International Materials Institute for New Functionality in Glass
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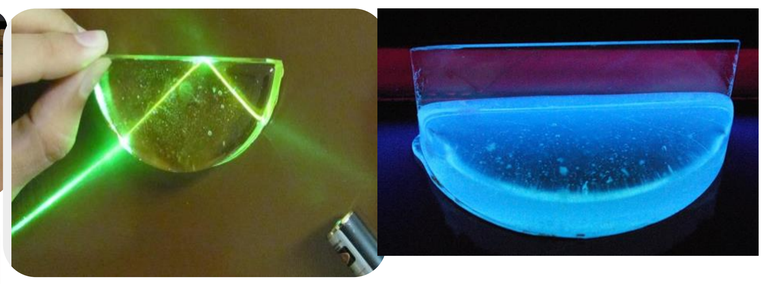
Teaching Nano-particle Fluorescence in Glass with Candy

William R. Heffner[1] and Donald Wright III[2]
[1] IMI-NFG, Lehigh University, Bethlehem, PA , [2] Oakwood University. Huntsville, AL

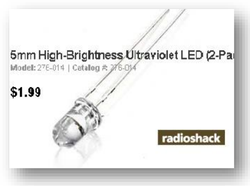
Abstract: For almost a decade the IMI-NFG has been developing low-cost experiments to explore glass and material science through sugar glasses, aka. hard candy, circumventing the high temperature processing required for oxide glasses. We present here an example of nano-particle optics in glass, namely fluorescence, surprisingly observed in these sugar glasses. We characterized the emission using a homebuilt system consisting of high intensity LEDs for the excitation and the student grade Ocean Optics Red Tide Spectrometer to resolve the emission. Both fluorescence and absorption increase with further caramelization from heating. Recent literature[1] has shown similar fluorescence in caramelized sugars to be due to the production of carbon nanoparticles and we propose the experiment as a cross-disciplinary and open-ended one for an undergraduate lab in physics, chemistry or material science.

Sugar Glass Preparation and the Excited Emission



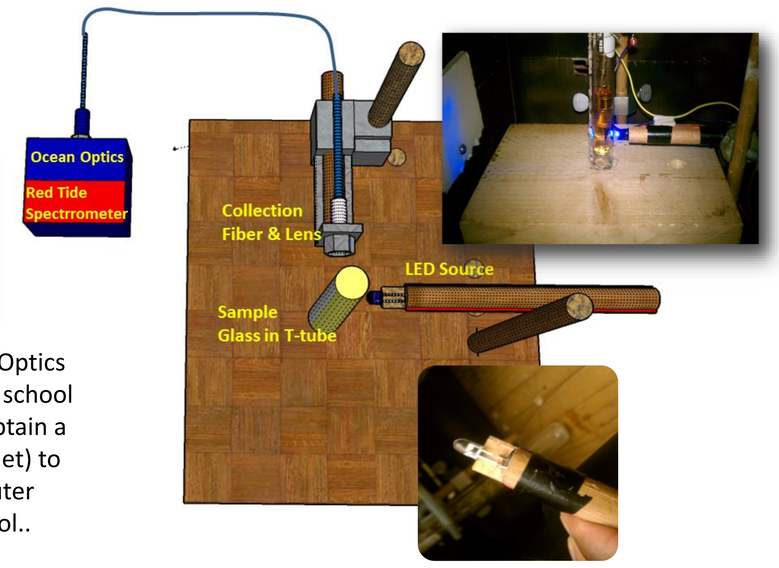
Cane sugar, corn syrup and water are heated to first dissolve all crystals and then remove most of the water. Boiling to ~ 150 °C leaves about 1-2% water and will make a glassy candy on cooling. A half disc was molded for a Snell's law demo; the yellowish scatter from green laser suggested something more interesting. Under UV (375 nm) light, the same candy glass sample emits blue.

