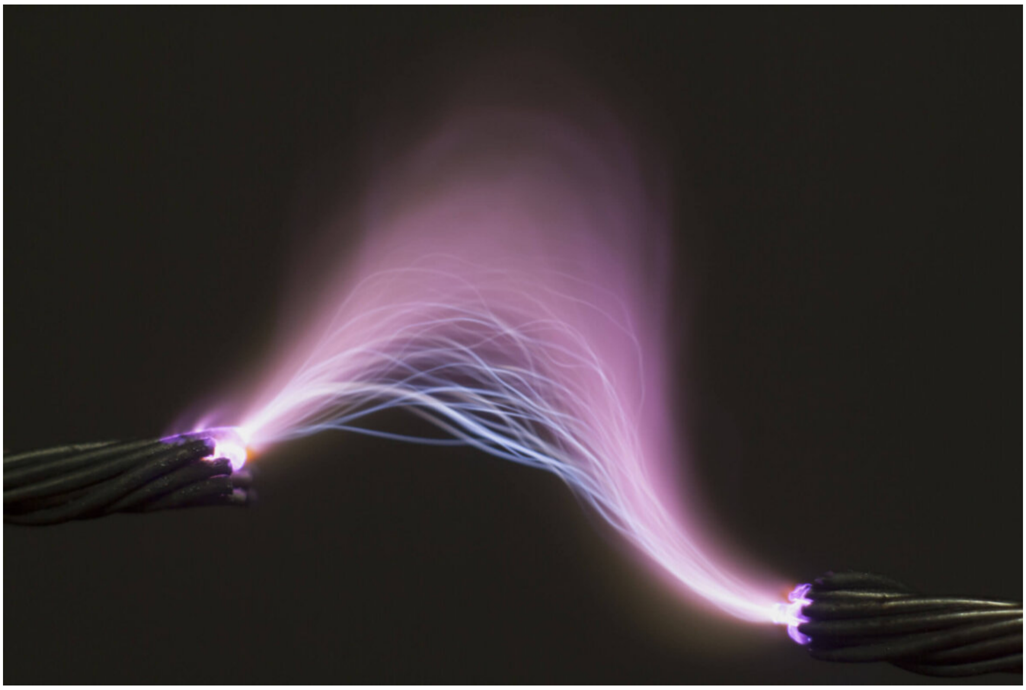

Four more technologies for turquoise hydrogen

By Stephen B. Harrison on Sep 13, 2021 | Translate NEWS

Turquoise hydrogen technologies are being developed by an increasing number of start-ups. Names like Monolith Materials, C-Zero, and Hazer are being joined by Transform Materials, Plenesys and Ekona Power.

The chemistry of turquoise hydrogen production by methane pyrolysis is similar in each process: the methane molecule is split into hydrogen and solid carbon through the application of energy at a high temperature and in the absence of oxygen.

Methane splitting was described by Louis S. Kassel in his 'Thermal decomposition of methane' paper of 1932. The reaction pathway is methane to ethane (some hydrogen is released) to ethylene (more hydrogen is released) to acetylene (yet more hydrogen is released) to carbon (the final hydrogen atoms are split from the carbon atom).

Monolith Materials has the highest level of technology maturity of the various turquoise hydrogen start-ups. Its process builds on the technology developed more than two decades ago by Kværner, and uses DC power to generate a high temperature hydrogen plasma. Methane flows through that plasma as it is split to form more hydrogen and carbon black.

Carbon black can be used in tyre production to facilitate vulcanisation of the rubber or in other plastics and rubber applications. In addition to carbon black, Monolith Materials will focus on the conversion of turquoise hydrogen to ammonia for use as a fertiliser in the US corn belt, where their plant is located.

Carbon black is required to make tyres.

AC Plasma for distributed hydrogen production

The French start-up Plenesys uses AC power to generate plasma. The use of AC electricity stabilises the plasma and eliminates the need for an external magnetic field to control the plasma. Also, no argon gas is required to enhance the plasma.

A strong feature of the Plenesys technology is automatic replacement of the graphite plasma torch electrodes so that the system can operate continuously. During pyrolysis, the graphite electrode is gradually consumed, and some turquoise hydrogen processes require periodic shut down to replace the electrodes. The automated replacement eliminates the need for periodic plant cooling, electrode replacement and re-start.

The international conviction to use hydrogen will stimulate major infrastructure investments such as hydrogen distribution pipelines. Regional liquid hydrogen storage and distribution networks will also emerge. However, the hydrogen transmission infrastructure is not yet mature.

Localised hydrogen production and utilisation can jump-start the hydrogen economy. Plenesys will exploit this with its small scale, low-CAPEX onsite turquoise hydrogen generator. It is a plug-and-play solution for small to mid-scale on-site hydrogen supply and would suit, for example, fuelling stations to enable them to add hydrogen to their fuels offering. Its basic unit is designed to produce 100 tonnes per year of hydrogen at a consumption of 100kW of power. A larger unit with a 1MW plasma torch producing 1,000 tonnes per year of hydrogen is also in development.

