Pore structure of different activated carbons and development of mesoporous versions

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Abstract: Activated carbons are widely used as catalyst supports in various industries for their large surface area and recyclability. Numerous studies focus on the optimization of the properties of carbon-supported catalysts, and while the pore structure is recognized as a fundamental parameter in achieving fine dispersion and distribution of the active phase, only few works actually take into consideration the intrinsic physical properties of the support. Here we characterized a variety of activated carbons produced using different raw materials and activation methods, including newly developed mesoporous versions, and fulfilling the requirements in terms or purity for use as catalyst substrates.
Keywords: activated carbon, catalyst support, pore structure.

1. Introduction

In a supported catalyst, the catalytically active phase is dispersed over the large surface of the supporting material, typically >1000m2/g in the case of activated carbons. The catalytic performance is mainly determined by the chemical properties of the active phase; however local properties influencing distribution across the support also play a major role [1]. The interaction between the active phase and the support, and the physical characteristics of the support are therefore key factors in developing efficient catalysts [2]. Activated carbons are produced by steam or chemical processing of a variety of raw materials (wood, coconut shell, coal, etc.), resulting in a large range of commercially available supports. Those are furthermore optimized to meet specific requirements in actual use as a catalyst, e.g. improved filtration rate for powders or improved attrition resistance for pellets. In consequence, no activated carbon is similar to another, and it is important to fully characterize the support properties when developing catalysts. Here we examined the pore characteristics of different activated carbons in order to highlight the wide variety of available supports. We also report the development of new mesoporous-rich activated carbons which unique structure is expected to influence catalyst performance.

2. Experimental

Activated carbons used in this study are steam and chemically (zinc chloride) commercially available activated carbons, including a new type of mesoporous carbons (pore size >2nm) referred to as High Mesoporous Volume (HMV) and Ultra Mesoporous Volume (UMV) grades. The BET surface areas and pore size characteristics were determined from nitrogen adsorption–desorption isotherms with a Micromeritics ASAP instrument. Other parameters were measured according to the JIS K1474 standard.

Grade	Form	Raw material	Activation method
FAC-10	Powder	Wood	Steam
FAC-10 HMV / UMV	Powder	Wood	Steam + pore-extended
Tokusei Shirasagi	Powder	Wood	Zinc chloride
C2x	Pelletized	Coconut	Steam
C2x HMV	Pelletized	Coconut	Steam + pore-extended
X7000	Spherical	Coal	Steam

Table 1. Activated Carbons used in the study.

3. Results and discussion

The pore structure is a crucial parameter in achieving the desired dispersion of catalyst (e.g. noble metal) over the substrate. Furthermore, mesopores are thought to influence catalyst reactions both as being the pathway between the substrate and the catalyst, and as the location where chemical reactions take place. The pore size and volume of activated carbon is widely controlled by the selection of raw materials (wood, coconut, coal etc.) and the activation method (steam, chemical). As a result, as shown on Fig.1., coconut or coal based steam activated carbons present less mesoporous volume than wood based steam activated carbons, and chemically activated carbons present the largest mesoporous profile. Chemically activated carbons however have the disadvantage of containing remaining traces of chlorides and metals that can adversatively affect catalyst performance. We therefore developed an industrial method to increase the mesoporous volume of wood based, steam activated powders. These new grades, FAC-10 HMV and UMV, present an increased pore volume especially in the range 2-10nm (Fig.2.). A similar method can be applied to pelletized activated carbons for which coconut shell is the preferred raw material. Different activated carbon pore characteristics are expected to lead to different reactivity and selectivity when used as a catalyst support. In further studies, full characterization of the support should include investigation of surface functional groups which can influence dispersion quality.

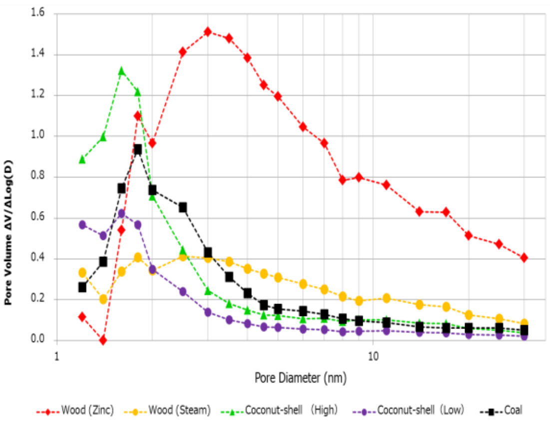

Figure 1. Pore characteristics of different activated carbons.

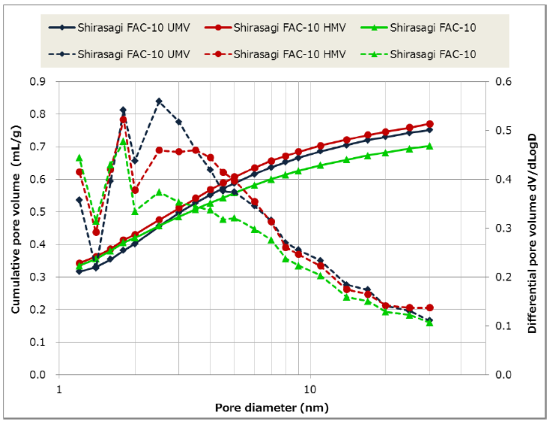

Figure 2. Tuning of pore characteristics on the same raw material (wood) and same activation method

4. Conclusions

Activated carbon is not a one and only material, as a whole range of different pores structures can be obtained depending on the manufacturing process. Selection of the right support for the right application is therefore of key importance. We also demonstrated that it is possible to tune macroporosity in order to optimize the properties of the substrate/catalyst complex, which in turn is expected to lead to improved chemical reaction yields.

References

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