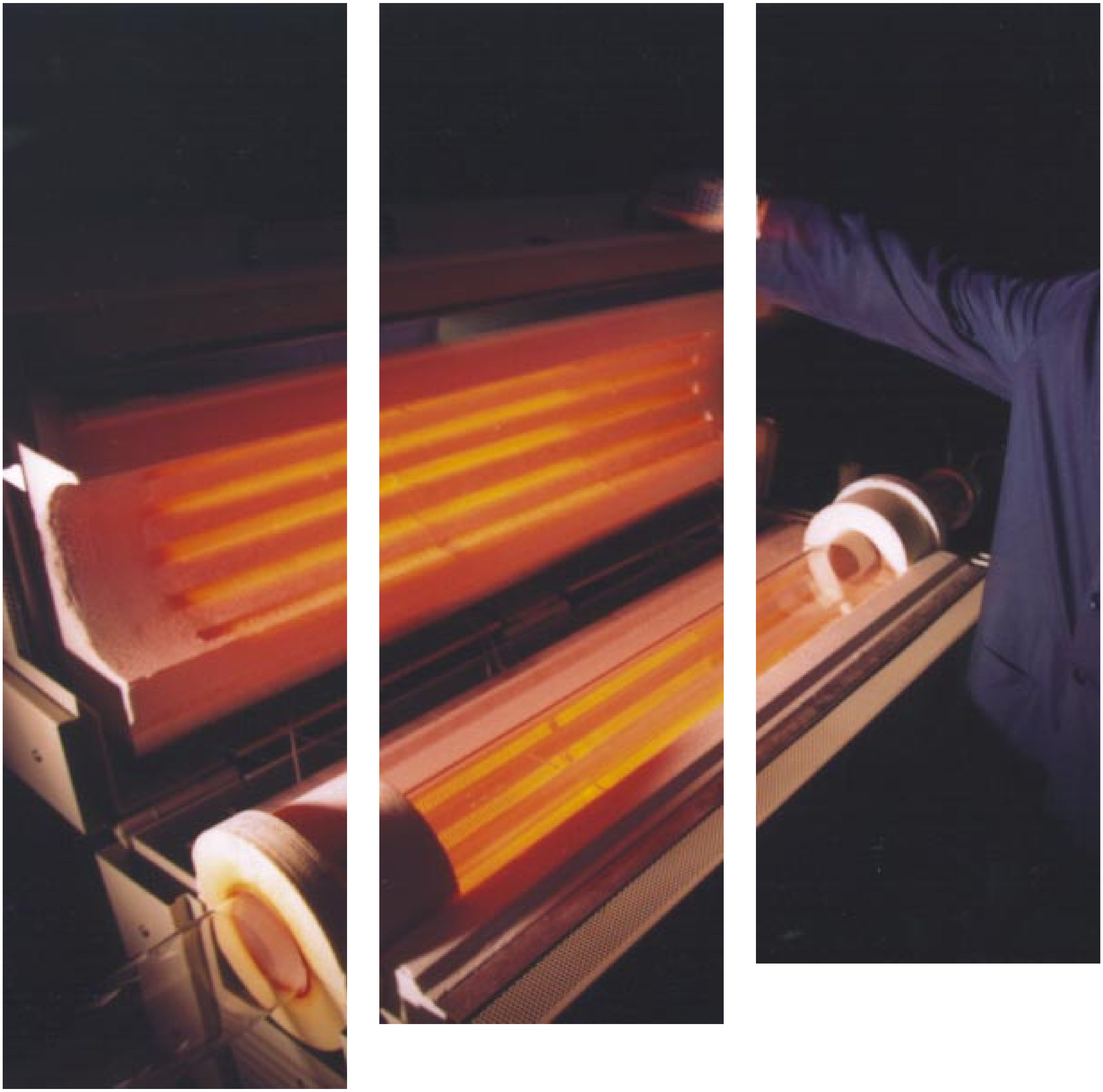


carbon materials – a unique approach

The Carbon Nanotube has been described as a graphitic sheet wrapped to form a seamless cylinder. These small cylinders (nanometers in diameter by microns in length) represent a whole new class of materials, which may one day find many uses in harsh environments or novel applications, where existing materials cannot perform.

