DEVELOPMENT OF A CARBON-BASED CATALYST FOR SYNGAS REFORMING TO MAXIMISE HYDROGEN PRODUCTION

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Abstract

Hydrogen derived from biomass gasification will be instrumental in reducing carbon emissions and achieving UK's net zero targets. Tar and other hydrocarbons present in syngas from biomass gasification could be catalytically reformed to maximise hydrogen production. However, current reforming catalysts suffer from deactivation caused by sulphur present in syngas and carbon deposition on catalyst surface. This study developed and synthesised a novel biochar-supported catalyst $NiCo_{0.25}Ce_{1.25}O_{3.75}$ which is expected to be tolerant to sulphur and carbon that are often present in biomass-derived syngas. The new catalyst is designed with a crystal lattice with presence of labile oxygen. During the catalytic reforming, when sulphur or carbon adsorb onto the catalyst surface, labile oxygen present in the crystal lattice reacts with the adsorbates, forming sulphur oxides and carbon oxides which subsequently desorb into the bulk gas. Figure 1 shows this proposed oxygen-sulphur/carbon interaction mechanism on the catalyst surface, and this is what renders the catalyst sulphur/carbon tolerant. Catalyst preparation was through the amorphous citrate method, followed by deposition onto the biochar support through wetness impregnation. A calcination step drove off carbon, hydrogen and nitrogen from the citrate process to leave a crystal metal oxide catalyst supported on biochar. Preparation of biochar was through carbonisation of wheat straw pellets. Catalyst characterisation was done to establish surface and porosity characteristics, structural, elemental, and thermal performance properties of the new catalyst, through the analyses Brunauer-Emmett-Teller (BET), X-ray diffraction (XRD), Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS), and thermogravimetric (TGA). Catalyst characterisation results showed that the new catalyst is relatively thermally stable under the test temperatures ranged from 600 to 850^{o}C, with a surface area of 377-384 m^2/g and microporous structure at 6.37-6.63 nm pore size, and thus is expected to be capable of accommodating larger hydrocarbon molecules present in syngas; naphthalene has kinetic diameter (0.62nm) less than the lower limit pore size. The carbon-based catalyst is thermally stable and applicable at 600-850^{o}C, and has the higher surface area, and thus has potential to be highly active in comparison with catalysts without support, or catalysts with non-porous supports, in catalytic reforming of syngas to maximise hydrogen production. Figure 2 shows XRD results of catalyst samples processed under different conditions (at calcination temperatures 600-900^{o}C). It is concluded that the catalyst is composed of more than a single phase of crystal, and the phases may prove to have differing catalytic efficacies during the reforming tests to be done.

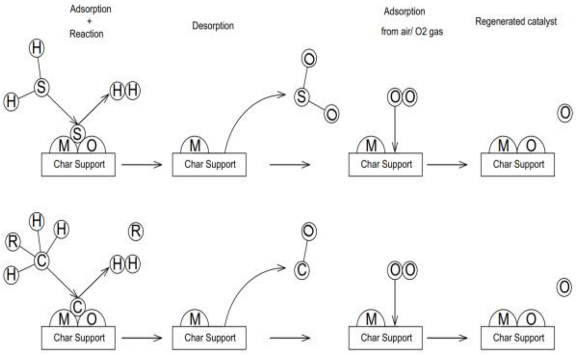

Figure 1: Sulphur/Carbon interacting on the catalyst surface. M = metal, S = sulphur, O = oxygen, H = hydrogen, C = carbon

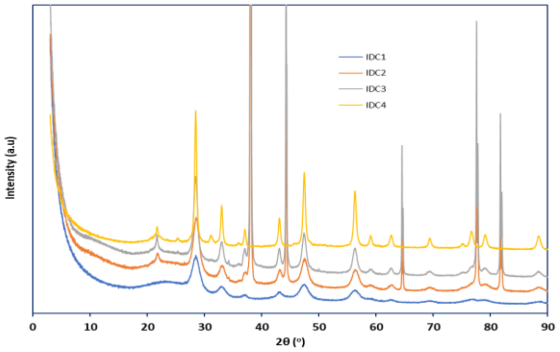

Figure 2: XRD patterns of catalyst samples for different calcination temperatures: IDC1 – 600^{o}C, IDC2 – 700^{o}C, IDC3 – 800^{o}C, IDC4 – 900^{o}C.