Thermal Conductivity Measurements of Silicone-Zirconia Nanocomposite for LED Encapsulation

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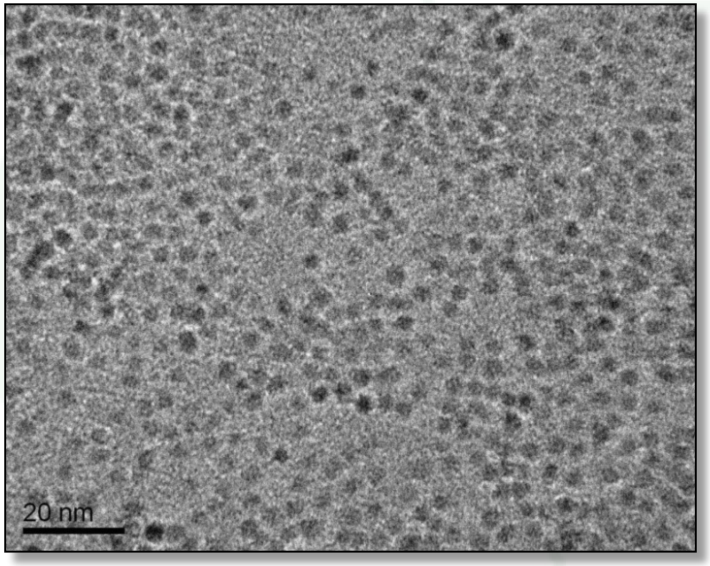
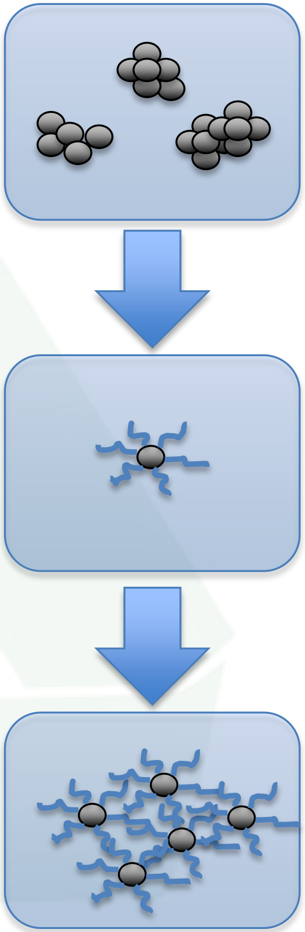
The Problem

- Blue LEDs using phosphor to make white LEDs
  - Phosphor place remotely
  - Dispersed in encapsulant
  - Conformally on semiconductor die
- Phosphor can get hotter than LED
  - Stokes shift losses $\rightarrow$ heat
  - Less efficient energy conversion
  - Lower Quantum Efficiency of Phosphor