PHOTOS: FORREST PAYNE

The number of new applications is growing constantly. Carbon nanotubes may find very broad use in a range of electronic, thermal, and structural applications. In a field that is less than a decade old, utilization could ultimately reach into outer space as ultra-light-weight nanotube composites replace metal structures currently blasting into space. Closer to home, much lighter nanotube composites may one day be substituted for steel in cars, thereby reducing weight and yield better fuel economy without compromising passenger safety.

uniformly dispersed nanotubes

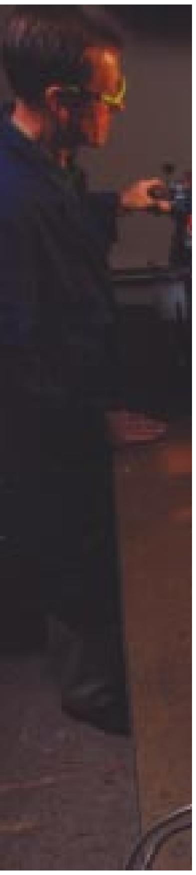
How are they used? In order to create structural composites or perfect the use of nanotubes in other applications, one must first have high purity, well-aligned nanotubes. These workhorses provide very high strength for very low weight, but the nanotubes must be uniformly dispersed as individual tubes (not bundles) to realize the nanotubes' remarkable reinforcing properties. Control of alignment allows development of structures with two and three-dimensional nanotube reinforcement.

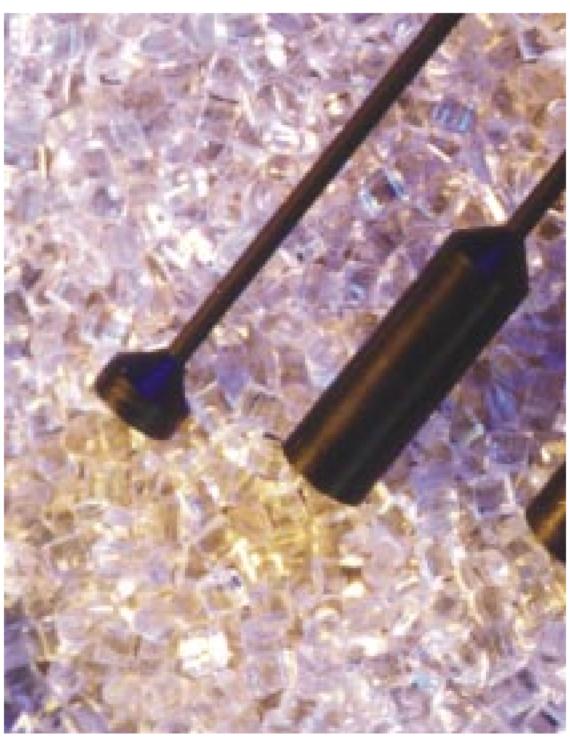
One of its biggest achievements of the CAER's Carbon Materials Group has been the great success it has realized in synthesizing high purity, aligned multiwalled nanotubes. One of the limiting factors in the commercialization of nanotubes is that they have not yet been produced in sufficient quantities, or with high enough quality. Through a novel method that is being patented, CAER scientists have devised a process for the production of high purity, well-aligned multiwalled carbon nanotubes. The process is scaleable and a continuous version has been proven at bench scale. The next step is to build a pilot-scale unit and work toward commercialization.

The field is specialized with several groups at other institutions exploring either fundamental characteristics or very specific research. The CAER group is focusing on commercial applications. Its goal is to make nanotube materials cheaply enough for them to be used commercially, replacing other materials, where they may be better suited.

