graphite/metal-oxide disks. This work was largely motivated by the prospects of using such endohedral TM metals for their catalytic activity without the well-known difficulties of effective support media and lack of control over particle size. Thus, while it will certainly be important to discover ways to efficiently scale up production (e.g., the solar generation method explored with DOE support), our efforts have concentrated more on characterization, purification, and manipulation of doped fullerenes.

Carbon nanotubes and continuous carbon fibers. For the past two years, much of the group's effort has involved the production, purification, and characterization of carbon nanotubes, novel objects holding a wealth of promise for materials applications. While pursuing the controlled growth of continuous individual nanotubes from seed crystals, several noteworthy advances have been achieved as offshoots. First, by microscopic analysis of nanotubes grown in the arc struck between two carbon electrodes, we were able to construct the first detailed model of nanotube formation as well as the source of defects in this principal production method. Also in the course of experiments aimed at controlled growth, we came to investigate the field-emission behavior of nanotubes. Our studies have led us to a model in which the electron-emitting structure is not simply the nanotube tip, but rather a single chain of carbon atoms, an atomic wire, unraveled from the tip, forming possibly the sharpest, strongest possible field-emitter. Furthermore, since the energy and angular distributions of emitted electrons are likely to be far narrower than those of any existing field-emission tips, these objects may prove to be of tremendous practical import.

Concurrent with this work, a remarkable discovery was made during laser-vaporization production runs of metalofullerenes. We found, during control experiments in which no metal was mixed into the graphite target rod, an abundance of nanotubes deposited on the cold copper collector at the end of the heated quartz flow tube. This discovery, under circumstances in which no extrinsic factors (e.g., a metal particle, electric field, hydrogen atoms) were present to help keep the nanotube tip open, led to a growth model in which the growing open end of the nanotube is stabilized against closure by an *intrinsic* factor: carbon adatoms "spot-welded" in positions between adjacent layers. Indeed, these spot-welds are likely to be important for multiwalled nanotube growth under *any* circumstances. We have demonstrated, however, that spot-welds cannot by themselves be sufficiently stabilizing to keep the tip open indefinitely. Our field-emission experiments on single mounted nanotubes confirmed the hypothesis, previously postulated by grantee, that the electric field of the arc is necessary to hold the tip open. Soon thereafter, single-walled nanotubes were synthesized by laser-vaporization by utilizing the catalytic properties of transition metals mixed into the graphite target. This work has likewise led to a firmer understanding of single-walled nanotube growth, and may be of practical significance for their bulk production.