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GRAPHENE/ POLYMER COMPOSITES FOR BIOMEDICAL APPLICATIONS: TISSUE SCAFFOLDS, PROSTHETIC JOINTS AND GENE DELIVERY

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We are working on graphene based polymer nanocomposites for use in biomedical applications, in particular, for orthopedics utilizing the large specific surface area and mechanical properties of graphene.

One major area of interest is the development of composite scaffolds for bone tissue regeneration. We prepared polycaprolcatone (PCL) composites incorporating graphene oxide (GO), reduced GO (RGO) and amine-functionalized GO (AGO) to investigate the role of chemical functionalization of graphene on material performance and biological response. It was observed that AGO imparts the optimal combination of improved modulus, increased stem cell proliferation and osteogenesis, and inhibition of biofilm formation in AGO-reinforced composites desired for orthopedic applications[1]. We have also prepared hybrid nanoparticles of graphene sheets (RGO) decorated with strontium metallic nanoparticles (RGO_Sr). Macroporous tissue scaffolds prepared by incorporating the hybrid RGO_Sr particles in PCL were found to elute strontium ions in aqueous medium and markedly enhanced osteoblast proliferation and differentiation in contrast to neat PCL and PCL/RGO scaffolds[2].

We are also working to incorporate graphene in polyethylene (PE) composites to enhance the modulus and hardness for use as articulating surfaces lining the sockets of prosthetic joints. We studied the combinatorial effect of addition of graphene (RGO) and processing by rolling. It was observed that whereas RGO increased mechanical properties of PE matrix but hindered chain alignment during rolling of the composite unlike the carbon nanotubes due to the shape of the nanofillers[3]. In more recent work, we have irradiated a RGO containing PE composite. RGO was shown to scavenge free radicals that led to enhanced crosslinking and grafting of the polymer chains on to the RGO sheets. The modulus and hardness of PE was thus shown to synergistically improve through irradiation and gamma irradiation.

To utilize the large surface area of graphene for gene delivery, polyamidoamine (PAMAM) dendron was conjuagted to GO by click chemistry to improve the DNA complexation capability and transfection efficiency of GO. The transfection efficiency of GO drastically increased after conjugation of PAMAM dendron. Thus, dendronized GO may be an efficient nonviral carrier for gene therapy in future.

Relevant Publications:

1. S. Kumar, et al, “Chemical functionalization of graphene to augment stem cell osteogenesis and inhibit biofilm formation on polymer composites for orthopedic applications” **ACS Applied Materials & Interfaces** 2015, 7: 3237–3252
2. S. Kumar, et al, “Strontium eluting graphene hybrid nanoparticles augment osteogenesis in a 3D tissue scaffold” **Nanoscale** 2015, 7: 2023–2033
3. E. Kolanthai, et al, “Combinatorial effect of rolling and carbonaceous nanoparticles on the evolution of crystallographic texture and structural properties of ultra high molecular weight polyethylene” **Physical Chemistry Chemical Physics** 2014, 16: 23108–23117