Carbon Recycling Technology (CART)

Modular carbon recycling technology for transformation of non-recyclable plastic waste into valuable chemicals and fuels

Category
Cleantech

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Background

The conversion of waste plastics into valuable chemicals and fuels has attracted crucial interest worldwide.

Problems with today's solutions. Catalytic depolymerization is a technology that tackles plastic waste pollution by converting end-of-life waste destined for landfill or incineration, or that ends up in our oceans, into chemical feedstock. This feedstock can be separated into components to generate useful chemical platforms for the manufacturing industry, such as olefins used to create virgin-like recycled plastics (closed-loop Plastic-to-Plastic) or advanced fuels for sectors that are difficult to be electrified (e.g. aviation).

• The biggest problem of current thermochemical technologies for tertiary recycling of plastic waste, such as pyrolysis, is that they give rise to a heterogeneous hydrocarbon mixture over an extremely wide range of molecular weights (C6-C50). For example, gas and wax are the two main by-products obtained during the pyrolysis of plastics for liquid fuel generation. The wax formed causes operating problems by plugging the product lines and condenser tubes, while the gas lowers the oil yields.

• Furthermore, a reactively broad spectrum of products is generated from the thermal degradation of macromolecules to small molecules complicating their utilization on an industrial scale at present. Therefore, the raw products have to undergo extensive downstream catalytic upgrading prior to being used, for example, as a clear naphtha or transportation fuels, making these processes inefficient at small and medium scales.

Technology Overview

UCL Chemical Engineering researchers have developed a novel and patented technology that combines catalytic depolymerisation and product refining into one single reactor, with extremely high liquid purity and yields in the range of C5-C19, which is particularly relevant to naphtha and jet fuel fraction.

The process is based on a novel, modular multi-stage fluidised bed technology, and further tested and validated through collaboration with Heathrow Airport. The resulting liquid product is a chemically clean, sulphur-free hydrocarbon mixture which can be easily upgraded into jet quality kerosene or synthetic olefins. Residual heat and gases are also recovered from the process to be used in the first depolymerization step, therefore requiring no additional energy input to the process.

Stage of Development

In 2019, UCL built a small pilot UMR unit connected to an existing thermal reactor for plastic waste treatment. Once constructed, a commissioning and extensive testing programme was undertaken for 12 months. The programme:

• demonstrated that waste-derived plastics can be converted to high-value products using a design appropriate for small-medium scale operation (50-100 kg/h plastic input)

• confirmed the final process is environmentally viable and provided a tangible demonstration to the low-carbon investment community and other stakeholders.

Based on the successful technical programme undertaken on the small pilot (TRL5), the technology is now ready for testing at the demonstration scale (TRL6-7).

Benefits

The modular Carbon Recycling Technology (CART) developed by UCL can take the non-recyclable plastic waste and convert it into a high-quality product suitable for new materials or substitute fuels production, with unprecedented conversion efficiencies and products selectivity.

The product is highly hydrogenated, meaning that no additional reforming is needed, for example, to be used in industrial naphtha crackers for plastic production. In addition, the absence of contaminants, as well as the low olefin and aromatic content in the oil, ensure excellent burning properties in commercial jet engines, with much lower associated fuel consumption and polluting emissions (PAH, NOx, CO, SOx, etc), when compared to existing fuels.

The CART technology can be described by 6 key features:

• CLEAN: simultaneously removes plastic from the environment and displaces fossil fuels from the economy

• ROBUST: The process can handle plastic waste streams with limited sorting and pre-treatment providing a valid alternative to expensive separation, landfill and incineration;

• FLEXIBLE: The process is highly adaptable and can be tailored to feedstock and product requirements;

• MODULAR: Small and compact design for distributed utilization; reduced waste transportation emissions;

• DROP-IN: Products are substitute fossil fuels without adaption to distribution or refinery infrastructure;

• ZERO EMISSIONS: residual carbon can be recovered as pure carbon or CO2 stream (no product gas separation, CCS-ready)

Applications

UCL’s concept of chemical recycling (Carbon Recycling Technology, CRT) is targeted toward “end-of-life plastic” that cannot be mechanically recycled. This is a result of both of the current technical limitations of mechanical recycling, including the number of times plastics can be mechanically recycled, and the quality of recyclate it produces, which often is not suitable for food-grade applications. End-of-life plastics are plastics that are mixed, contaminated, multi-layered, as well as plastics that can no longer be mechanically recycled. So, CRT can complement mechanical recycling by diverting plastic waste from landfills or incineration, creating a fully circular economy.

The product can find multiple applications in the manufacturing or fuel industry, including:

• Production of substitute jet fuel. The kerosene fraction produced by the process is of very high quality and provides a cleaner alternative to current JetA1 fuels.

• Naphtha for plastic production. The process can be tuned to produce a significant fraction of naphtha product (up to 60-70%), which in turn can be used for polyolefins manufacturing (i.e. recycled plastics). The embedded use of electrolytic hydrogen in the process makes the naphtha product of superior quality compared to other competing technologies, avoiding the use of additional hydrocracking treatment before use in existing steam crackers.

• Other applications. The technology has so far been tuned to focus on a kerosene-like fraction and its primary use as jet fuel, and naphtha like fraction which can be used as fuel (blended with gasoline) or steam cracked to produce chemicals. There is also a smaller LPG like fraction that could be used as a fuel (e.g. forklift trucks) or as a chemical feedstock. With specific design changes, CART could be tuned to produce different hydrocarbons, including Benzene, Toluene and Xylene (BTX) that has uses in both fuels and chemicals.

Opportunity

The UCL team is primarily seeking partnership and investment to build a large pilot or demonstrator plant that would advance TRL to a level of 6 or 7.

The team is also looking at engaging with commercial partners to explore the value and feasibility of different commercial opportunities.

Seeking

Development partner, Commercial partner, Licensing, Seeking investment

IP Status

Patented