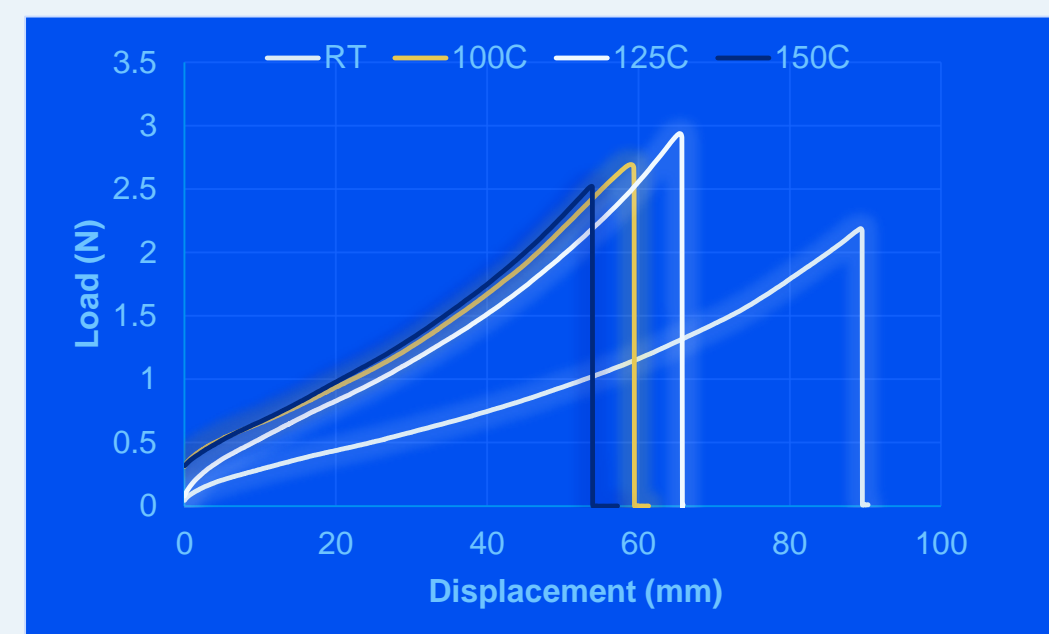
crosslinked between room temperature and 150°C; which bounds the range of recommended cure temperatures. A lightweight, 10 gsm, E-glass veil was used to support the elastomer within the composite architecture.

Stoichiometry	Temperature (°C)	Time
10:1, 10:1.5	RT	48 hours
10:1, 10:1.5	100	35 min
10:1, 10:1.5	125	20 min
10:1, 10:1.5	150	10 min

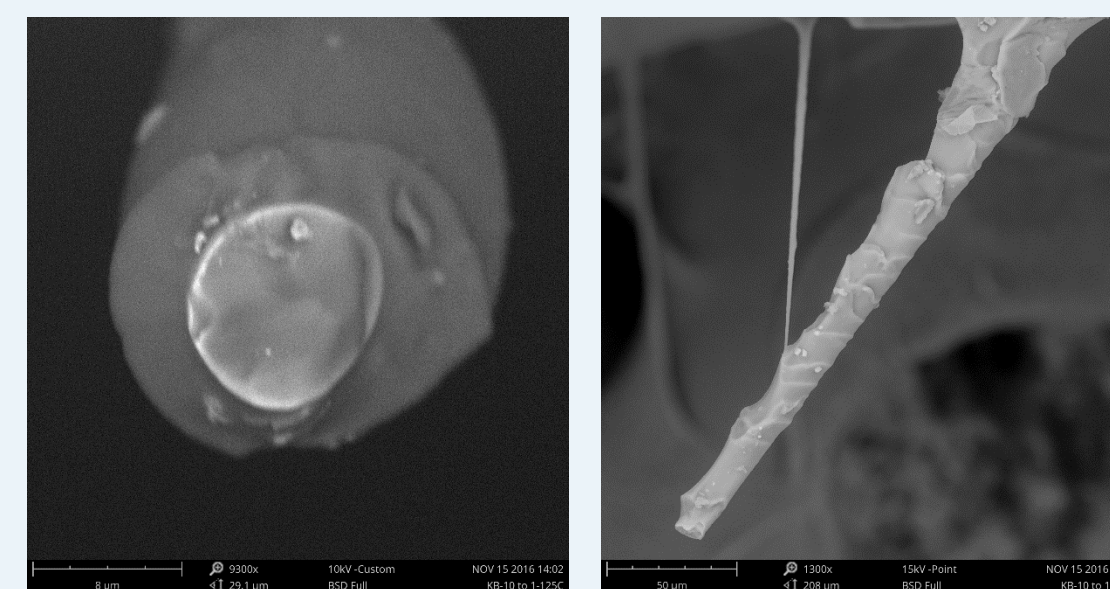
As the relative catalyst concentration increased, we see an average 5-10°C increase in composite thermal stability. The intent in moving to a glass supported composite architecture was two-fold; the veil would impart mechanical strength and stiffness and was predicted to benefit the dielectric breakdown voltage. The thermal stability of the composite was comparable to that of the 10:1 neat resin, irrespective of the lower stability of the glass itself (360°C).



A plot of representative stress strain curves is shown for the 10:1 neat resin. The low modulus and long extension of the room temperature curve is typical of a lightly cross-linked elastomer. As the cure temperature is elevated we see an increase in modulus and reduction of elongation.

