Abstract

Introduction:

Carbon nanodots (CNDs) or carbon quantum dots are a novel group of material with exceptional physico-chemical properties. Being carbonaceous in nature, these groups of 0-D carbon structures with exceptional photoluminescence and non-photo bleach-ability are safer for biological imaging applications with respect to its semiconductor and metallic counterparts. Instead of traditional arc discharge or laser ablation based methods of CNT and other graphite based precursors, here, a simple biomass based microwave irradiation induced route was explored.

Hypothesis:

CNDs were observed to take part in different chemical reduction reaction and possess unbleachable fluorescent property. This allowed author to postulate a research problem based on CNDs to be a future smart theranostics probe. This concept was extended further to multimodal imaging and tissue engineering applications.

Materials and Method:

CNDs and CND doped nanostructures were successfully synthesized via simple microwave assisted or hydrothermal route. They were characterized using different spectroscopic tools such as UV-Vis, FTIR, fluorescence, XPS and Raman along with different imaging analysis like TEM, SEM, AFM, and DLS etc. The synthesized nanostructures were evaluated for cytocompatibility and hemocompatibility. These nanomaterials were explored for ROS scavenging and various bioimaging applications as well. Further, CND and CND derived nanostructures were incorporated into scaffolds for exploring tissue regeneration and wound healing applications.

Results and Discussion:

The CNDs were observed to be capable of in situ free radical scavenging along with *in vitro*, *in vivo* bio-imaging and live cell-tracking. Silver nanoparticles are effective in surface enhanced Raman Scattering (SERS) imaging and demonstrated significant antimicrobial efficacy. Silver nanoparticles are also known to generate oxidative stress. In the present study, a multimodal imaging probe was established via silver nanoclusters doping into CNDs with fluorescence/SERS activity without hampering the antimicrobial efficacy and retaining low ROS generation ability.

Similarly, copper nanoparticles are known for their antimicrobial property, applicability in SERS imaging and enhancement in angiogenesis.

However, copper nanoparticles are often limited in health care application due to ROS generation related toxicity. This problem was mitigated in the current study by CND doped copper nanowires through in situ scavenging of ROS from cellular microenvironment. Manganese oxide nanoparticles are utilized as novel biocompatible alternatives to Gadolinium (Gd) based T1 contrast agents in MRI. Recent study suggests generation of ROS induced toxicity in neurological system due to MnO2 nanoparticles. In the current study, CND doped MnO_2 nanoparticles were prepared as a multimodal imaging probe (Fluorescence/MRI) with ROS scavenging properties.

CNDs were substituted in a PCL-gelatin nanofibrous scaffold and were explored for *in situ* tissue imaging during healing progression. Super paramagnetic iron oxide nanoparticles (SPION) are observed to be effective for T2 weighted magnetic resonance imaging. SPIONs were synthesized with doping of CNDs to make dual mode imaging probe (Fluorescence/MRI). Further, the composite nanoparticles were mixed with gelatin for printing 3D lattice structures to magnetically actuate scaffolds towards mechano-transduction of seeded MSCs. Calcium phosphate nanorods (CaP) are known for osteogenic differentiation potential of MSCs. Notably, doping of CNDs into CaP was not only effective to impart fluorescence in the CaP particles, but also enabled the fate of MSCs towards chondrogenesis via oxygen depletion and activation of HIF-α pathway.

Conclusion:

CNDs are useful as a smart nanolight to not only illuminate cellular microenvironment but also to save cells from phototoxicity in a long term study. Moreover, its ROS scavenging property could be transferred into other nanoparticles via doping to enhance its biocompatibility.

Keywords:

Carbon nanodots, Reactive Oxygen Species, Cell tracking, Multimodal Imaging,

Tissue engineering