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# Cr and $CeO_2$ promoted Ni/SBA–15 framework for hydrogen production by steam reforming of glycerol

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Environmental Science and Pollution Research

Aims and scope

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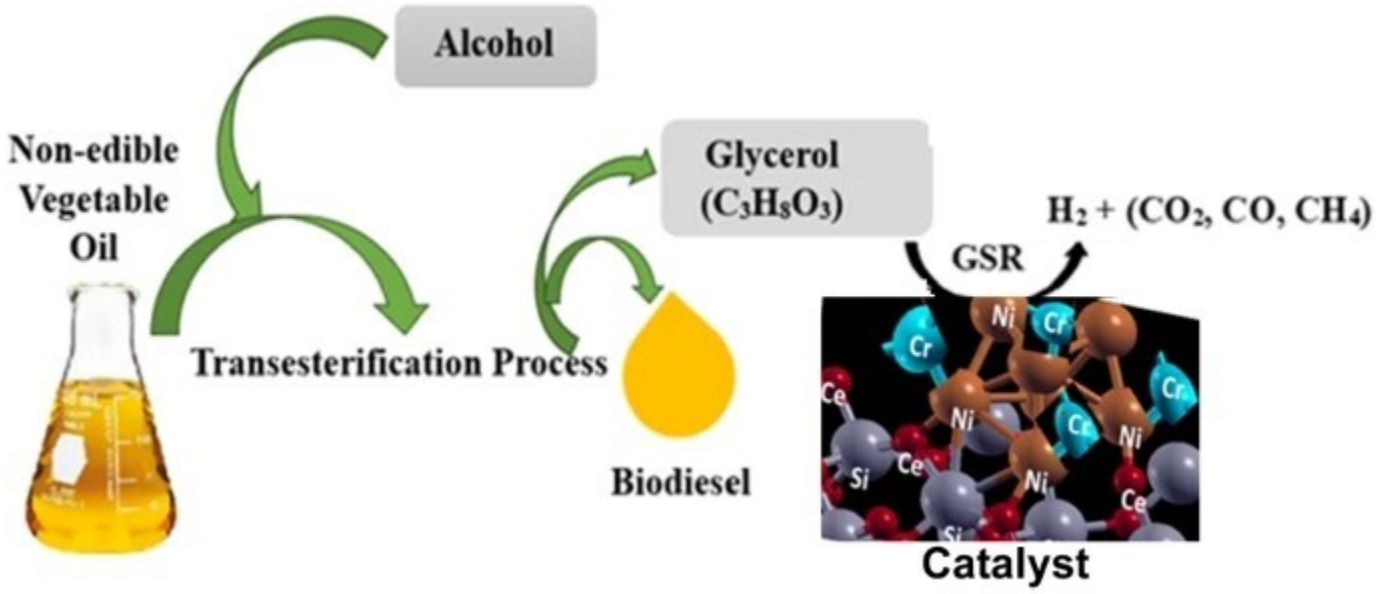
## Abstract

Ni/SBA-15 meso-structured catalysts modified with chromium and $CeO_2$ (Ni–Cr-$CeO_2$/SBA15) were utilized to produce hydrogen from glycerol steam reforming (GSR). The catalysts were synthesized by a one-pot hydrothermal process and extensively characterized by analytical techniques such as $N_2$ adsorption–desorption (BET), $H_2$-temperature programmed reduction ($H_2$-TPR), powder X-ray diffraction (PXRD),