coal

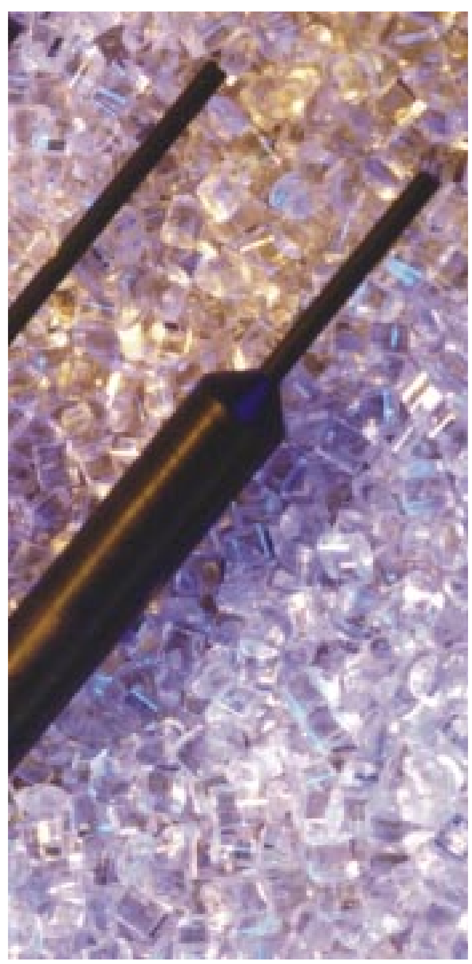
What does this have to do with coal? It could provide an alternative uses for coal. While the largest fraction of coal is now used as a fuel to produce electricity, it could realistically supply non-traditional markets for transportation fuels, chemicals and carbon materials. This would actually represent a return to the past: before the advent of cheap petroleum, gaseous and liquid by-products from the coking industries were the main feedstocks for the chemical industry. The production of low volume, high value-added products could augment and diversify the use of coal. It could provide additional independence from oil imports, allow the development of new industries, and provide new incentives for mining.





carbon materials

continued



PHOTOS: FORREST PAYNE

The CAER has a long and illustrious history in the development of coal-derived distillates and pitches, and this work continues to the present day. Energy is the largest use for coal, but if one takes a small fraction of the coal and uses it to produce materials (such as fibers or binders), the value goes up exponentially. One project draws on existing capabilities in direct coal liquefaction and applies those technologies to the production of pitch materials from coal. Coal tar pitch, a byproduct from coke ovens, has been primarily used as a binder pitch for anodes in aluminum production and is now also finding increasing demand as a precursor for carbon fibers. However, increasingly stringent environmental regulations are leading to the closing of many of these coke ovens even though the demand for coal tar pitch is increasing. Viable alternative sources of pitches are needed. A process is being developed to make pitch and chemicals from coal. This process is unique in that it integrates a carbonization step with an extraction step. The carbonization produces the solvent needed for the pitch extraction step, obviating the use of expensive, hydrogenating solvents common to other processes. The pitch yield from this process is as high as sixty percent, while also co-producing oxygenate chemicals recovered during carbonization. Finally, all waste streams are suitable as feed to a gasifier. After pitch is made from the coal, a whole range of carbon materials can be synthesized, such as binders used in the manufacture of graphitic materials, for low and high performance structural carbon fibers, and as high surface area activated carbon fiber adsorbents. The carbon fibers produced from this process have properties similar to those of commercially available fibers. Tying in with the work on nanotubes, CAER's Materials Group is adding nanotubes to coal-derived pitch to produce fibers with even more enhanced properties (1 wt% addition of nanotubes yields approximately a twenty percent increase in strength).

carbon dioxide sequestration

Alternative uses of coal aside, nanotubes could also help coal remain the predominant fuel in power production. The "Vision 21" power station of the future, as envisaged by the DoE, will be a near zero emission polygeneration facility producing power, fuel and chemicals. The plants would produce multiple products — electricity in combination with liquid fuels and chemicals, materials or hydrogen. Coupled with carbon sequestration technologies, they would also emit little if any greenhouse gases.

A project under early development is a method of removing the carbon dioxide from the flue gas stream is to use nanotubes. In research funded by the Department of Energy's University Coal Research Program, CAER scientists use a membrane where the cores of open-ended nanotubes act as pores. These membranes can be produced in situ, wherein the nanotubes are grown aligned perpendicular to the substrate, and then infiltrate with a matrix to form a membrane. This creates a huge array of perfect pores that induce molecules to line up and travel through single file. The reason to consider a membrane, or molecular filter, to capture the carbon is that it could be cheaper and would work continuously. The CAER currently sees this as a fundamental-science project for characterizing carbon dioxide uptake and transfer by nanotubes.