Plasma assisted oxygen functionalization of olefins

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Abstract: The non-thermal plasma behind plasma synthesis with organic liquids is an exciting branch of plasma science and engineering. We are interested in the conversion of ethylene to added-value, oxygen-functional organics using non-thermal plasma technology. Their application range includes pharmaceutics, food conservation, advanced materials, pesticides and solvents.

Keywords: Olefins, ethylene, oxidation, non-thermal plasma technology

Organic chemistry plays an essential role in our daily lives, as it is the source of many products that we use regularly Organic molecules such as proteins, carbohydrates, and lipids are essential to life, and their synthesis and breakdown are carried out through organic chemistry pathways. The current processes for pharmaceutics, food conservation & additives, pest control, dyes, advanced materials are all made through classical thermal pathways that use fossil feed stock (oil & natural gas). Of particular interest is ethylene [1], a major building block in organic synthesis. It is an unsaturated hydrocarbon (olefin) with the molecular formula C_2H_4. It is the simplest member of the alkene family, which are organic compounds that contain a carbon-carbon double bond.

Fig 1 show some typical added value organics products based on ethylene, finding application in polymers & resins, special solvents, advanced materials and precursors for pharmaceutics.

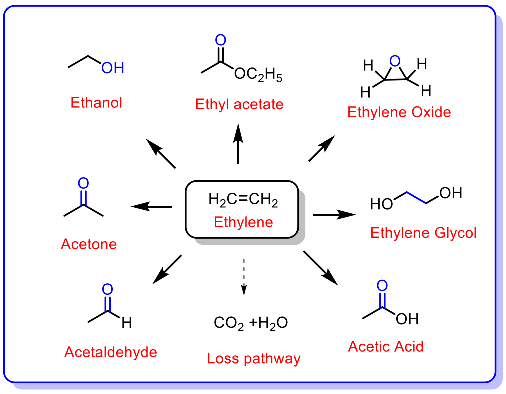

Fig 1. Classical synthesis of oxygen functional compounds via olefins

Chemical reactions involve overcoming the activation energy barrier, typically achieved through thermal activation in classical pathways. This involves the application of electrical energy for heating, resulting in molecular collisions and the production of translation energy, leading to the formation of radicals. Alternatively, energy obtained from natural gas or gasoline combustion can be used to induce vibration excitation of reactants via infrared photons. Therfore, broad-range excitation can activate multiple reaction pathways, leading to non-optimal energy efficiency. On the other hand, plasma processes directly apply electrical energy to activate species to higher energy states and produce radicals. By utilizing pulsed power technology to efficiently generate energetic electrons, vibration excitation of reactants can be induced depending on the applied energy density and electron distribution function. This allows for selective tuning of reaction pathways through non-thermal plasma technology, resulting in improved energy efficiency. Additional benefits are autonomous operation and scalability.

In classical thermal chemistry, transition metal catalysts are used in organic transformation, it has been used to oxidize the ethylene to aldehydes, which is one the famous name reaction developed by German research team [2] called “Wacker Oxidation” (**Fig 2**).

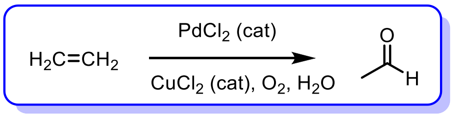

Fig 2. Wacker oxidation

Generallly these reactions take place under severe reaction conditions like enhanced temperature & pressure. Additionally several synthesis steps are needed involving high amounts of solvents and catalytic materials.

Hereby, we provide a possible alternative to thermal activation by using non-thermal plasma technology (**Fig 3**). Several process parameters are available in plasma chemistry, like energy density, voltage wave shape, electrode topologies, precursor recipies & auxiliary additives, pressure and temperature. We’ll report on benchmarking plasma pathways of ethylene/olefin oxygen functionalization relative to classical thermal activation and will focus on improved production energy efficiency and product selectivity. Infrared spectrometry and gas chromatography-mass spectrometry will be applied as physical-chemical diagnostics.

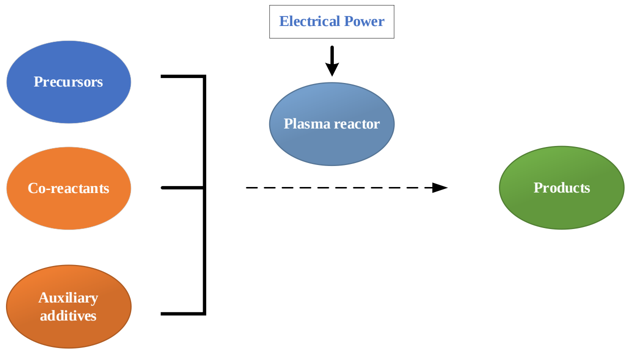

Fig 3. A Schematic of plasma-induced hydrocarbon functionalization

References

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