Sustainable production of styrene carbonate using heterogeneous catalysts

Victor Onyenkeadi[1], Basu Saha[2,*]
[1]School of Engineering, London South Bank University, 103 Borough Road, London SE1 0AA, UK.
[2]School of Engineering, Lancaster University, Lancaster LA1 4YW, UK
*Presenting author (email: b.saha@lancaster.ac.uk)

Abstract

The rapid deterioration of the global environment due to the continuous release of CO_2 into the atmosphere is considered a global concern for the protection of the environment. Hence, there is a wide intention for the emission of CO_2 to be drastically reduced. The usage of fossil fuels as primary sources of energy requires serious shifting to alternative green fuels to reduce the amount of released CO_2 into the atmosphere [1]. In addition, the valorisation of CO_2 has drawn much attention not just because of the potential use of CO_2 as a cheap, abundant, safe, renewable C1 source for the formation of valuable chemicals, but also contributing to the quest of preventing global warming [2]. CO_2 is a stable compound due to the exceptional distance bond of 0.116 nm between carbon and oxygen (C=O), which is shorter than the normal bond length. This bond distance provides a CO_2 compound with unique properties, where it is hard to activate and requires high energy to transform into another compound. The use of high-energy as precursor materials for the formation of oxidised low-energy synthesis is one of the few effective methodologies for CO_2 utilisation.

The valorisation of emitted CO_2 into a value-added chemical such as styrene carbonate (SC), not only provides a solution to global warming but also offers a greater application in the processing industry. SC is an essential cyclic carbonate that can be used as an electrolyte for making lithium-ion batteries and can be utilised as a feedstock to produce other useful organic carbonates. In this work, the synthesis of SC from the cycloaddition reaction of styrene oxide (SO) and carbon dioxide (CO_2) has been investigated using several heterogeneous catalysts in the absence of an organic solvent. Ceria and lanthana-doped zirconia (Ce-La-Zr-O) is the most active and selective catalyst for the synthesis of SC as compared to other heterogeneous catalysts that have been assessed as part of this study. Studies of catalyst reusability have been conducted to investigate the long-term stability of the best-performed catalysts for the synthesis of SC. Amongst all the catalysts studied in this work, the Ce-La-Zr-O catalyst has shown the best performance in terms of reusability as it could be reused several times without losing its catalytic activity. Response Surface Methodology (RSM) is a significant tool to investigate the interaction between process parameters and quantitatively illustrate the effect of each parameter on the process responses [3]. RSM has been used to develop mathematical regression models illustrating the effect of four selected reaction-independent variables e.g. temperature, pressure, catalyst loading and time on reaction responses using Ce-La-Zr-O catalyst. SC conversion and SO yield have been considered as reaction response variables. Two quadratic polynomial models have been developed representing an empirical relationship between each reaction response variable function in all independent variables. The predicted results of RSM models are in good agreement with the experimental results.

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