Investigation of silicon nanoparticle-polystyrene hybrids

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Abstract

Current LED lights are created with quantum dots made of metals like selenium, tellurium, and cadmium which can be toxic. Silicon is used as a non-toxic substance and is the second most abundant element in the earth's crust. When silicon is prepared at a nanometer size, unique luminesce optical properties emerge that can be tuned using sized surface chemistry. Therefore, silicon nanoparticles can be used as an alternative emitter for LED lights. To produce hydride-terminated silicon nanoparticles we must synthesize the particles. Hydrogen silsesquioxane (HSQ) is processed at 1100 °C for one hour causing Si to cluster and form a SiO2 matrix, also known as the composite. The composite is then manually crushed in ethanol. The solution is further ground using glass beads, then filtered to get the composite powder. The final step is the HF etching. The hydride-terminated particles are then functionalized using three different methods to synthesize silicon nanoparticle-polystyrene hybrids, which determine the magnitude of luminosity and the quality of the hybrids. We spin coat each method and results were analyzed. Method 1 uses heat to functionalize hydride-terminated silicon nanoparticles with styrene. This process also causes styrene to attach to styrene to form a polystyrene chain. Method 1 gave a homogeneous mixture which yielded a consistent, bright and homogenous film. In method 2, dodecyl-terminated silicon nanoparticles are mixed with premade polystyrene. While this method gave better control of the amount of silicon nanoparticles inside the polymer hybrid, a homogeneous mixture was not created due to the different structures of polystyrene and dodecyl chains. Method 3 has dodecyl-terminated silicon with in-situ styrene polymerization. It generated a homogeneous mixture. The in-situ polymerization stabilizes the particles, allowing for brighter luminescence. Because of the stability and lower molecular weight, the mixture was easier to dissolve. We concluded that the different methods resulted in different polymer molecular weights and this created distinct properties between the polymer hybrids when spin-coating.

Key words:
Silicon Nanoparticles, Silicon Nanoparticle-Polystyrene Hybrid Silicon hybrid, nanoparticle, chemistry, luminescence, Hydride-Terminated, Silicon Nanoparticles,silicon nanoparticle hybrid

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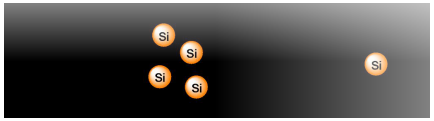
Introduction

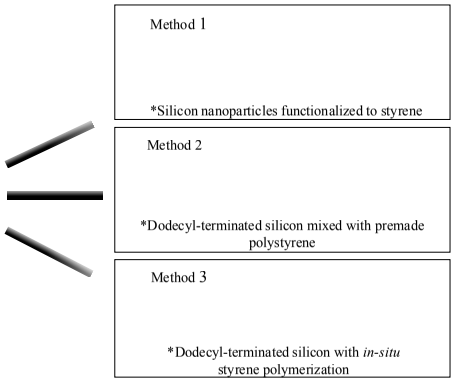
- The problem with current method of creating quantum dot (nanometer sized semiconducting particles) LED lights is that the quantum dots currently used are toxic
- Silicon nanoparticles are better because they are biocompatible and less toxic than other quantum dots
- Silicon nanoparticles offer tunable luminesce and unique chemical properties
- Silicon is also the second most abundant element in the earth's crust
- The object is to use silicon nanoparticle-polymer hybrid to make LED lights and getting the lights onto flexible material

Methods

How to Make Hydride-Terminated Silicon Nanoparticles



Synthesis of Silicon Nanoparticle-Polystyrene Hybrid



Results

Figure 1: Silicon nanoparticle-polystyrene hybrids under visible and UV light

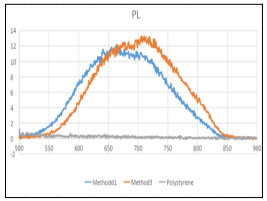


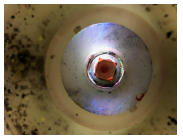
Figure 2: Photoluminescence spectra comparing the silicon nanoparticle-polystyrene hybrids from each of the methods

Figure 3: FTIR spectrum showing functionalization of dodecyl-terminated silicon nanoparticles

Spin Coating

0.05g/ml composite in toluene, 30 µL, 30 seconds

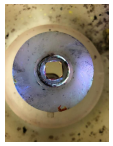
Method 1



1000 rpm

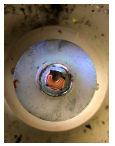
Solution yielded a consistent, bright, and homogeneous film. Method 1 was an ideal sample. High molecular weight therefore the polymer evenly spread over the film

Method 3



1000 rpm

Homogeneous film but not very bright. Assumption is that there is low molecular weight therefore the polymer resulted in a thinner film



500 rpm

The film was not homogeneous. Speed is too slow for solvent to completely evaporate therefore polymer didn't evenly spread

Conclusion

- Method 1 gave a homogeneous mixture that resulted in the best films after spin coating
- Method 2 gave better control of the amount silicon nanoparticles inside the polymer hybrid
  - Did not create a homogeneous mixture most likely due to the different structures of dodecyl-terminated silicon nanoparticles and polystyrene
- Method 3 was a homogeneous mixture
  -The *in-situ* polymerization stabilizes the PCl_5-functionalized particles
  - We use PCl_5 to functionalize the particles because we want to have brighter particles
  - Lowered the temperature for the polymerization step to lower the molecular weight of the polymer for easier operation (i.e. easier to dissolve)
- Different methods resulted in different polymer molecular weight. This created distinct properties between the polymer hybrids when spin-coating

Future Work

- Tune the polymer concentration when spin-coating
- Adjust amount of particles placed in the polymer
- Additional characterization of polymer hybrids

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