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Fabrication of Novel 3D Structured Electrode for Electrocatalytic Hydrogen Generation Applications using Additive Manufacturing

D. Advanced sustainable materials for energy applications

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Abstract

Considering its clean and fully recyclable nature, hydrogen generated through water electrolysis is a potential alternative to fossil fuels. However, the ability of hydrogen to hold the next-generation fuel capability is largely affected by the unaffordability of the water electrolyzer systems and unachievable practical-level electrochemical performance. Moreover, the oxygen evolution reaction remains enigmatic in the overall water splitting reaction. Recently 3D printing additive manufacturing technology [1, 2, 3] has been explored for various electrochemical applications and to a greater extent addressed the academic concerns raised for the electrocatalytic water splitting. Additive manufacturing involves the rapid prototyping of complex and novel geometries which are pre-designed using computer aided design (CAD) softwares offering low-cost manufacturing methods with low fabrication waste. This work involves fabrication of polymer template-based electrode using stereolithography (SLA).

The main novelty of the work lies in using a Rod-Connected Diamond-based geometry, i.e. whose topology is similar to that of an atomic diamond crystal, where bonds between atoms are represented by cylinders. According to literature, the electrode activity can be improved by increasing and optimising the active surface area and the intrinsic activity of the material [4]. Hence printable 3D polymer structures with different filling fraction can be designed and subsequently analyzed for material and electrochemical performance. The post-processing involves carbonizing the polymer template through thermal decomposition [5] followed by

nickel electroplating and nitrogen plasma treatment with the purpose of obtaining nitrogen-carbon-nickel hybrid electrode and functionalizing the electrode surface with emerging two-dimensional layer materials.

Primarily, the thermal decomposition processes have been carried out and tested for different ramping rates. The scanning electron microscopy (SEM) and electron dispersive x-ray spectroscopy carried out for the annealed polymer template are promising in terms of improved surface area with minor cracks noticeable and major presence of carbon composition with traces of silicon dioxide impurities respectively. Further, this work explores the crystallographic structure of the annealed template using x-ray diffraction (XRD) spectroscopy and electrochemical performance of the as-prepared electrode after post-processing to investigate whether the material exhibit high current densities and lower overpotentials sufficient for the practical level hydrogen generation rather than laboratory-scale application. The electrochemical analysis involves examination such as cyclic voltammetry and Tafel analysis.

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