Title:	Exploring low-cost elements-based nanostructured electrocatalysts for sustainable energy conversion
Authors:	Garg, Reeya
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Abstract:	As the global demand for energy continues to rise, coupled with concerns about climate change and resource depletion, there is a growing urgency to develop efficient and environmentally friendly energy conversion technologies. One promising avenue is electrocatalytic energy conversion, wherein catalysts are employed to facilitate electrochemical reactions which are involved in fuel cell and energy storage batteries that convert chemical energies of fuels like hydrogen and oxygen into usable forms of energy, such as electricity. These electrocatalytic energy conversion technologies hold the potential to offer a global solution towards the energy crisis by integrating intermittent and geographically specific renewable energy sources. Conventionally, noble metals like platinum and iridium have been utilized as catalysts due to their exceptional catalytic activity. However, their scarcity and high cost hinder their large-scale adoption. This thesis focuses on an alternative approach by exploring nanomaterials composed of earth-abundant elements as catalysts for electrocatalytic reactions. Along with choosing sustainable materials for the production of highly efficient electrocatalysts, bringing sustainability into the production protocol also has been emphasized in this thesis. Therefore, nanomaterials studied in several projects were fabricated using cost-effective synthetic pathways, making them an attractive option for scalable energy conversion technologies. The first part of the thesis focused on the sustainable production of atomically dispersed first-row transition metals over nitrogen-doped carbon nanosheets (M-N-C) and deriving governing factors behind achieving atomic dispersion instead of nanoparticle formation, utilized for electrocatalytic ORR and OER. We further quantify and explain for each metal a negative mass balance originating from anomalous mass loss of both metal and carbon content, and a massive reconstruction of the carbon backbone catalyzed by the very metal. In the next part, emphasis has been given to incorporate Pd nanoparticles on the surface of M-N-C with minute loading to enhance the stability along with high electrocatalytic efficiency and meanwhile we reveal the photo response of M-N-C and utilize this unique property to bring a green synthetic pathway to load Pd nanoparticles whereas realizing highly active Pd-electrocatalysts under mild conditions is a challenge for industries. Theory and experiments establish that the Co-N4 moieties in the carbon-matrix act as semiconducting centres to generate excitons under sunlight, which are capable of reducing Pd-salts to deposit Pd nanoparticles (NPs) on Co-N-C at room temperature, which exhibited very high performance towards ORR due to strong metal- support interaction. The last part of the thesis depicts the potential of the composite of M-N-C and carbon nanotubes in achieving high electrocatalytic efficiency with long durability without any dependence on expensive noble metals. Thus, by offering a cost-effective and sustainable alternative to conventional noble-metal catalysts, the outcomes of this research have the potential to impact the development of next-generation energy conversion technologies that are both economically viable and environmentally responsible.
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