TSF21-2021-000070
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Abstract for an Invited Paper
for the TSF21 Meeting of
the American Physical Society

Biomedical Imaging with Biocompatible Graphene Quantum Dots[1]

ANTON NAUMOV, Texas Christian University

Due to a variety of their remarkable properties, nanomaterials serve a plethora of applications in biomedicine including molecular sensing, drug and gene delivery as well as photothermal and photodynamic therapy. Most of these applications can benefit from additional modality of biomedical imaging that is often performed by a dye attached to the nanomaterial. Nanomaterial imaging agents are more rare due to the need of high quantum yields and low toxicity at high concentrations which are complex to achieve for nanostructures. In this work we utilize simple scalable one-step hydrothermal synthesis to develop graphene quantum dots (GQDs) with high biocompatibility (up to 2 mg/mL) and substantial (over 60%) fluorescence quantum yield in the visible. These GQDs show efficient cellular internalization maximized at 12 h as well as remarkable biodegradability in cell medium. Furthermore, their backbone can be doped with a variety of heteroatoms during the synthetic process with minimum effect to their biocompatibility. Such doping can serve to develop a number of beneficial biomedical imaging applications. For instance, Gd or Mn doping can generate magnetic resonance imaging capabilities allowing to perform joint fluorescence and MR imaging for in vitro and in vivo detection respectively. Nitrogen doping renders GQD fluorescence linearly sensitive to temperature in the biological range allowing those to serve in nanothermometry imaging applications. Rare earth metal doping makes these GQDs emissive in the near-infrared (NIR), which is beneficial for therapeutic imaging in the NIR water window, where biological tissue is more transparent. Several NIR-emissive GQD structures are tested in our work for imaging in vitro as well as in live sedated animals. Due to high NIR penetration depth, GQD fluorescence was observed through the bodies of live mice injected intravenously with GQD suspensions and imaged with diffuse 808 nm laser excitation. Excised organs show NIR GQD emission from kidneys, liver, spleen and intestine with GQDs also detected in single organ slices indicating their location within the particular organ. Based on the variety of observed imaging modalities, we suggest these biocompatible GQDs as a novel modifiable imaging platform that can be further doped and tailored for specific bioapplications.

[1]Authors Acknowledge NIH R15 grant EB031528-01