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Investigation of the growth mechanism of carbon nanomaterials by arc discharge and their applications in Na-CO_2 batteries

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Amorphous spherical carbon nanoparticles (SCNs), typical 'dahlia-like' nitrogen doped carbon nanohorns (N-CNHs), and graphene with the layer numbers of 2-12 were synthesized controllably from the inner wall of the chamber by DC arc discharge method using argon, nitrogen, and hydrogen as buffer gas. Simultaneously, the effect of buffer gas pressure on the morphology of carbon nanomaterials was investigated systematically. Furthermore, the formation mechanism of these carbon nanomaterials by DC arc discharge was also investigated. Given that argon atom was difficult to bond with the carbon cluster, the random bond between carbon clusters contributed to combine into amorphous SCNs; the C-N bond was the key factor in the formation of N-CNHs, and hydrogen contributes to form graphene sheets by terminating carbon dangling bonds. Graphene sheet has thick edges than the central area, but the thickness of each edge is not consistent, the hydrogen-induced marginal growth (HIMG) model is deduced to study the growth mechanism of graphene by combining experiment with numerical simulation results (Fig.1). Benefiting from N dopants, unique internal and interstitial nanoporous structures, N-CNHs have large surface area for discharge products accumulation, offer substantial structural defect sites for CO_2 adsorption and electron transfer, contributing to high catalytic activity and reversibility in Na-CO_2 battery. As shown in Fig.2, the Na-CO_2 battery exhibits a low charging voltage of 2.62 V and a small voltage gap of 0.49 V at the current density of 0.1 mA·cm^{-2}.

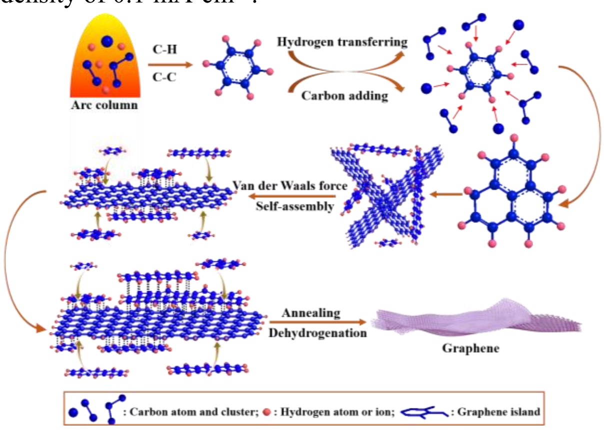

Fig. 1 Schematic diagram of the HIMG model on synthesizing graphene by arc discharge.

Given abundant surface charges, SCNs provide plentiful active sites for CO_2 adsorption and reduction, the Na-CO_2 battery using SCNs as catalyst presents a small voltage gap of 0.50 V at a current density of 0.1 mA cm^{-2}.

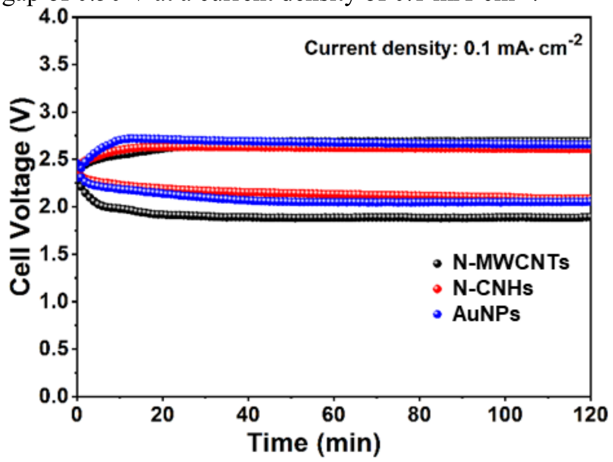

Fig. 2 Discharge-charge voltage curves with N-MWCNTs, AuNPs, and N-CNHs as catalyst at a current density of 0.1 mA cm^{-2}.

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