Low Cost Approach for Investigation

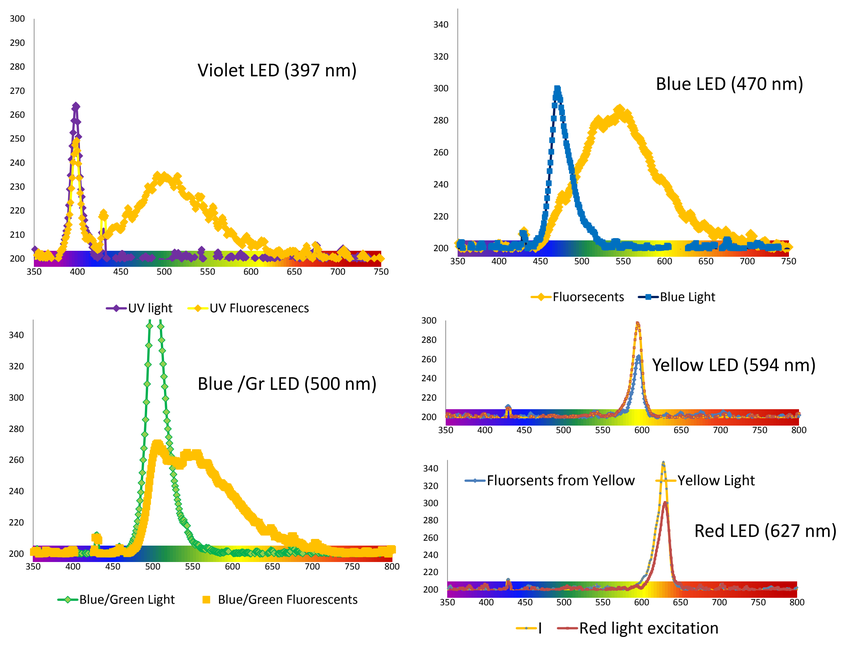


Low-cost fluorescence monitoring system using the Ocean Optics Red Tide USB Spectrometer (~$1150) available in many high school and undergraduate labs. High brightness LEDs are used to obtain a range of excitation wavelength sources. LEDs from UV (violet) to RED were used. A nichrome wire was wrapped around an outer glass tube to provide a simple heater for temperature control..

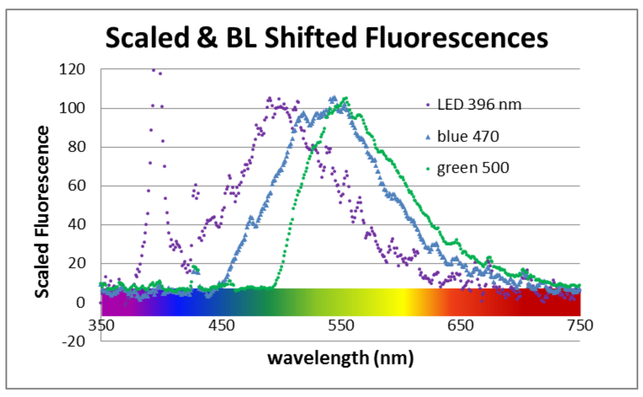
The Fluorescence Monitoring System



RT Emission from Various LED Sources

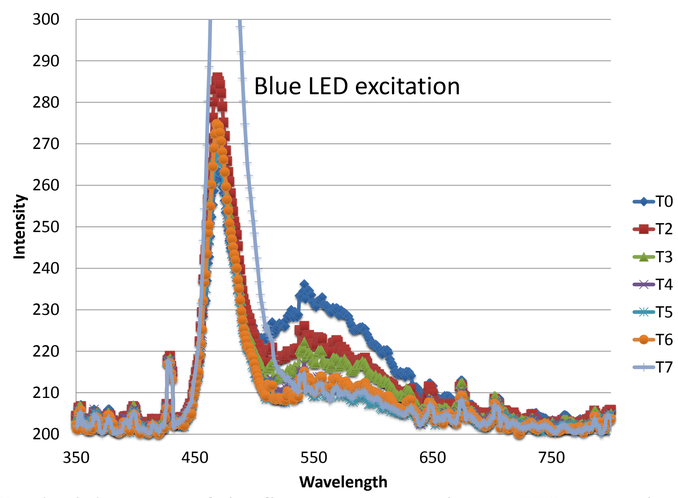


Left - The luminescence is very dependent on source wavelength, with essentially no emission for yellow or red LEDs. Violet led provides the best separation between source and fluorescence. Radiation.



