Technical Meeting on Emerging Applications of Plasma Science and Technology

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Catalysis and plasma processing: The tip of the iceberg

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Several renewable energy harvesting technologies have matured and become affordable and the main output, renewable electricity, is becoming a commodity. The new challenges are short and low-term storage, as well as its conversion into dense, easily transportable forms. Gases and liquids are energy-dense storage media, and the handling infrastructures are already well established for several important chemicals. Renewable electricity-to-chemical conversion processes are not common and are rarely deployed at scale. Plasma processes are uniquely poised to play a significant role in this transition. Near-equilibrium (thermal) plasmas (e.g. plasma torches, electric arc furnaces) have been used for decades for niche gas conversion applications and not only for highly endothermic reactions (e.g. dry reforming of methane, hydrogen production from methane). Transitional (warm) plasmas (e.g. gliding discharges) are already used with lesser endothermic reactions, such as hydrogen production from hydrogen sulfide. Historically, there has been less interest to use non-equilibrium (cold) plasmas (e.g. dielectric barrier discharges, atmospheric pressure glow discharges) for gas conversion, mostly because of their much lower power densities. There are also additional challenges associated with high-throughput requirements which, traditionally, require pressures far above atmospheric where non-thermal plasma generation and maintenance is uneasy. Times are changing though, and new design criteria appear, such as small scale, on-demand, and/or distributed electricity conversion and storage which open the paths to non-thermal plasma processes. There is hope that the non-thermal plasma will compensate for the loss of activity associated with the lower temperatures by locally producing active radicals by electronic impacts, and that cheaper and greener catalysts will be developed thanks to the milder conditions. Nowadays, non-thermal plasma catalysis rapidly gains interest in the plasma processing community. The premise is that the catalyst plays its usual role of lowering the energy requirement/providing the kinetics, while the non-thermal plasma provides the activation energy, excited and dissociated species, photons, electric field, and localized heating. Recent studies highlighted the vast realm of possible applications, plasma-catalyst interactions and complexity, as well as the limited knowledge we gained thus far. Unfortunately, most research work has thus far been heavily inspired by conventional thermal catalysis. As recently stated, “the largest potential benefits of plasma-driven catalysis are in regions of operating parameters space far from that where conventional thermal catalysis is most optimal [1]”. This tells us that “standard”catalyst materials may no longer work as well due to favorable plasma-catalyst interactions. Furthermore, contrarily to thermal processes with their characteristically large inertia and time constants, plasma excitation and dissociation processes occur on a sub-ns time scale, fast reactions and localized catalyst particle heating in the ⊠s, slow reactions and bulk heating in the ms to s range. The temporal aspects have thus far not been exploited. Finally, plasma processes offer unique environments for the synthesis on non-conventional catalysts such as highly energetic phases, mixed and high-confined metal nanostructures, and catalyst reactivation. These are all vastly unexplored territories. In this talk, I will review the latest work in plasma catalysis and highlight several opportunities for fundamental research and technology development.
1: https://doi.org/10.1021/acsenergylett.9b00263

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