PERLEMAX
Plasma factsheet

What are plasmas?

Plasmas are ionized gases, brought about by electric fields. The northern lights are a classic, naturally occurring example. Plasmas are used in industry for surface treatment, semiconductor manufacture, ozone generation, air purification, and other specialised applications.

Why use plasmas?

Chemicals from thin air

Alternatives to some expensive, highly used chemical reagents, such as bleach or peroxides, can be produced at point of use with plasmas. All that is required is electrical energy and a gas stream, such as atmospheric air, or a waste gas stream such as stack gas or steam.

Precise control of process

Plasmas can respond within microsecond or even nanosecond timescales to adjust the reaction rates to match real time requirements (such as reducing the output of oxidants as the COD in water decreases). This reduces waste energy in reagent formation, and waste energy in disposal of excess chemicals.

Reduction in resource usage

Plasmas can reduce the requirement of raw materials in chemical processes by replacing them with finely tuned electrical energy pulses applied to chemical components already present in the process. In some cases raw material requirements can even be eliminated altogether (such as ozone from air instead of chlorine).

High energy reactions at room temperature and pressure

Plasmas are capable of facilitating high energy reactions at room temperatures and pressures. Nitrate formation, for example, requires very high temperatures (such as those found in combustion processes), but nitrates can be formed in plasmas without the need for high temperature apparatus.

Put simply, plasmas can perform chemical processes with nothing but feed gas, and energy. They can be improved with their incorporation into microreactors.

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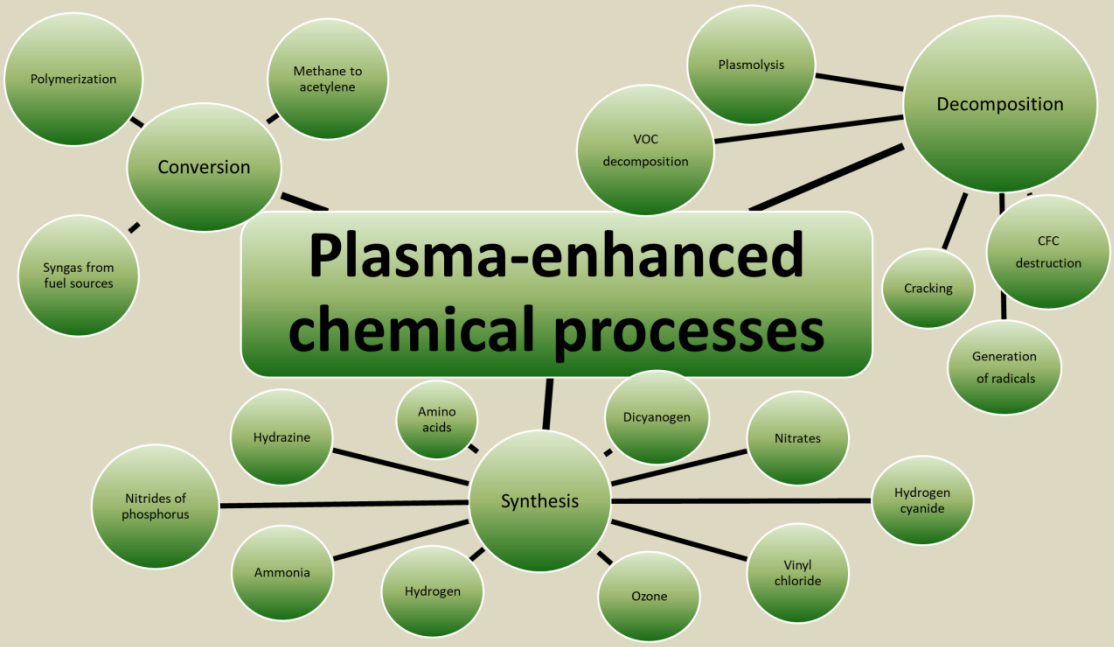

Figure 1: Overview of some plasma-enhanced chemical processes (Fridman 2008, Miller 1953)

What are microreactors?

Microreactors are miniaturised reaction systems with characteristic dimensions within the sub-micrometer and sub-millimetre ranges.

Why use microreactors?