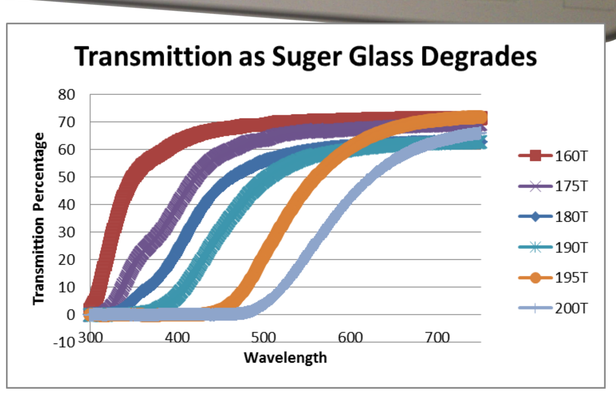
Scaled luminescence shows a distinct dependence on the excitation wavelength characteristic of NP fluorescence.

Fluorescence Decrease with Temperature



Gradual decrease of the fluorescence peak near 550 nm as the temperature increases from RT (T0) to T7 (near boiling). After heating the room temperature fluorescence has increased appreciably, associated with a deeper yellow color in the sample from caramelization

Increased Absorption with Caramelization



Transmission for sugar glass heated to increasingly higher temperatures from 160 to 200 ºC. The highly caramelized samples are quite absorbing in the blue, resulting in a reabsorption of any fluorescence.

Connection to Carbon Quantum Dots In Caramelized Bread and Sugars

Table 1 | Quantum yield of CNPs extracted from different food items

CNPs extracted from	Size (nm)	QY (%)
Bread	27.5 ± 6.1	1.2
Jaggery	20.3 ± 7.5	0.55
Sugar caramel	4.3 ± 1.5	0.63

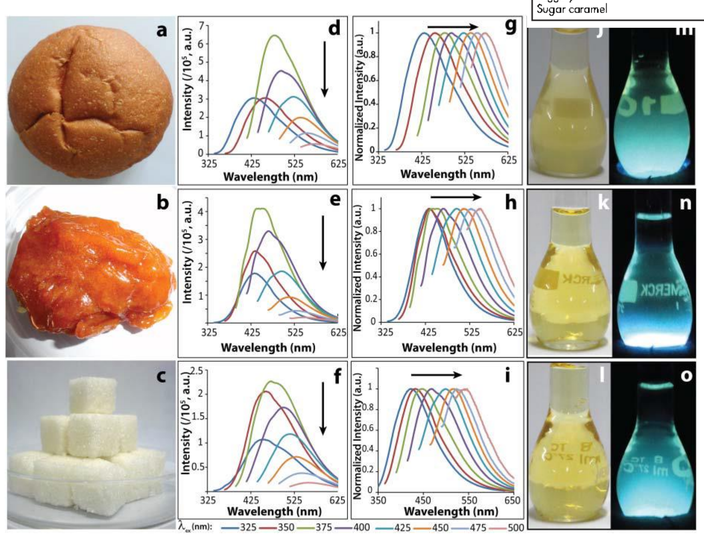


Figure 2 | (a), (b), (c) Photographs of commercial bread, *jaggery* and sugar. (d)–(i) excitation wavelength dependent emission spectra of CNPs from bread, *jaggery* and sugar caramel. (j)–(l) photographs of dispersions of CNPs from bread, *jaggery* and sugar caramel observed under white light and (m)–(o) the same under UV light.

Sk, et. al. 2012 [1] show TEM analysis of carbon nano dots in caramelized foods and provide more thorough yet similar measurements of the excitation dependent fluorescence.

Summary

We provide a simple and highly accessible system to engage students in nano-particle optics within glassy materials.

- The fluorescence arises from the formation of carbon nano-spheres in caramelized sugar glass and can be examined qualitatively with simple LED multi wavelength sources or quantitatively with the addition of a low-cost student spectrometer..
- This study provides a good example of how exploring even common materials like candy, with some basic tools such as a simple student spectrometer, can bring the curious student to discovery of real, contemporary science.
- Photoluminescence from carbon nano-particles was first reported in 2006 by Sun[2], and the system is drawing increased interest as an environmentally friendly fluorescent biomaterial[3].
- The activity could be appropriate the undergraduate lab and especially as an open-ended introductory research project.
- To our knowledge, topics such as temperature dependence of photo emission in candy has not been reported previously.

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References:
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2. Sun, Ya-Ping, et. al., "Quantim-Sized Carbon Dots for Bright and Colorful Photoluminescence", J. Am. Chem. Soc., 128 (2006), 7756-7.
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