

## Scalable Synthesis of N-doped Porous Carbon Network with a Multidirectional Structure as a Highly Efficient Metal-Free Catalyst for the Oxygen Reduction Reaction

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Metal-free catalysts have gained substantial attention as a promising candidate to replace the expensive platinum (Pt) catalysts for the oxygen reduction reaction (ORR). Development of highly efficient and mass-producible N-doped carbon catalysts, however, remains to be a great challenge. In this study, N-doped porous carbon (NPC) materials were synthesized via a simple, cost-effective and scalable method for mass production by using the D-gluconic acid sodium salt, pyrrole, Triton X-100 and KOH. The resulting NPC possessed a multidirectional porous carbon network ( $S_{\text{BET}}$ :  $1026.6 \text{ m}^2 \text{ g}^{-1}$ ,  $V_t$ :  $1.046 \text{ cm}^3 \text{ g}^{-1}$ ) with hierarchical porosity and plenty of graphitic N species (49.1%). Electrochemical tests showed that the NPC itself was highly active for the ORR under alkaline and acidic conditions via a four electron pathway with highly improved long-term durability and methanol tolerance.