Synthesis and structure of graphene-POSS hybrid aerogels

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Abstract

Aerogels are extremely porous materials with large pore volume, high surface area and low bulk densities[[1]]. Recently, graphene aerogels have attracted attention due to their extraordinary characteristics and their potential application in many fields, such us thermal insulation, oil absorption, energy storage, catalyst supports, and supercapacitors [[2-4]]. However, the aerogel-based application performance strongly depends on the morphology and structure of the graphene aerogels. Different strategies have been developed to fabricate graphene-based 3D framework. In this work, we propose the preparation of three-dimensional self-assembly of graphene by mild chemical reduction[[5]] and in situ simultaneous deposition of polyhedral oligomeric silsesquioxane (POSS) on graphene sheets (Fig.1). Tetra-silanol phenyl-POSS (tetra-POSS) has been employed to functionalize graphene sheets(Fig. 1b), just before gelling and supercritical drying.

The morphology and structure of the graphene-POSS hybrid aerogel was investigated by scanning electron microscopy) and X-ray powder diffraction tests. From the SEM inspection of the graphene aerogel (Fig.2a), a well-defined and interconnected 3D porous network is observed, and the pore walls consist of thin layers of stacked graphene sheets. However, the addition of low amounts of POSS resulted in aerogels with large pores and lower densities (Fig. 2b).

The porous property of the resulting aerogels was investigated by nitrogen adsorption/desorption tests. The type IV nitrogen adsorption/desorption isotherms of hybrid aerogels showed a distinct hysteresis loop in the P/P_0 range of 0.4 –1.0, implying the presence of relatively large macropores and mesopores in the frameworks (Fig.3). Furthermore, the mesopore size calculated by the BJH method ranged from 2.0 to 3.5nm with a narrow distribution (inset in Fig.3).

The thermal stability, together with mechanical properties of the hybrid aerogels, was analyzed by thermal gravimetric analysis as well as compression tests. The results showed that the incorporation of low loading levels of POSS can significantly enhance the thermal stability, the compression strength and Young's modulus of the resulting hybrid aerogels. These results demonstrate that graphene-POSS hybrid aerogels prepared by supercritical CO2 drying of the graphene-POSS hybrid hydrogel precursors possess macro-and mesoporous structures with lower densities and higher compressive stress than neat graphene aerogel.

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Figures

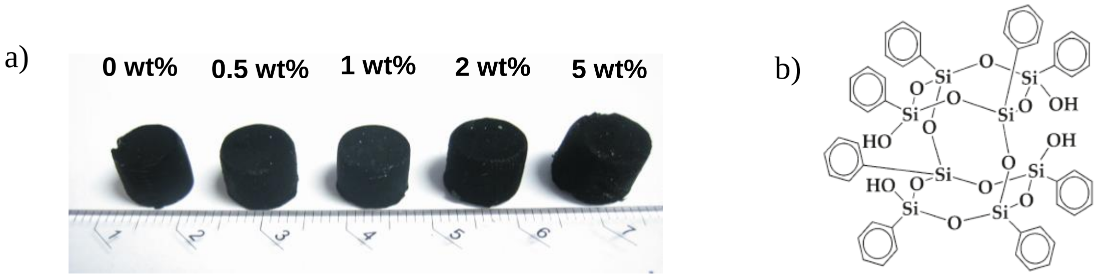

Figure 1: (a) Photographs of as-prepared 3D-graphene aerogels with different content of tetra-POSS; b) Chemical structure of Tetra-POSS

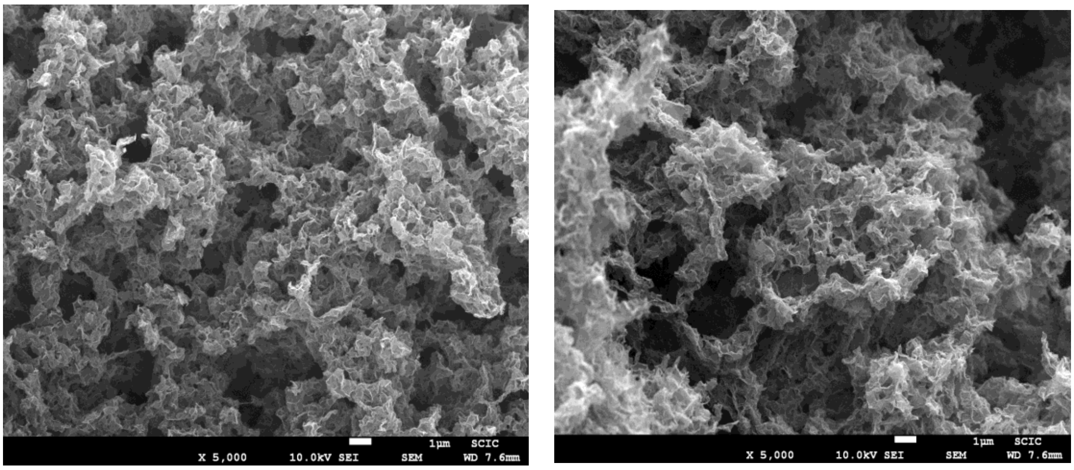

Figure 2: Cross-sectional SEM images of graphene aerogel(a) and graphene-1%wt POSS aerogel (b).

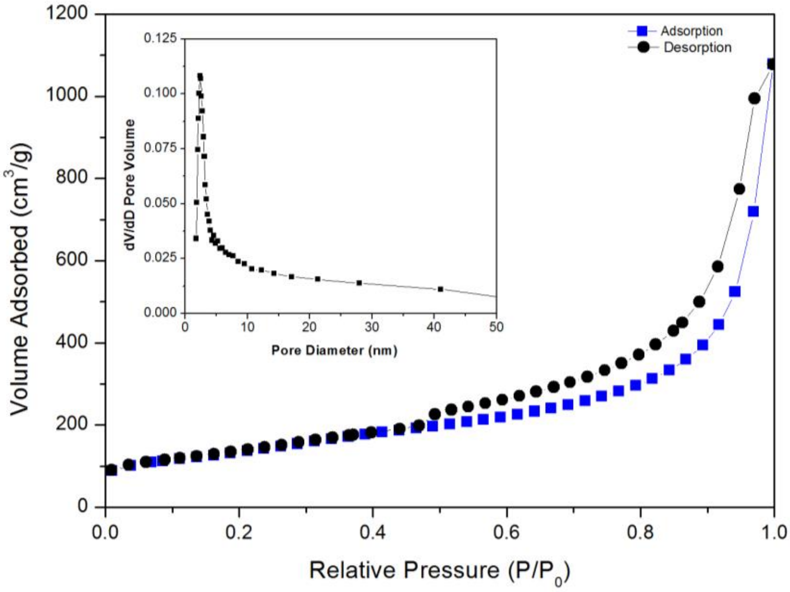

Figure 3: Nitrogen sorption isotherms and BJH (Barrett-Joyner-Halenda) adsorption pore size distribution curve (inset) of graphene aerogel.