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Glucose-derived carbon catalyst supports: the future of green and sustainable ethylene glycol direct production from cellulose

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PURPOSE OF THE ABSTRACT

Efficient catalytic cellulose conversion into value-added chemicals is of great importance for utilization of abundant and renewable biomass, in order to reduce our dependence on fossil fuels [1,2]. The one-pot hydrolytic hydrogenation of cellulose into valuable chemicals, especially ethylene glycol (EG), over heterogeneous catalysts is one of the most efficient pathways for a future sustainable society dependent on lignocellulosic biomass [3]. EG is one of the most highlighted target molecules, since it can be used as antifreeze or coolant liquid in vehicles, or as precursor and coating agent in the plastics and food industries such as for polyester fibers and polyethylene terephthalate [2,4]. This work studies the effect of the preparation method on the final properties of the catalysts, the main focus being the development of an efficient and sustainable process for the direct transformation of cellulose into EG using Ru-W bimetallic catalysts supported on glucose-derived carbon materials.

A glucose-derived carbon support (CG) and a glucose-derived carbon/carbon nanotube hybrid (CG-CNT) were prepared by hydrothermal treatment. Tungsten monometallic catalysts were then prepared by incipient wetness impregnation of these carbon supports, by adding W (30 wt.%) in three different stages of the preparation process of the supports, which resulted in the following catalysts: i) W/CG and W/CG-CNT from W addition after carbonization of the carbon supports; ii) W/CGorg and W/CG-CNTorg from W addition prior to the thermal treatment and iii) W/CGsynt and W/CG-CNTsynt from W introduction prior to the hydrothermal treatment. Afterwards, Ru-W bimetallic catalysts were prepared by incipient wetness impregnation of Ru (0.4 wt.%) on the prepared W monometallic catalysts, and the resulting materials were denoted as Ru-W/CG, Ru-W/CG-CNT, Ru-W/CGorg, Ru-W/CG-CNTorg, Ru-W/CGsynt and Ru-W/CG-CNTsynt. The different catalysts were then tested in the one-pot hydrolytic hydrogenation of cellulose into EG, by introducing 300 mL of water, 750 mg of ball-milled cellulose and 300 mg of catalyst into a 1000 mL stainless steel Parr reactor. After heating under N₂ to 205 °C, the reaction was initiated by switching to H₂ (50 bar), and samples were periodically removed for analysis by HPLC and TOC.

The prepared Ru-W catalysts were in general highly efficient, with 100 % cellulose conversion after just 2 h. The EG yield depended on the type of support and on the preparation method (Figure 1). Independently of the presence or absence of CNT, W deposition during hydrothermal carbonization had a negative effect on the yield of EG, and CG supported catalysts allowed attaining higher EG yields than CGorg supported catalysts, although no significant differences were observed on the porous properties of both materials. Ru-W/CG was the most efficient for EG production, with a yield close to 35 % after 5 h. Similar results have been previously obtained using Ru-W/CNT [5], indicating that CNT can be successfully replaced by low-cost supports derived from biomass.

To conclude, Ru-W supported on glucose-derived carbon materials are efficient for the direct EG production from cellulose, the synthesized materials being herein presented as low-cost and sustainable catalytic supports.

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FIGURES

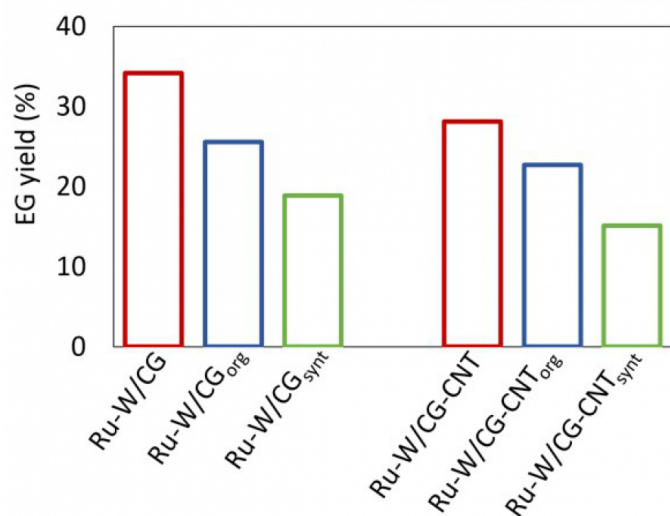


FIGURE 1

Figure 1

Ethylene glycol yields after 5 h of reaction.

FIGURE 2

KEYWORDS

Cellulose conversion | hydrolytic hydrogenation | glucose-based materials | ethylene glycol

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