Characterization of the Photothermal Effect of Various Nanomaterials

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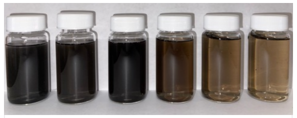
Abstract

Photothermal Therapy (PTT) provides a promising new method of radiative therapy cancer, using infrared wavelengths. In my project, the ability of these materials to heat up when shone with near infrared light, or the photothermal effect, of various nanomaterials—including reduced graphene oxide, reduced graphene quantum dots, and copper sulfide nanoparticles—is characterized by irradiation of the aqueous materials with near-infrared radiation.

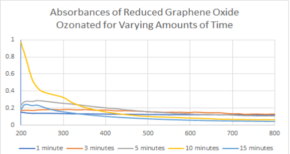
Reduced Graphene Oxide Nanoparticles

Reduced Graphene Oxide Nanoparticles (rGOs) absorb in the near-infrared (NIR) region, however, they are not water-soluble. Graphene Oxide Nanoparticles (GOs) have a reduced absorption at NIR wavelengths, but they are water soluble. To take advantage of rGO's absorbance in NIR and the water solubility of GO, samples of rGO were treated with ozone (O3) for varying amounts of time to give samples of rGO with varying amounts of oxidation. The sample chosen for characterization of the photothermal effect was the sample that was most water-soluble, while still retaining absorbance in NIR. This was experimentally found to be rGO treated with ozone for 10 minutes. These properties, along with the low cytotoxicity and good biocompatibility of rGO/GO make these slightly-oxidized rGO nanoparticles a good candidate for Photothermal therapy (PTT).

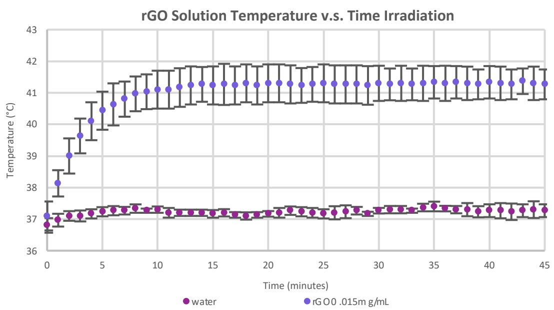
Slightly Oxidized rGO Preparation



Left to right: rGO treated with ozone for 1, 3, 5, 10, 15, and 25 minutes



Photothermal Characterization Results for rGO



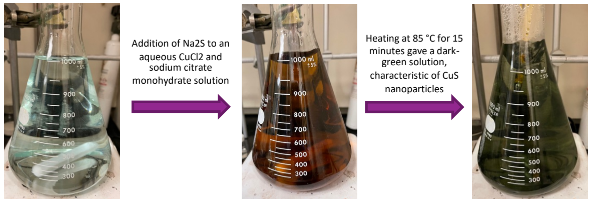
Sample	Water	rGO 0.015 mg/mL
ΔT (°C)	0.5	4.2

Copper (II) Sulfide Nanoparticles

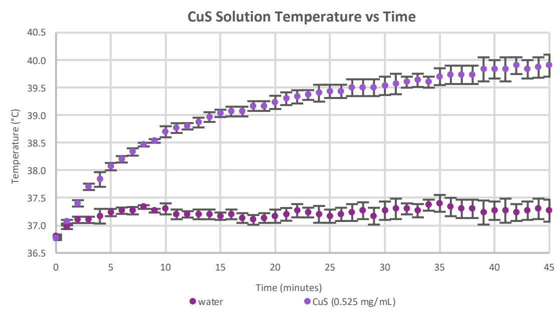
Citrate-coated copper sulfide (CuS) nanoparticles were synthesized for characterization of their photothermal properties. CuS nanoparticles have relatively low cytotoxicity, a good biocompatibility, are water soluble, and have been shown to have absorbance in the near infrared. These properties make them possible candidates for a photothermal therapy agent. These particles were used in photothermal experiments to characterize their photothermal effect.

CuS Nanoparticle Preparation

Synthesis Reaction: $CuCl_2 + Na_2S \rightarrow CuS + 2Na^+ + 2Cl^-$



Photothermal Characterization Results for CuS

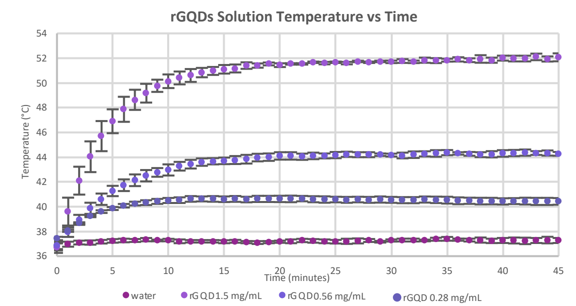


Sample	Water	CuS (0.525 mg/mL)
ΔT (°C)	0.5	4.2

Reduced Graphene Quantum Dots

Reduced graphene quantum dots (rGQDs) are very small (1-10 nm) conjugated carbon structures. They are named quantum dots because they exhibit the quantum confinement effect: the electrons are trapped in such a small space, limited by the size of the structure, which leads to a transition from continuous to discrete energy levels where the electrons exist. This broadens the spacing between energy levels, giving rGQDs special fluorescent and absorptive properties. These absorptive properties in conjunction with their low cytotoxicity and water solubility make rGQDs a good candidate for a phototherapy agent.

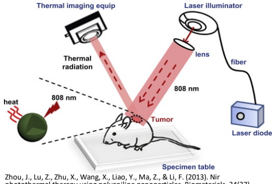
Photothermal Characterization of rGQDs



Sample	Water	rGQD (1.5 mg/mL)	rGQD (0.56 mg/mL	rGQD (0.28 mg/mL
ΔT (°C)	0.5	15.4	7.4	3.0

Ultimate Goal of Photothermal Therapy

The goal of my research is to characterize the photothermal effect of near-infrared absorbing materials that are candidates for photothermal therapy agents. In the image on the right, is an example of photothermal therapy. The mouse has a tumor that has been injected with a PTT agent and irradiated with near infrared light. The PTT agent absorbs the light and heats up to a biologically detrimental temperature (around 40 °C), selectively killing the cancerous tissue.



Zhou, J., Lu, Z., Zhu, X., Wang, X., Liao, Y., Ma, Z., & Li, F. (2013). Nir photothermal therapy using polyaniline nanoparticles. Biomaterials, 34(37), 9584–9592. https://doi.org/10.1016/j.biomaterials.2013.08.075

Conclusions

All three of these nanoparticles showed potential as photothermal therapy agents. The concentrations used for each of these experiments were those where 80% of cells remained viable during bioluminescence assays. The rGO heated from 37 °C to above 41 °C during the laser experiments, The CuS heated to over 39.5 °C, and the reduced graphene quantum dots heated up the most. At the highest concentration tested—which was consistent with >80% cell viability—the aqueous solution of rGQDs heated to a final temperature of 52 °C after 808 nm (a near-infrared wavelength) laser irradiation for 45 minutes. We found that the rGQDs exhibited the greatest photothermal effect. We plan to do further characterization, specifically irradiation of these agents in live cell cultures, of these nanoparticles to determine their potential as photothermal agents.

References and Acknowledgements

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