Evolution of Fullerene Production by Combustion: From Kilograms to Tons and More

J. Michael Alford[1], Matthew Cates[1], Michael D. Diener[1], Hiroaki Takahara[2], Mineyuki Arikawa[2], and Hideki Murayama[2]

[1]TDA Research, Inc.
12345 West 52nd Avenue, Wheat Ridge, CO 80033, USA

[2]Frontier Carbon Corporation
Kyobashi Nissyoku Blvd. 1-8-7 Kyobashi, Chuo-ku, 104-0031 Tokyo, Japan

Recent developments suggest that commercial uses of C_{60} in such diverse areas as fuel cells and pharmaceuticals for AIDS and Parkinson's disease may not be far away. However, one critical factor that has limited the development of such applications is the high cost and limited availability of fullerenes. Much of this problem is due to the small-scale, batch nature of fullerene production using carbon arcs. In contrast, the combustion method generates soot with a very high yield of fullerenes using a continuous and easily scalable process similar to that employed for commercial carbon black production. In addition, the precursors are cheap, readily available feedstocks such as benzene that are combusted with oxygen in specially designed burners operating at low pressure.

Unlike the carbon arc, which utilizes pure carbon, the sooting flame contains substantial hydrogen. In the carbon arc this is known to be very detrimental to fullerene formation. However, at the conditions present in the sooting flame, fullerenes are the most thermodynamically favored form of carbon, and since many suitable kinetic pathways for their formation are available, they should constitute the majority of the soot. We will outline the basic thermodynamic and kinetic processes involved in production of fullerenes by combustion and show that combustion is the cheapest known method for fullerene production. This point will be demonstrated by showing how over the past ten years the combustion process has evolved from small research machines producing only grams or kilograms to industrial plants capable of producing metric tons of extracted fullerenes.