E-Field Enhanced Thermo-Catalytic Decomposition (TCD) of Methane

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Thermo-catalytic decomposition (TCD) of methane, an alternative energy technology that produces turquoise hydrogen, is an envisioned bridge to the hydrogen economy. For both TCD and associated regeneration reactions, an applied electric field (E-field) offers the potential for maintaining and increasing the reaction rate, either through an increase in the number or type of active sites or a shift in their energy level. Two complementary experimental configurations are being tested: (1) a capacitive configuration (high voltage, near-zero current) using either a parallel or radial electrode configuration, and (2) a resistive (low voltage, high current) using Joule-based heating. The capacitive configuration is well suited for collecting kinetic information via FTIR while the Joule-based system is best suited for active site measurements of the deposited carbon by TPD or XPS. In conventional TCD, deposited carbon covers active sites, leading to declining rates and catalyst deactivation. Catalyst regeneration then requires gasification. As verified by SEM/TEM, the E-field facilitates non-planar dendritic carbon growth, maximizing surface area and thereby increasing the number of active sites available for catalyzing reactions. This unique carbon growth pattern could make E-field TCD autocatalytic. E-field TCD was found to have a 36% lower activation energy (90 vs. 140 kJ/mol) with a higher conversion rate at lower temperatures than standard TCD. Notably, a hydrogen conversion of 65% was achieved with 75% SNG at 1050 °C. The E-field promotes free-space conversion that does not clog the reactor and can be cleaned by mechanical means. Raman analysis on graphite, as a model carbon, showed that partial gasification by CO_2 using Joule-based heating left a morphology that was significantly more amorphous as compared to partial gasification using a thermal furnace at the comparable temperature of 1000 °C, leading to the postulate that Joule-based heating may be more effective at producing active sites during gasification reactions.

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