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Nitrogen fixation using the "Propeller Arc" discharge in air

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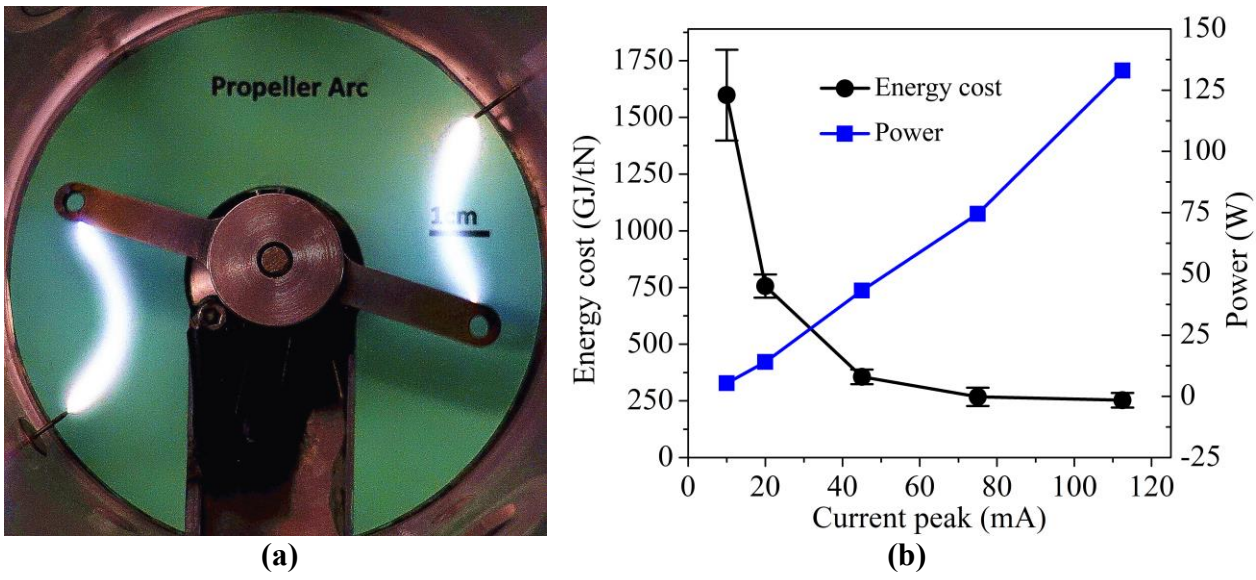
Fixation of nitrogen due to naturally occurring electrical discharges, such as lightning, is well known. Based on the same principle, reactive nitrogen produced from N_2 and O_2 by non-thermal plasma has been recently proposed as an alternative technology for agricultural nitrogen fixation. A key metric is electrical energy expended per molecule of fixed nitrogen. A novel plasma source named "Propeller Arc" (PA) was designed to efficiently fix nitrogen in air as shown in Figure 1(a) [1,2]. The PA device consists of a rotating cathode, driven by a DC motor, with a fixed anode. The device can be operated using pulse modulation or a DC power supply. Using pulse modulation, the plasma is ignited at the narrowest gap (~0.5 mm) between cathode and anode, and is then drawn away by the rotating electrode to a length up to ~55 mm. In this way, a relatively large plasma volume can be produced while achieving breakdown at a relatively low voltage. What's more, it is easy to imagine more complex and specialized versions of the design, including the use of multiple cathodes and anodes; modified diameter and shape of the rotating blade cathode; various changes in discharge power supply; coupling with gas flow control devices, etc. The primary species produced by PA operated in air under atmospheric pressure and room temperature are NO and NO_2. The energy cost of NOx production (energy expended per unit NOx produced) is measured to be lower than ~3.5 MJ/mol N, making PA a promising new device for nitrogen fixation. The coupling of PA and catalyst to reduce the energy cost has also been studied.

References

[1] X. Pei et al., Plasma Sources Science & Technology, 27(12) 125007, 2018.
[2] X. Pei et al., Chemical Engineering Journal, 362, 217-228, 2019.



(a) (b)

Figure 1. (a) Propeller Arc (PA) in air with 2 electrodes; (b) energy cost (GJ/tN) and power consumption vs discharge current peak.