- **Increased efficiency of mass and heat transfer processes** - due to increased surface area-to-volume ratio
- **Increased process safety** - due to decreased individual reactor volume
- **Precise control of process conditions** (temperature, pressure, residence time, reaction rate)
- Distributed chemical production and therefore **lower costs for transportation and energy**
- **Reduction in wasted energy and resources** due to precise control over chemical processes
- Possibility of a rapid shift in chemical compositions
- **Increased efficiency of catalytic processes** due to increased surface area to volume ratio
- **Rapid and convenient scale up** due to multiplexing ease
- **Flexibility of product synthesis**

(Ehrfeld *et al* 2000)

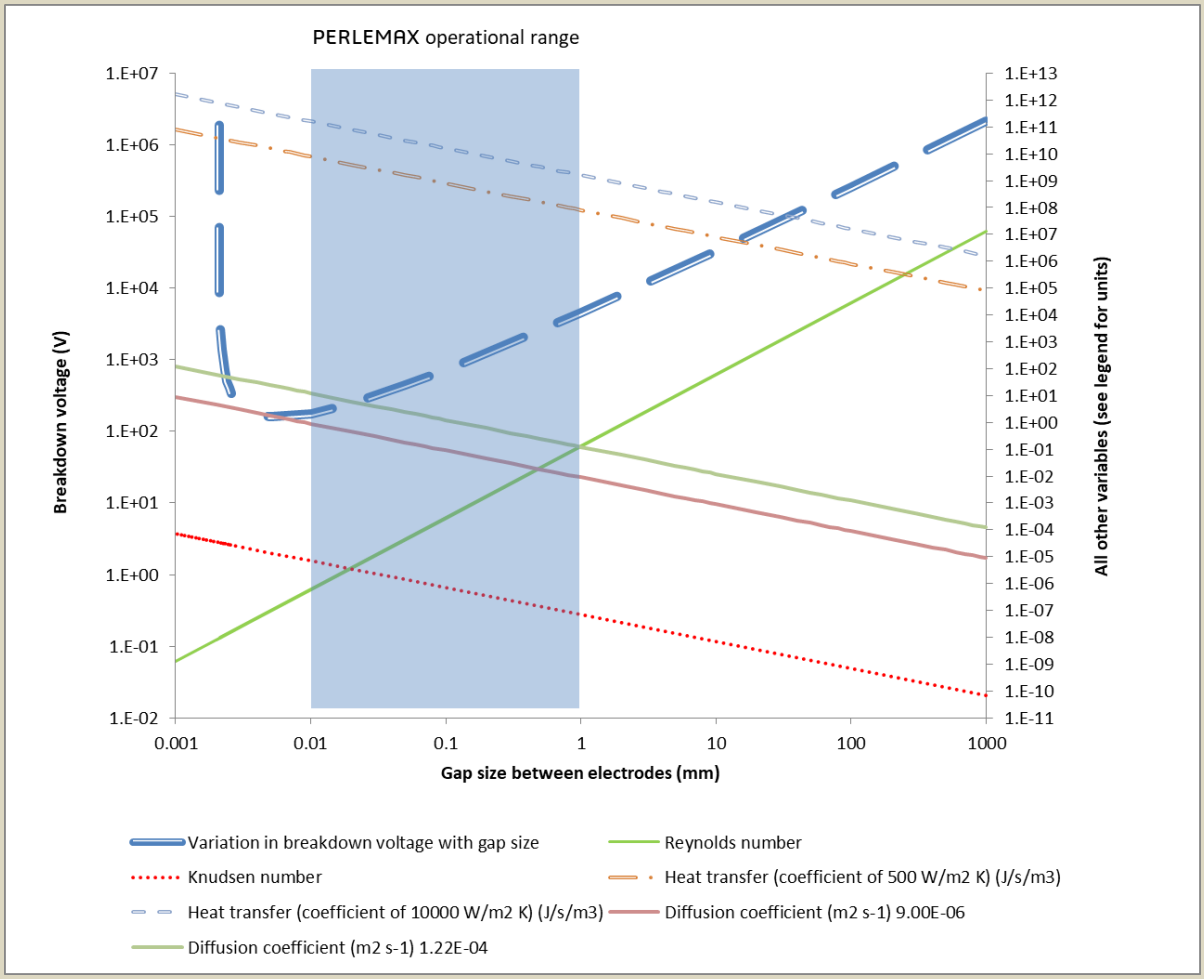

Figure 2: Graphical representation of the effects of scaled down plasma processes.

Perlemax plasma microreactors

Perlemax can combine the benefits of plasmas with the benefits of microreactors for chemical processes. Perlemax plasma-microreactors offer improved efficiencies in a number of plasma chemical processes compared to many commercially available plasma sources. Perlemax's plasma-microreactor technology can also offer alternatives to conventional chemical processes, or the means of improving existing ones.

Over the range in which Perlemax designs operate, cooling is ten times more effective, catalytic process effectiveness increases tenfold, and the breakdown voltage is lowered by thousands of volts. This all serves to dramatically improve the performance of plasma reactors over those with larger dimensions (many conventional ozone generators, for example, use inter-electrode distances on the order of 1mm and above).

