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Hydrogen and Solid Carbon Production by Discharge Plasma Decomposition in Liquid-Phase Hydrocarbons

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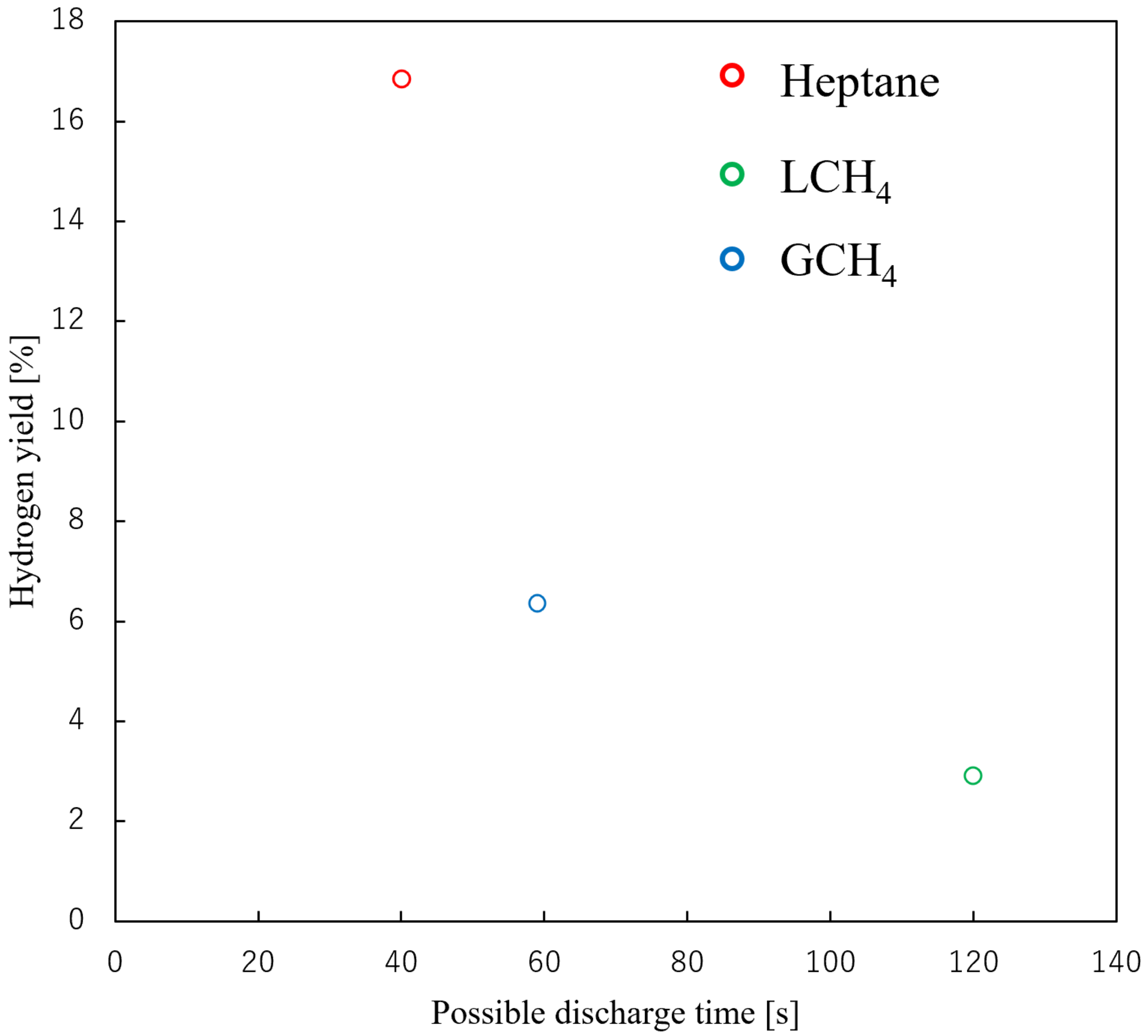
Turquoise hydrogen production has attracted attention as a promising route for producing hydrogen without direct CO2 emissions. Among several approaches, plasma-assisted reactions can provide localized high-energy input and are expected to promote hydrocarbon decomposition. In this study, discharge decomposition in high-density liquid-phase hydrocarbons was investigated by focusing on the localized high-energy field generated by plasma. The objective was to clarify hydrogen production characteristics different from those of gas-phase reactions.

The experimental apparatus consisted of gas supply, cooling, reaction, and product gas analysis sections. The reactions were conducted in gas- and liquid-phase hydrocarbons using an igniter with vertically arranged electrodes. Carrier gas was supplied from the lower electrode to generate bubbles near the electrode tip. In the gas-phase experiments, hydrocarbon gas was introduced after nitrogen purging, and discharge was generated while the gas was supplied near the igniter tip. In the liquid-phase experiments, nitrogen gas was supplied from the igniter tip installed in the liquid-phase hydrocarbon to promote bubble formation and discharge-path formation. The product gas was analyzed using gas chromatography and a hydrogen concentration meter, and the generated solid carbon was evaluated by SEM and EDX.

Fig. 1 shows the discharge duration and hydrogen yield obtained during discharge reactions in hydrocarbons. When the reaction was conducted in heptane, the hydrogen yield reached 16.8%, which was higher than those obtained under the other conditions This result is attributed to the localized concentration of discharge energy inside bubbles or near the gas–liquid interface, where a high-energy reaction field may be formed. Therefore, a larger fraction of the discharge energy may have been used for hydrocarbon decomposition. The discharge duration was also extended when carrier gas was supplied from the electrode tip compared with the case without carrier-gas supply. This result may be attributed to bubble-induced liquid flow, which may have suppressed carbon accumulation on the electrode surface. This suggests that liquid-phase discharge can delay short circuiting caused by carbon deposition, providing an advantage over gas-phase discharge.



Discharge Duration and Hydrogen Yield in the Liquid and Gas Phases

These results suggest that liquid-phase plasma decomposition can utilize the localized high-energy nature of plasma by concentrating discharge energy inside bubbles or near the gas–liquid interface. Hydrogen formation from hydrocarbons that are liquid at room temperature also suggests the potential application of this process to hydrogen production and carbon fixation using hydrocarbon-based waste liquids as feedstocks.