Chapter 13
Novel Chalcogenide-Based Nanocomposites as Electrocatalysts for Nitrogen Reduction Reactions

P. Selvakumar
https://orcid.org/0000-0002-3650-4548
Department of Science and Humanities, Nehru Institute of Technology, Coimbatore, India

Santosh Kumar Nathsharma
https://orcid.org/0000-0003-3935-2938
Stewart Science College, India

T. C. Manjunath
https://orcid.org/0000-0003-2545-9160
Rajarajeswari College of Engineering, India

ABSTRACT

Despite this abundance, atmospheric nitrogen is chemically inert due to the presence of a strong triple bond (N≢N) that has a high bond dissociation energy of about 941 kJ/mol. This inertness renders N_2 unavailable for direct assimilation by most living organisms, thereby necessitating its conversion into reactive nitrogen species such as ammonia (NH_3), nitrate (NO_3^-), or nitrite (NO_2^-), which are essential for the biosynthesis of amino acids, nucleotides, and other vital biomolecules. The process by which inert nitrogen gas is converted into ammonia is termed nitrogen fixation, and

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among the strategies employed to achieve this transformation, Nitrogen Reduction Reactions (NRR) have emerged as a focal point of research, especially in the context of sustainable and environmentally friendly chemistry.Traditionally, the conversion of nitrogen gas into ammonia on an industrial scale has been accomplished through the Haber–Bosch process, developed in the early 20th century.

INTRODUCTION TO NITROGEN REDUCTION REACTIONS (NRR)

Despite this abundance, atmospheric nitrogen is chemically inert due to the presence of a strong triple bond (N≡N) that has a high bond dissociation energy of about 941 kJ/mol. This inertness renders N_2 unavailable for direct assimilation by most living organisms, thereby necessitating its conversion into reactive nitrogen species such as ammonia (NH_3), nitrate (NO_3^-), or nitrite (NO_2^-), which are essential for the biosynthesis of amino acids, nucleotides, and other vital biomolecules, (Tari, 2015b). The process by which inert nitrogen gas is converted into ammonia is termed *nitrogen fixation*, and among the strategies employed to achieve this transformation, Nitrogen Reduction Reactions (NRR) have emerged as a focal point of research, especially in the context of sustainable and environmentally friendly chemistry, (Tari et al., 2022). Traditionally, the conversion of nitrogen gas into ammonia on an industrial scale has been accomplished through the Haber–Bosch process, developed in the early 20th century, (Asiri et al., 2021) It operates under harsh conditions, typically at temperatures of 400–500°C and pressures of 150–300 atm, using iron-based catalysts. These demanding conditions result in high capital and operational costs and present challenges for decentralization and integration with renewable. Nitrogen is one of the most abundant elements on Earth, constituting approximately 78% of the Earth's atmosphere in the form of dinitrogen (N_2) gas, (Tari, 2015a; Tari, 2015b). This inertness renders N_2 unavailable for direct assimilation by most living organisms, thereby necessitating its conversion into reactive nitrogen species such as ammonia (NH_3), nitrate (NO_3^-), or nitrite (NO_2^-), which are essential for the biosynthesis of amino acids, nucleotides, and other vital biomolecules. The process by which inert nitrogen gas is converted into ammonia is termed *nitrogen fixation*, and among the strategies employed to achieve this transformation, (Aslam et al., 2023), Nitrogen Reduction Reactions (NRR) have emerged as a focal point of research, especially in the context of sustainable and environmentally friendly chemistry. Traditionally, the conversion of nitrogen gas into ammonia on an indus-