What Perlemax can offer

Plasma-microbubble technology

Where the benefits of plasma chemical processes are required to be transferred to a liquid medium, Perlemax's patented process guarantees rapid mass transfer of plasma particles into the liquid media. This has applications ranging from bioreactor regulation to conventional water treatment.

In house problem solving expertise

Perlemax are able to devise, design and fabricate bespoke solutions to problems faced by industry, which can often lead to new innovations.

We are experienced in working with industrial partners to provide solutions from lab bench to pilot scale. We are always learning of new problems where plasmas and microbubbles can offer a solution.

Plasma microreactors have great potential, and Perlemax have the knowledge and skills to bring these benefits to industry.

Durable plasma microreactors

With our in-house microfluidic and plasma chemical expertise, Perlemax can design durable plasma microreactors that make use of all the benefits of microreactors whilst overcoming the drawbacks of many microplasma sources (such as their limited lifetime). Examples of applications include:

- Water and wastewater treatment applications
- Treatment of lignocellulosic biomass
- Applications in laundry processes
- Plasma-microreactors for research applications

Residence time optimisation

Optimum residence time is one of the major factors affecting performance and is found by chemical kinetic studies.

The basic principle is that conditions within a reactor are at first productive for a given chemical, but then become destructive. The chemical is then removed from the destructive conditions as quickly as possible.

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Figure 3: Plasma bubble reactors installed into a pilot plant.

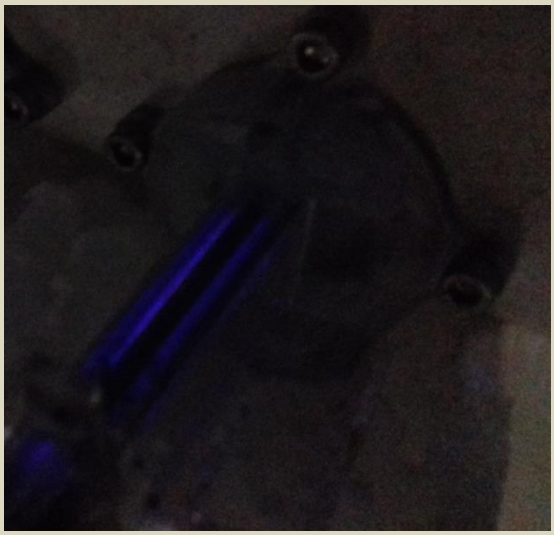

Figure 4: Close up of a plasma bubble reactor installed in a pilot plant.

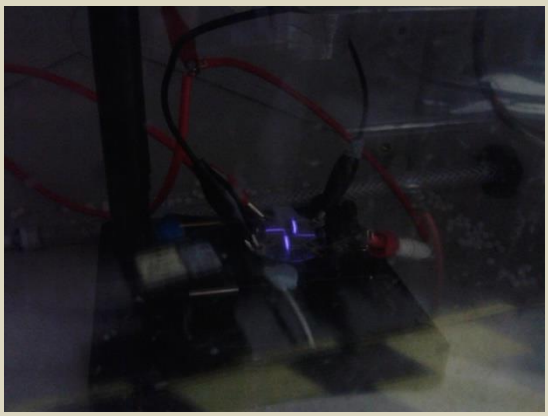

Figure 5: An operational plasma-microreactor unit, designed to be easily multiplexed.

Figure 6: A plasma microreactor unit on "full throttle"!

Figure 7: A sub-millimetre diameter plasma jet with fluidic oscillation.

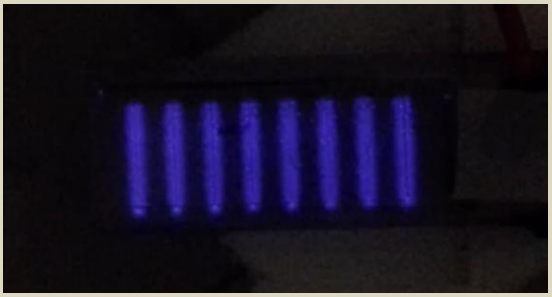

Figure 8: A 2D plasma-microreactor wafer for process optimisation.

Figure 9: Controlled spatial distribution of plasma streamers for process optimisation.

References

Ehrfeld, W., Hessel, V., Lowe, H., (2000) *Microreactors: New Technology for Modern Chemistry*. Wiley-VHC

Fridman, A. (2008) *Plasma Chemistry*. Cambridge University Press

Miller, S.L., A production of amino acids under possible primitive earth conditions. *Science, (1953)*, 117(3046), pp.528–529

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