80 years of ultra-high temperature plasma pyrolysis

In the city of Marl, Germany, an ultra-high temperature electrical plasma technology has been used for more than 80 years to crack hydrocarbons to produce chemicals such as acetylene. With such a long track record, the Marl process is certainly the grandfather of plasma pyrolysis.

The Marl process uses a 10MW electric arc that is generated between carbon steel electrodes in a reactor that is 2m tall and 0.15m in diameter. The maximum temperature of the plasma is 20,000 °C – more than three times hotter than the surface of the sun. The gases are quenched using a direct contact water spray and exit the reactor at approximately 1,200 °C.

The temperature reduction terminates the reaction to optimise production of acetylene because, at Marl, that is the target gas. Acetylene is used to produce petrochemicals and the carbon powder is burned in a nearby power plant. If the carbon powder were to be processed into pellets, it could be used as a coke-substitute in steel making, which is a major industry in the German state of North Rhine-Westphalia, where the City of Marl is located.

At present, about 20 tonnes per day of hydrogen is produced as a co-product. The technology and know-how accumulated over these decades of operation can be modified and applied to optimise the process for low-carbon turquoise hydrogen in the future.

Based on natural gas prices in the region, the Marl process could generate turquoise hydrogen at around €2/kg. That is substantially less than the cost of green hydrogen from electrolysis. At present, CCS is not possible in Germany so, there is no possibility to produce blue hydrogen from natural gas reforming with CCS.

If the solid carbon from the Marl process could be stored or used in a way that avoids CO_2 emissions, if the methane is from biogas and the power for the arc is from renewable electricity, then this method of turquoise hydrogen production could contribute to a decarbonised energy system in Central Europe.

Microwave plasma pyrolysis

Moving from two European cases to North America, the start-up Transform Materials relies on microwave plasma energy to split methane molecules in its turquoise hydrogen process. There is a similarity to the Marl process here, because the Transform Materials technology can also produce acetylene. The trick is to stop the Kassel reaction pathway of thermal methane decomposition at precisely the right point.

Following the microwave plasma reactor, the Transform Materials process uses temperature swing adsorption (TSA) to remove heavier hydrocarbon impurities from the product gas stream. Then, the lighter hydrogen and acetylene leaving the TSA are separated to capture the acetylene. Finally, the hydrogen is purified using a pressure swing adsorption (PSA) system, which is a common final-stage hydrogen purification technology.

Microwave energy was also used by Atlantic hydrogen in their turquoise hydrogen pilot plant in Eastern Canada. Today, the New-Brunswick based start-up Nu:ionic is also developing microwave based catalytic reforming to produce hydrogen in a process with integrated carbon capture.

Pulsed methane pyrolysis

All the processes above use electrical power and plasma to perform methane pyrolysis. In contrast, the Canadian start-up Ekona Power has developed a process known as pulsed methane pyrolysis. It uses heat recovery and combustion to generate the heat energy and high temperatures that are required to drive the methane splitting reaction.

The process starts with preheated methane admitted to a feedstock reactor and a fuel and oxidant admitted to a combustor. Combustion is initiated and the energy released is used to directly raise the temperature of the methane in the feedstock reactor where is splits into hydrogen rich gas and solid carbon products. These products are exhausted from the reactor and following separation stages remove the solid carbon, then separate the hydrogen from other gases. These gases are recycled back to the feedstock reactor and combustor to be reprocessed and combusted, respectively.

This cyclical process is repeated, and multiple reactors are operated such that a continuous output of hydrogen and carbon are produced. The pulsating flow overcomes carbon fouling which can be a problem with some other types of pyrolysis reactors.

While some of the combustion energy is provided by burning hydrogen, a small amount of other carbon containing gases are also consumed and vented. Therefore, the process does result in CO_2 gas generation, however, the quantity of CO_2 produced per kg of hydrogen is significantly less than from steam methane reforming. As with reforming, the CO_2 can be captured and stored or utilised to minimise the carbon footprint of this technology.

Ensuring that turquoise hydrogen is green

In some of these turquoise hydrogen processes, the energy is from electricity, which can be from a renewable source to reduce the carbon intensity of the process. The methane can either be from natural gas, or biomethane to yield low-carbon hydrogen.

A critical point to consider in the greenhouse gas (GHG) emissions life cycle analysis of these technologies is how the solid carbon will be used. If it is locked away, there are no carbon dioxide (CO_2) emissions. If it is burned or used as a coke substitute without carbon capture and storage (CCS), then CO_2 emissions will be the result.

Turquoise hydrogen has the potential to be a low-cost, low-carbon source of hydrogen. The technology can be applied at scale for centralised production combined with gas or liquid hydrogen distribution. Or it can be used in smaller decentralised plants for on-site hydrogen production. Whilst blue and green hydrogen have been getting a lot of attention recently, we are likely to hear much more about turquoise hydrogen in the future.

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