Plasma-Assisted Nitrogen Fixation in the Presence of Water

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Abstract:

The world's economy is now entering a new era of process electrification, aimed at the possibility of eliminating natural resource overuse and minimizing CO_2 footprint. In this context, non-equilibrium plasma is considered an appealing alternative tool in many applications, including nitrogen fixation for agricultural needs (N-containing fertilizers)[1,2].

Plasma-based nitrogen fixation has received a new wave of attention due to the possible integration with renewable (green) energy sources, as well as using N_2 from the abundant, ubiquitous air and H_2 from water, as shown in Figure 1. This technology can change the current paradigm of N-containing fertilizers synthesis, moving away from large-scale manufacturing towards decentralized on-site production, i.e., small-scale portable systems.

In this work, we focuss on the role of a plasma/liquid interface in both major pathways of nitrogen fixation: reduction ($N_2 \rightarrow NH_3$)[3,4] and oxidation ($N_2 \rightarrow HNO_x$)[5–7] of molecular nitrogen. We discuss the specifics of both processes and the main fundamental challenges associated with the energy-expensive process of dissociation of the chemically inert molecule N_2, evaluating the role of vibrationally excited nitrogen ground states and nitrogen fixation kinetics in the presence of water. Finally, we address the energy efficiency of systems with and without a plasma/liquid interface and indicate the main directions towards improving the process metrics and obtaining a maximal energy efficiency.

Keywords: nitrogen fixation, non-equilibrium plasma, ammonia, nitric acid, electrification of the chemical industry.

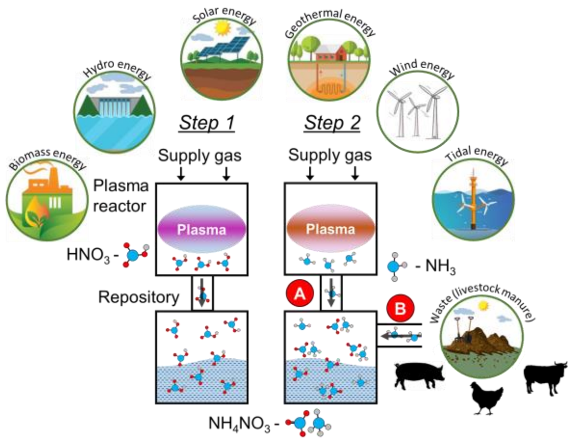

Figure 1: The concept of ammonium nitrate (NH_4NO_3) production using plasma technology. Step 1 – HNO_3 synthesis; Step 2 – Route A: NH_3 synthesis using atmospheric pressure plasma; Route B: using live-stock manure/wastewater from the farms as a source of NH_3.

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