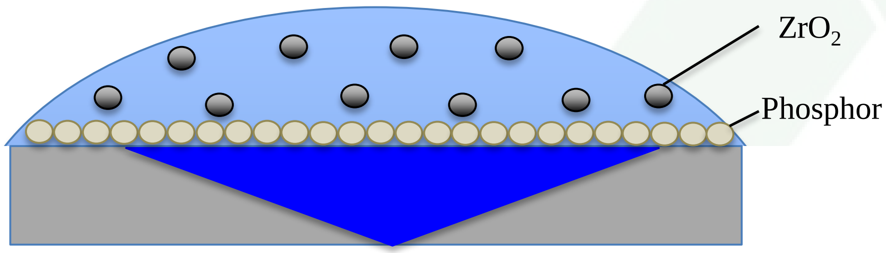
An Issue of Dispersion

- TEM image of ZrO_2 nanoparticles

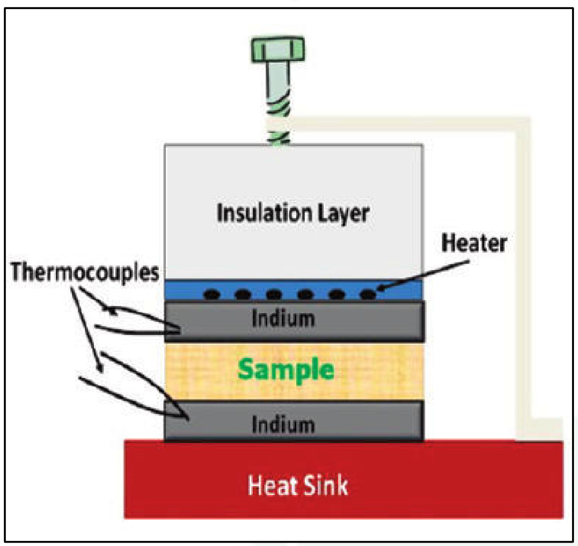




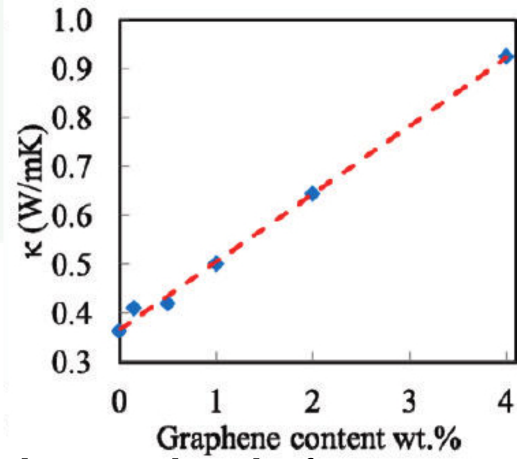
Thermal Conductivity of ZrO_2 in Silicone



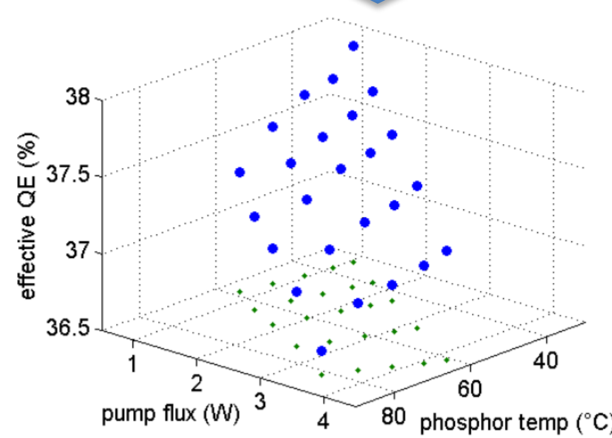
LED with phosphor and ZrO_2 nanocomposite



Thermal Conductivity Testing Method[2]



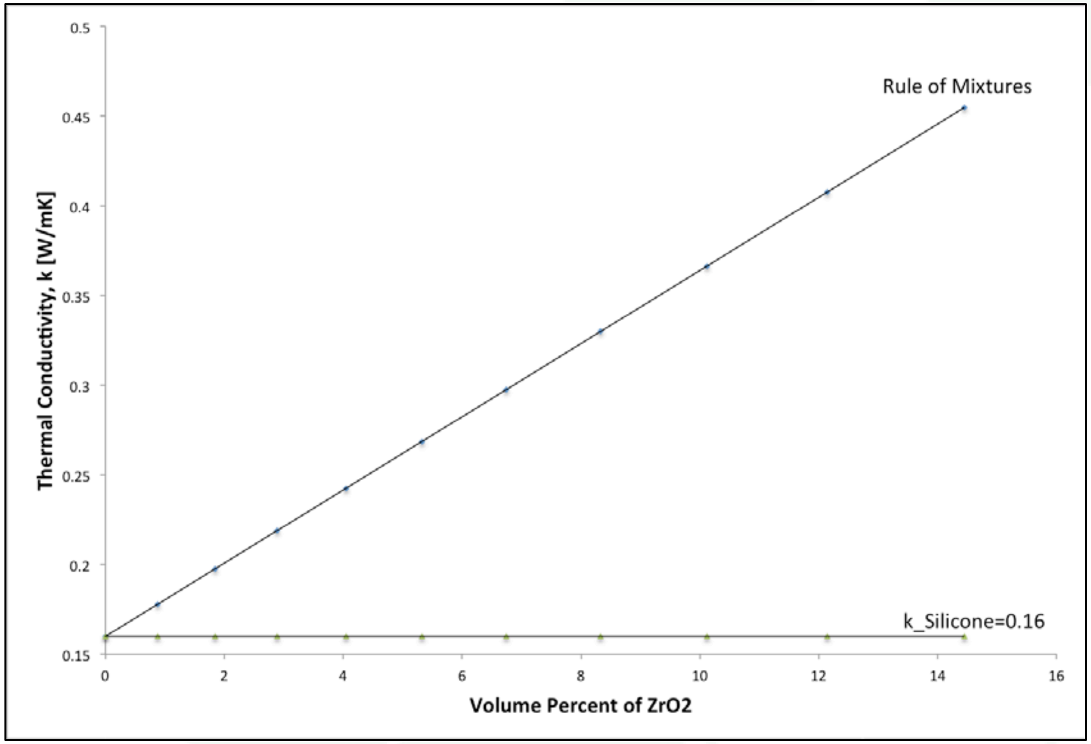
Example output data plot from measurement[1]. For this project ZrO_2 wt% would be plotted instead of graphene



