infertility research, which is a multi-
crore business/industry, may be a good
way of attaining self-sufficiency in this
industry.

In vitro fertilization techniques are
mainly offered by the private sector,
which is very heavily dependent on im-
ported drugs, equipment and devices in-
cluding disposable plasticware used in in
vitro culture. Consequently, the cost of
IVF is extremely high in India and una-
fordable to many. Research into aspects
of human reproduction is almost non-
existent in the private sector and there is
hardly any scientific paper that emerges
from Indian laboratories or clinics prac-
tising IVF. In the symposium, collabora-
tion between the private and public sector
funding agencies was stressed. Examples
were given of the programmes available
under the Department of Scientific and
Industrial Research such as the Program
Aimed at Technological Self-Reliance
(PATSER) and Co-operative Research
Associations that enable the establish-
ment of research centres as a collabora-
tive effort between the private sector and
Government funding agencies. This as-
ppect was appreciated by the participants
who endorsed the view that similar col-
aborations must be established between
private IVF clinics and even the ICMR to
address issues that are of common inter-
est and are aimed at improving patient
care and more importantly, providing in-
digenous substitutes for imported equip-
ment, supplies and drugs.

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RESEARCH NEWS

An elegant synthesis of multi-walled carbon nanotubes

C. Srinivasan

Since the exciting discovery of multi-
walled carbon nanotubes (MWNs) by
Iijima\textsuperscript{1} in 1991 and subsequent produc-
tion of single-walled carbon nanotubes\textsuperscript{2,3}
(SWNTs), research studies in carbon
nanotubes (CNTs) have acquired the im-
portant status of one of the most active
fields of nanoscience and nanotechnol-
yogy. Several CNT characteristics like the
mechanical properties, viz. Young’s modu-
lus and tensile strength, field emission,
possible storage of hydrogen in CNTs
and others will have potential applica-
tions\textsuperscript{4,5}. There are several reports on the use
of these nanotubes in catalysis\textsuperscript{6}. The elec-
tron emission characteristics of CNTs
have motivated a Korean company to de-
vlop a flat-panel display for television
and computer monitors. The switching times
in devices fabricated from field-effect transistors with CNTs have been esti-
mated to be very fast, allowing clock
speeds of a terahertz, which is four times
faster than the present processors\textsuperscript{7}. The
recent observation of Ghosh\textsuperscript{et al.}\textsuperscript{7,8} that
the flow of a liquid in SWNT bundles
induces voltage in the sample along the
direction of flow, points out the device po-
tential for CNTs as sensitive flow-
sensors.

Several methods are now available for
the production of CNTs\textsuperscript{5,8–10} and each
method has its strength and weakness.
The preparation techniques include arc-
discharge, laser ablation, catalytic decom-
position of hydrocarbons and electrolysis
methods. The isolation protocol of CNTs
requires a complex purification process
to remove nanoparticles of catalyst and
carbon and graphite pieces with consid-
erable loss of CNTs, and these result in
an escalation of production cost. In spite
of the availability of a variety of methods
for the production of CNTs, the cost of

Figure 1. Scheme for the formation of MWNTs from graphite rods (reproduced from ref. 11 with permission from Zhenhui Kang and Enbo Wang).
nanotubes is high and the current challenge is the search for a low-cost industrial method of preparation of these nanotubes. Recently, Kang et al.\textsuperscript{11} have reported a one-step water-assisted synthesis of high-quality CNTs directly from graphite. For the transformation of graphite into pristine CNTs, two things are essential: (i) to get necessary power that can make the graphite sheets crimp and (ii) to wrap the honeycomb pattern back on top of itself and let the edges join by the C–C σ-bonds.

Kang et al.\textsuperscript{11} employed a water-assisted method that realizes the above two processes. Graphite rods were rapidly heated to red-hot (above 800°C) in air and then dipped into cold water (0°C). The water turned a little turbid after a slight explosion. The process was repeated several times and MWNTs formed were separated. From TEM measurements, the yield was found to be > 40%. On immersing the hot graphite rod into cold water the temperature of the graphite surface was lowered, but the internal temperature was still very high that provided enough power for the graphite sheets to crimp (Figure 1). Though it is well known that many complex chemical reactions occur between red-hot carbon and water, the detailed mechanism for the formation of CNTs in such conditions is yet to be understood. However, it seems that water plays an important role in the connection of the edges\textsuperscript{11}.

Recently, a chemical route to carbon nanoscrolls (with two free edges, one inside and the other outside the tube) has been reported\textsuperscript{12}. In this method graphite was intercalated with potassium and exfoliated with ethanol. Upon sonication, the exfoliated graphite sheets curled onto themselves, forming nanoscrolls. That the product obtained by the one-step water-assisted process\textsuperscript{11} was MWNTs and not the simple carbon nanoscrolls was established from the following observations: (i) TEM image shows that the wall-to-wall distance is uniform, 0.34 nm, which is akin to the 002 distance of graphitic carbon; (ii) the electron diffraction patterns of the products are single crystalline, which is not possible with a scroll; (iii) the Raman spectral bands resemble those reported for nanotubes with concentric multi-wall layers of hexagonal carbon lattice.

The study by Kang et al.\textsuperscript{11} reveals that graphite can be transformed into pure and high-quality pristine CNTs using a one-step treatment, with the assistance of water at atmospheric pressure without any catalyst.


Methane fuse for Cambrian mass evolution, volcanism for mass extinction: Proponents review their hypotheses

A. V. Sankaran

Life began on earth, close to 4 billion years (b.y.) ago, but its progress to higher forms was haltingly slow to begin with, and suddenly at the end of the Proterozoic period, about 550 million years ago, there was a burst in its progress. Complex multicellular forms began to evolve at a rate some 20 times the rate observed in the younger Mesozoic period, triggering a veritable ‘evolutionary big bang’ or the ‘Cambrian explosion of life’. The march of life thereafter was not unimpeded either for it periodically experienced extinction en masse. Explanations, so far, for these phenomena were not entirely convincing, but now, in the wake of accumulating new data, two papers published recently have underscored the role of sudden and voluminous bursts of methane for the Cambrian evolution\textsuperscript{1} and the periodic flood basalt volcanism in earth’s history for repeated global extinction of life\textsuperscript{2}.

In 1997, Kirschvink, along with Rippen dan and Evans\textsuperscript{3}, had claimed that a unique event, known as the True Polar Wander (TPW) (see Box 1) involving change in direction of earth’s spin axis, relative to the continents, occurred intermittently during Vendian–Cambrian period and this promoted development of congenial scenarios for rapid expansion of life. They explained how the balance of mass within the earth was disturbed due to the TPW and how all continents remaining stable till then were forced to shift to different latitudes. These TPW shifts, unlike those that occurred in later geologic times, were unique in earth’s history, as they had resulted from interchange events in earth’s moment of inertia tensor term – Inertia Interchange True Polar Wander or IITPW (see Box 1). The authors suppose that at least half of Earth’s continental lithosphere rotated by nearly 90° between 534 and 505 m.y. ago. Their movements were rapid (≥ 30 cm/yr), far exceeding tectonic motions of a few cen-