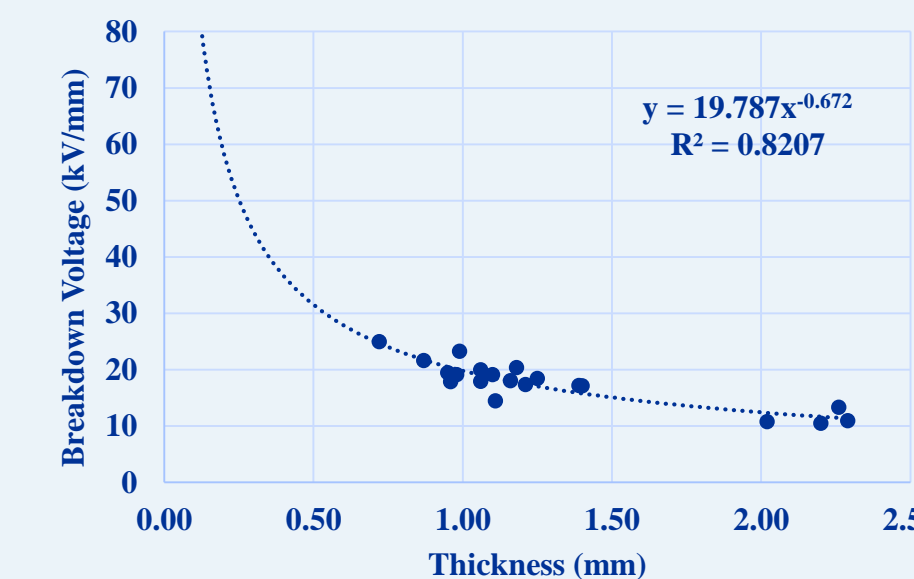
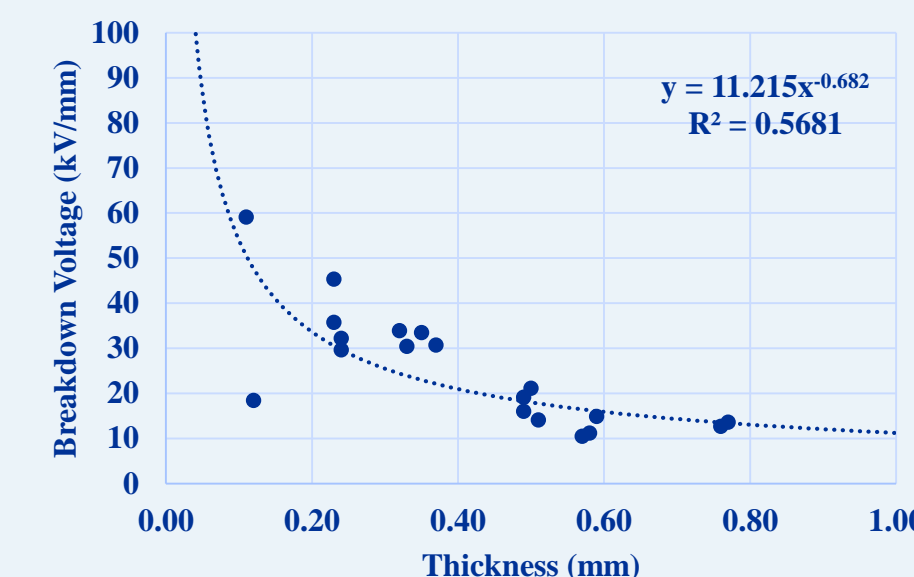


Within the composite materials we see a marked increase in tensile strength and modulus as the cure temperature increases from room temperature to 100°C or greater. The composite coupons cured at room temperature exhibited a strength and modulus predicted by the rule of mixtures. Increasing the cure temperature substantially increased the mechanical properties of the composite. In addition, the increased strength and modulus of the 10:1.5 glass reinforced coupons is attributed to the formation of a strong glass-matrix interface, effectively incorporating the reinforcing phase into the PDMS network.



SEM images of the tensile coupon fracture surface show a strong PDMS to glass interface. The role of coupon thickness in the measurement of PDMS and composite breakdown voltage was investigated through fabrication of coupons at various sample thicknesses. Data was plotted based on breakdown voltage measured over a range of sample thicknesses and curve fitted to allow extrapolation to

values for either thinner or thicker samples. Plots generated from neat resin and composite data are shown below.



Summary

While marginal changes to thermal stability were noted as a function of these processing variables, the greatest benefit to the PDMS performance was incorporation of a glass veil support. The strong interface between two materials generated a 10 fold improvement in tensile strength and modulus. The influence of the glass veil was most notable at the 10:1.5 base/catalyst ratio due to bonding between the materials. An increase in dielectric breakdown voltage was noted in the composite structure, however due to variation in sample thickness, further work is required to elucidate the influence of the glass veil.

Acknowledgments:

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Requirements for conductor insulator materials:

- High thermal resistance and thermal conductivity
- Excellent mechanical and dielectric properties
- Variable hardness and high dimensional stability
- Good chemical resistance and high permeability

Results and Discussion

Polydimethylsiloxane, Sylgard 184, was purchased from Dow Corning. The recommended base to catalyst ratio of 10:1 was used in this study. Additional coupons were prepared with an excess catalyst concentration of 10:1.5. Samples were