Phosphor Quantum Efficiency variance with temperature[3]

1. Yavari, F., Fard, H. R., Pashayi, K., Ra, M. A., Zamiri, A., Yu, Z., … Koratkar, N. (2011). Enhanced Thermal Conductivity in a Nanostructured Phase Change Composite due to Low Concentration Graphene Additives,
8753–8758.
2. Keppens, A., Zong, Y., Ohno, Y., Deconinck, G., Hanselaer, P. (2010). DETERMINING PHOSPHORS ' EFFECTIVE QUANTUM EFFICIENCY FOR REMOTE PHOSPHOR TYPE LED MODULES, 1–4.

Modeled Thermal Conductivity



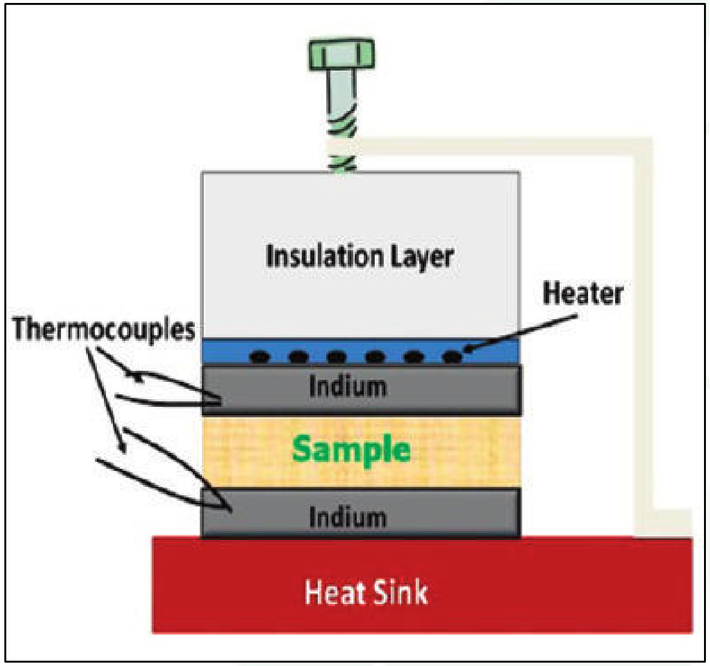
RULE OF MIXTURES

$$\kappa_c = f_m \kappa_m + f_p \kappa_p$$

Model predicts a 120% increase in thermal conductivity at 10 volume% (40 wt%)

κ_c – 0.16 → 0.366 W/mK

Measurement Methods



Thermal Conductivity Testing Method[2]

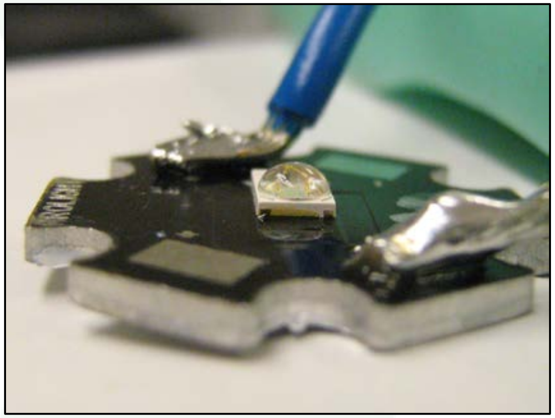
$$R=\Delta T/q=t/\kappa A$$

R - Combined thermal resistance
ΔT - Temperature difference across sample
q - Power
t - Thickness of sample
κ - Thermal conductivity of sample
A - Area of contact between thermocouple and sample (sample cross sectional area)

Next Steps

- Make and test 40 wt% ZrO_2 samples
  - Show how TC changes between base and loaded
    - If not, why?

- Test on LEDs
  - (with phosphor added)
  - Integrating sphere for intensity



- Aging testing
  - Run LEDs and check for degradation

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