Large-Scale Production of Fullerenes, Carbon Nanotubes and Fullerenic Materials

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The manufacturing cost of C_{60}, C_{70}, higher fullerenes, fullerene black and carbon nanotubes has been greatly reduced by controlled premixed combustion of hydrocarbons. The potential of the combustion method for targeted large-scale production of different classes of fullerenic materials resulted from three decades of combustion control research in the Department of Chemical Engineering at MIT involving detailed characterization of materials collected in well-defined flames. Fullerenes of molecular weight up to C_{116} were identified by analysis of toluene extracts of condensable combustion products using high-pressure liquid chromatography with UV-vis and mass spectrometric detection. UV-vis spectra were measured for fullerenes up to C_{108} and isomers were discerned for C_{78}, C_{90} and C_{94}. Abundances of nearly all fullerenes larger than C_{70} were found to be significantly higher in the combustion method than in the electric arc discharge method which had previously been used for fullerene synthesis. Evidence of growing commercial interest in numerous applications of fullerenes together with the need for lower-cost and scalable fullerene production methods led in 2001 to the founding of Nano-C as licensee of the patented MIT technology. The mission of Nano-C is to commercialize these products while further developing the process to a large industrial scale. Major improvements in fullerene production technology were achieved through better understanding of the chemical mechanisms and kinetics involved in the formation of different carbonaceous materials such as soot and fullerenes, and in the competition between these alternative product routes. Optimized operating parameters and process control have led to significantly improved conversion efficiencies of the initial fuel and abundances of extractable fullerenes of more than 90% of the condensable reactor product. This advanced reactor capability together with improved purification technology allows Nano-C to supply high-purity fullerenes up to C_{96}. Nano-C develops and produces fullerene derivatives for a large range of applications including photovoltaic devices. The company also produces single-walled carbon nanotubes using combustion modified by the addition of suitable catalyst precursors to non-sooting hydrocarbon flames. Both fullerene- and nanotube-producing combustion processes are exothermic, a characteristic which is expected to simplify scale-up significantly. Concentrations of H_2 and CO between approximately 20 and 50% in the exhaust gas allow for energy generation either in the form of thermal energy by means of an afterburner or in the form of hydrogen. In the latter case, CO is converted to H_2 by means of the water-gas-shift reaction, which opens the door to many alternative energy applications.