Engineering a non-thermal plasma electrochemical device for decentralized ammonia production at ambient conditions

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Ammonia (NH_3) plays a vital role in the chemical industry, serving as a key precursor for fertilizers, pharmaceuticals, and various chemical intermediates. However, its conventional synthesis via the Haber-Bosch process is among the most energy-intensive and carbon-emitting industrial operations.[1] Finding sustainable and low-carbon alternatives for NH_3 production is thus a major challenge in chemical engineering. In this study, we present a catalyst-free plasma-electrochemical system capable of producing NH_3 directly from dinitrogen (N_2) and water at ambient conditions, using only electricity, ideally derived from renewable sources. This electrochemical device incorporates a non-thermal N_2 plasma microjet, serving as the cathode, generating reactive radical species at the plasma-liquid interface to drive the reduction of N_2 to NH_3 in aqueous media (Figure 1a). We systematically explored and optimized key design and operational parameters, including gas flow rate, plasma-liquid gap, capillary geometry, and applied current, to enhance the plasma-electrolyte interaction and maximize NH_3 yield. A maximum Faradaic Efficiency (FE) of 70% and an NH_3 production rate of 0.26 mg h^{-1} were achieved (Figure 1b), demonstrating the potential of non-thermal plasma–driven systems for decentralized, NH_3 production powered by renewable electricity.[2]

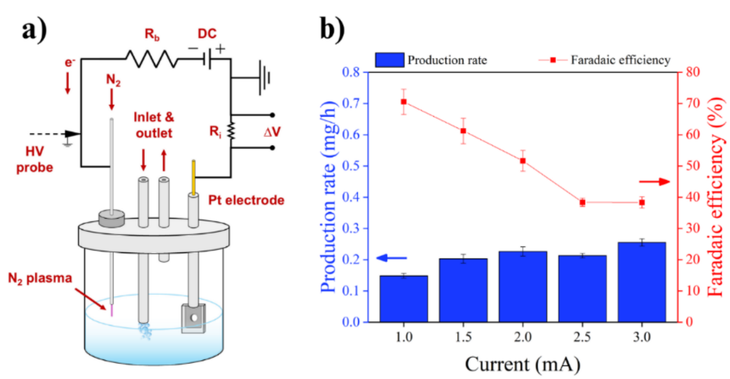

Figure 1) a) Plasma-electrolytic device and b) ammonia production rate (mg h^{-1}) with corresponding FE%.

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References

1. F. Tavella, D. Giusi, C. Ampelli, *Curr. Opin. Green Sustainable Chem*. **2022**, *35*, 100604.
2. C. Ampelli, M.L. Carreon, Y. Liu, *J. Energy Chem*. **2024**, *99*, 300-301.

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