Synthesis of Ni-W catalysts supported on glucose/carbon nanotube hybrid carbons for the one-pot cellulose conversion to ethylene glycol

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Background and motivation. Ethylene glycol (EG) is a versatile chemical that is widely used as a precursor in the production of polyester fibres, plasticisers, cosmetics, antifreeze, coolants, and as a solvent or surfactant, among other applications [1]. Currently, EG is mainly derived from petroleum and coal. However, growing environmental concerns and its broad applicability have led to significant interest in the production of EG through renewable biomass-based processes [2]. Cellulose is the major component of lignocellulosic biomass, accounting for 40 to 80 wt.% [2]. Hence, converting cellulose into high-value chemicals such as EG is one of the most promising and sustainable approaches. In this work, for the first time to our knowledge, a series of low-cost Ni-W bimetallic catalysts supported on glucose/carbon nanotube hybrid carbons were synthesised and used to convert cellulose to EG.

Materials and methods. Glucose/carbon nanotube hybrids were synthesised by hydrothermal polymerisation of the sugar, followed by a thermal treatment to increase the porosity of the resulting materials. Two different strategies were combined: carbonisation/activation and addition of carbon nanotubes (CNT) to obtain a hybrid material. Carbonisation was carried out at 700 ºC under N_2 for 2 h, resulting in the sample CG-CNT. Activation was performed under CO_2 using 3 different temperature/time conditions: i) 700 ºC for 2 h (AG-CNT_{450}), ii) 900 ºC for 2 h (AG-CNT_{700}) and iii) 900 ºC for 6 h (AG-CNT_{1200}). The samples were named according to their calculated surface area values ($m^2\ g^{-1}$). These supports were then used to prepare Ni-W catalysts. The properties of the materials were characterised by N_2 adsorption, ICP, XRD and elemental analysis. The catalysts were tested in the one-pot hydrolytic hydrogenation of cellulose at 205 ºC and 50 bar of H_2. For this, 300 mL of water, 750 mg of ball-milled cellulose, and 300 mg of catalyst were added to a 1000 mL Parr reactor and stirred at 300 rpm. The reaction mixture was then analysed by high-performance liquid chromatography and total organic carbon analysis.

Results and discussion. By optimising the catalyst properties, in particular the metal content, a synergistic effect between C-C bond cleavage and hydrogenation capabilities was achieved, allowing the highly selective production of EG. The balance between Ni and W active sites proved to be a critical factor, resulting in complete cellulose conversion (100 %) and EG yields of 60-62 %, ranking among the highest reported for catalytic cellulose conversion to EG using carbon-supported catalysts [3].

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