inductively coupled plasma-optical emission spectrometry (ICP-OES), and transmission electron microscopy (TEM). The low-angle XRD reflections affirmed that the catalysts were crystalline and possessed a 2D-ordered porosity. The BET results depicted that all the catalysts exhibited a good surface area ranging from 633 to 792$m^2$/g, and the pore sizes were consistently in the mesoporous range (between 3 and 5 nm). TEM analysis of both calcined and spent catalysts revealed that the metal active sites were embedded in the hybrid $CeO_2$-$SiO_2$ support. Overall, the Ni-based catalysts exhibited higher glycerol conversion -12Ni-SBA-15–99.9%, 12Ni3$CeO_2$-SBA-15–89.4%, and 8Ni4Cr3$CeO_2$-SBA-15–99.7%. Monometallic 12Ni/SBA-15 performed exceptionally well, while 12Cr/SBA-15 performed poorly with the highest 71.48% CO selectivity. For short-term GSR reactions, $CeO_2$ addition to 12Ni/SBA-15 did not have any effect, whereas Cr addition resulted in a 32% decrease in $H_2$ selectivity. The long-term stability studies of 12Ni-SBA-15 showed $H_2$ selectivity of ~ 64% and ~ 98% glycerol conversion. However, its activity was short-lived. After 20–30 h, the $H_2$ selectivity and conversion dropped precipitously to 40%. The doping of mesoporous Ni/SBA-15 with Cr and $CeO_2$ remarkably enhanced the long-term stability of the catalyst for 12Ni3$CeO_2$-SBA-15, and 8Ni4Cr3$CeO_2$-SBA-15 catalyst which showed ~ 58% $H_2$ selectivity and ~ 100% conversion for the entire 60 h. Interestingly, Cr and $CeO_2$ seem to improve the shelf-life of Ni-SBA-15 via different mechanistic pathways. $CeO_2$ mitigated Ni poisoning through coke oxidation whereas Cr bolstered the catalyst stability via maintaining a well-defined pore size, structural rigidity, and integrity of the heterogeneous framework, thereby restricting structural collapse, and hence retard sintering of the Ni active sites during the long-term 60 h of continuous reaction. Hydrogen generation from renewable biomass like glycerol could potentially serve as a sustainable energy source and could substantially help reduce the carbon footprint of the environment.

## Graphical Abstract



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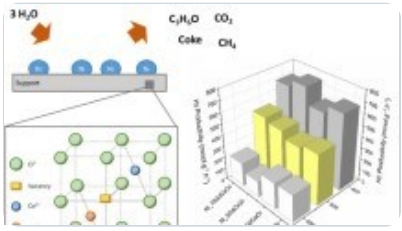

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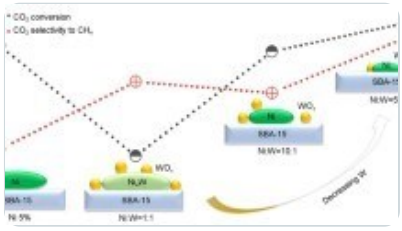

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## Data availability

I, Dr. Richard Y. Abrokwah, and all the co-authors agree with the data and materials disclosure policy of this journal and shall provide experimental raw data requested by the journal officials anytime.

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### Contributions

1. Dr. Richard Y. Abrokwah, supervised all the synthesis of the catalyst, discussed all the experimental reaction results, and ensured proper operation and maintenance of the gas chromatography. Dr. Debasish

Kuila, Dr. Sujoy Bepari, Dr. T. Hossain, and Dr. N. Mohammad discussed the results of the characterization techniques and formatting of the manuscript. Eric B. Ntow, Terrence Jennings, and Robert Stevens-Boyd performed the glycerol steam reforming reactions, collation of data, and maintenance of the set-up. John Swain and Saif Hassan performed characterizations of the spent catalysts after the stability studies and ordered reactor parts and reagents.

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## Ethics declarations

### Ethical approval

Not applicable.

### Consent to participate

Not applicable.

### Consent for publication

I, Dr. Richard Y. Abrokwah, and all the co-authors give our consent for the publication of this manuscript in this journal and special issue.

### Competing interests

The authors declare no competing interests.

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## Research Highlights

- Meso-structured $CeO_2$-SBA-15 hybrid support for Ni and Cr metals was prepared by a onepot hydrothermal method.
- Ni-SBA-15 showed the highest $H_2$ selectivity of ~ 64% and ~99% glycerol conversion but deactivated precipitously after 20–30 h.
- Addition of Cr and $CeO_2$ remarkably augmented the performance and long-term stability of the Ni/SBA-15 catalyst.
- Stainless-steel fixed-bed reactor was used for glycerol steam reforming (GSR).
- 8Ni4Cr3$CeO_2$-SBA-15 catalyst exhibited highest stability and glycerol conversion of ~100%.

## Supplementary Information

Below is the link to the electronic supplementary material.

**Supplementary file1 (DOCX 17788 KB)**

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## About this article

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