Background

Luminescence means giving off light; most things in our world produce light because they have energy that originally came from the Sun, which is the biggest, most luminous thing we can see. It is a mechanism by which (light) photons are created without the use of heat [4,3,5].

Triboluminescence is a mechanism by which (light) photons are created as a result of friction or instant force (pressure) experienced by the material. The property that some materials become luminous upon being scratched, crushed, or rubbed. Examples of substances exhibiting triboluminescence include the minerals fluorite (CaF₂), sphalerite (ZnS), and wintergreen LifeSavers! [4,5,6].

Current Challenges: Almost all luminescencing materials are currently available in a powder form with particles sizes in the nm-um range. Such small particle sizes create challenges for design of advanced sensors due to the hazardous nature of nanoparticles.

Goal of the Study: To create thin-film flexible sensors that are triboluminescencing and the powder is fully encapsulated and can produce sufficient output (light emitted) that can be detected above noise level.

Sample Preparation

Polymer used for encapsulation: Sylgard 184 (part A and B), also referred to as PDMS. ZnS:Mn was the triboluminescence powder. Mixed polymer and ZnS:Mn at different ratios. We stirred it to make a homogeneous mixture. Outgassed the mixture in a vacuum oven. We would also like to perform spectral studies before and after the drop tower test to see if we can get a detectable output signal from um thick films. We proved that it is possible to get detectable output signal from um thick films.

Sample Characterization

Tensile testing: The tensile behavior of the doped polymers was tested using an ESM301 Motorized test stand.

UV-Vis Spectroscopy: The EVOLUTION 220 UV-Visible Spectrophotometer was used to measure absorbance / transmission in the UV and visible light range for each sample type.

Beer-Lambert Law is the linear relationship between absorbance and concentration of an absorbing species [7,8].

A=εb*c

A=measured absorbance
ε=molar absorptivity coefficient
b=pathlength
C=concentration

Drop tower tests: Intensity of emitted signal (light seen) as a function of impact force was measured using a home built drop tower and Agilent 650 Digit Multimeter connected to the sample chamber.

Expansion rate of Sylgard 184 and ZnS:Mn as a function of temperature: The thermal response of the sensor was measured by means of a MX 1000 Temperature Controller positioned on the stage of a Unitron Examet-4 Reflective Microscope.

Optical Micrographs of Thin Film Sensors: Optical microscope images of ZnS:Mn particles cued in a polymer mix under different spin conditions. Image magnification: X 5. Particle clusters formed when mixed with the polymer.

UV-Vis Spectra of Thin Film Sensors:

The signature peaks associated with each material (polymer, luminescing nanoparticles) were measured separately and then compared with the combined material behavior. The amount of absorbance depended on the RPM which effects the path length (thickness) of sample as well as the concentration. The graphs follow the Beer Lambert law.

Effect of Spin Speed on Thickness:

Drop Tower Tests:

The intensity of the emitted light due to the impact force depended on the particles concentration. The force of impact was kept constant for all samples. Some samples were bright enough to be seen by naked eye.

Table 3: Emission intensity values

Table 2: Sensor thicknesses measured as a function of RPM.

Table 2: List of samples made for this study.

Summary, Conclusion, & Future Work

- A series of thin film impact sensors were created such that the sensing powder was fully encapsulated inside a polymer, allowing for safe handling.
- We proved that it is possible to get detectable output signal from um thick films.
- The composite material (thin film sensor) was still elastomeric at a doping concentration of 30%.
- Temperature dependence expansion measurements proved to be technically challenging and not completed during this portion of the study.
- We would also like to perform spectral studies before and after the drop tower test to see if we can identify damage to the sensors (deposits) as a result of the drop tests. We did not have time to complete that exp. this year.
- In the future we will repeat this study with aerogels instead of PDMS. Other factors we could consider changing would be thermoluminescent powder, different concentrations of powders, and different RPMs. We will also do consistent damage on the polymers and see using the spectrometer how damage affects the absorbance of the polymers. Lumininescence is a very good sensor to be used in various situations.

References

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Thermal, Mechanical, and Optical Characterization of Luminescence - Doped PDMS Thin Film Sensors

Table 1: List of samples made for this study.

The thermal response of the sensor was measured by means of a MX 1000 Temperature Controller positioned on the stage of a Unitron Examet-4 Reflective Microscope.

Table 4: Emission intensity values

Table 4: Expansion rate as a function of temperature for pure PDMS polymer

Image magnification: X 5.