Sustainable porous carbon spheres with precisely tailored from dense to hollow structure derived from Kraft lignin

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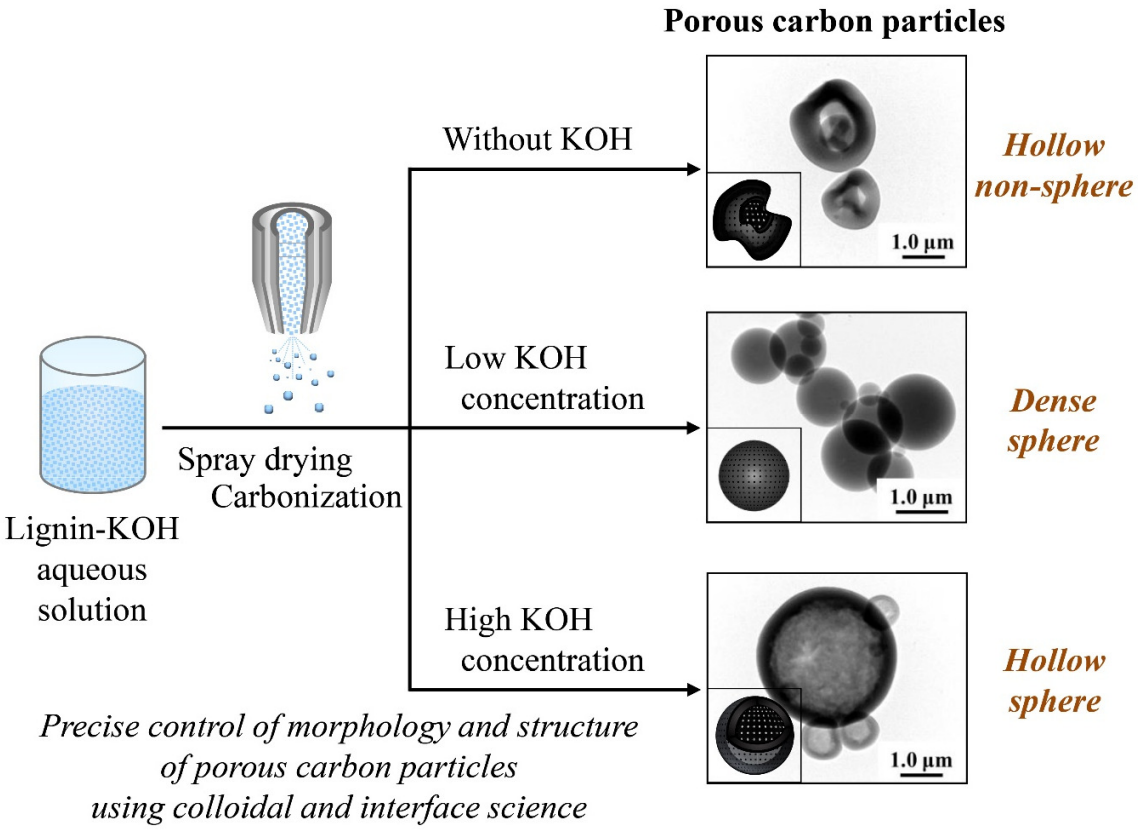
Spherical carbon particles have attracted tremendous interests in recent years due to their intriguing structure-induced physicochemical properties and great potential for widespread applications. The production of carbon-based materials from green, renewable, and cost-effective resources in accordance with sustainable development goals is of high interest and encouraged. In this regard, lignin has been considered as a potential sustainable source for the preparation of advanced porous carbonaceous materials due to its high carbon content (above 60 wt%), abundant, low feedstock cost, and extensively crosslinked polyphenolic structure. However, their preparation with the precise design and controllable structure using a facile and scalable strategy remains a significant challenge. In this work, the spherical carbon particles were successfully fabricated through a spray drying method followed by the carbonization process, using Kraft lignin as the carbon source and potassium hydroxide (KOH) as the activation agent. As the results, the proposed method successfully controlled the structure and shape of the carbon particles from dense to hollow by adjusting the KOH concentration for the first time. In addition, to obtain an in-depth understanding of the particle formation of carbon particles, a possible mechanism is also investigated in this research. Furthermore, the high specific surface area (2424.8 m^2g^{-1}) with micro-mesoporous structure of hollow carbon spheres (HCSs) were obtained at a low KOH-to-lignin mass ratio (below 1.5), which was in accordance with green chemistry principles. These HCSs have applications as electrode materials in supercapacitors for energy storage devices. With the great achievements and continuous efforts in this important field, these results suggest that our approach adopted herein will open up opportunities for the development of advanced carbon materials and high value-added utilization of Kraft lignin as a promising material for potential applications.


Porous carbon particles
Without KOH
Low KOH concentration
High KOH concentration
Spray drying
Carbonization
Lignin-KOH aqueous solution
1.0 μm
1.0 μm
1.0 μm
Hollow non-sphere
Dense sphere
Hollow sphere
Precise control of morphology and structure of porous carbon particles using colloidal and interface science