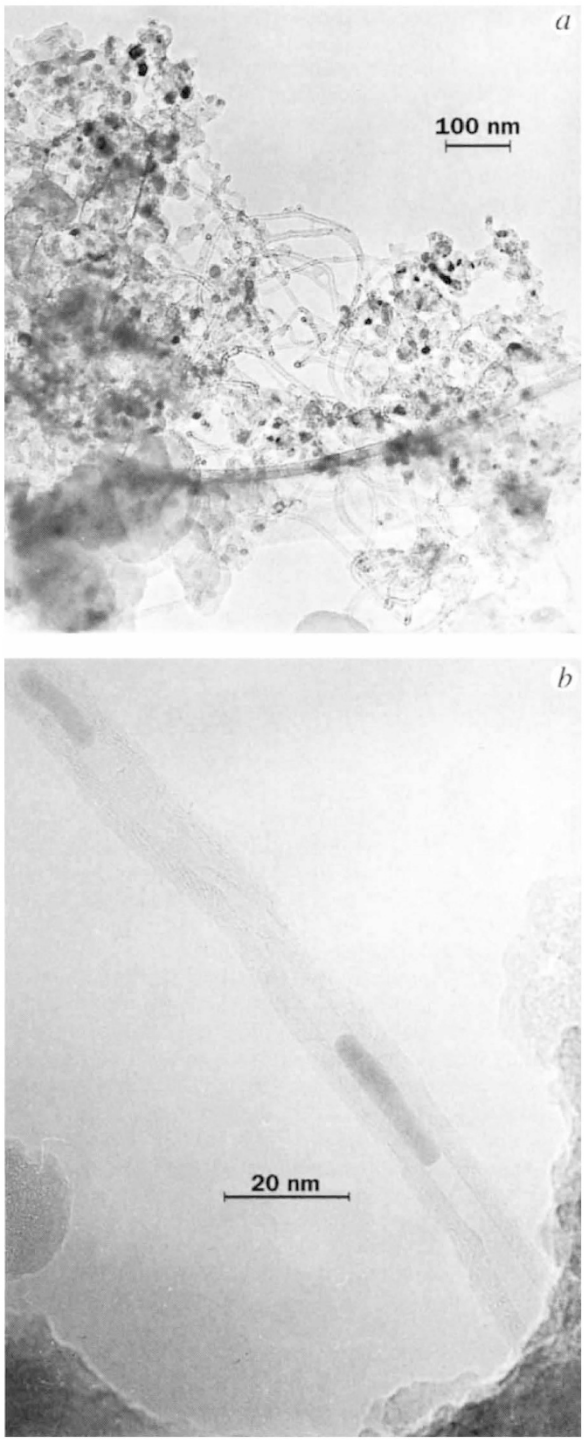
Condensed-phase nanotubes

SIR — Carbon nanotubes[1] are conventionally prepared by gas-phase deposition in arc reactors, or by thermal decomposition of hydrocarbons[2]. We have found that the synthesis of nanotubes from a condensed phase is also possible. Specifically, we have prepared multi-walled nanotubes by passing an electric current between carbon electrodes in molten lithium chloride.

A simple carbon crucible, made by drilling a cylindrical hole (2.5 cm × 3 cm) in the centre of one face of a 5 × 5 × 5-cm cube of high-purity carbon, was filled with around 1 g of lithium chloride and heated to its melting point (600 °C) in air. A 3-mm-diameter high-purity carbon rod was immersed in the melt (to a depth of about 1.5 cm) in order to form the cathode of an electrolysis cell; the crucible acts as the anode. Around 30 A was maintained through the melt for 1 min. The immersed surface of the cathode rod was eroded during electrolysis, small pits appeared and particulate material (10–30 mg) was found dispersed throughout the melt. After cooling, the solid melt was added to water in order to dissolve the lithium chloride and react with the residual lithium metal. The mixture was set aside for 4 h, then toluene was added to the aqueous suspension and the whole was agitated for several minutes.



a, Low-resolution TEM image of a sample of the particulate material collected from the LiCl melt after electrolysis. The curly structure is typical. *b*, High-resolution TEM image revealing encapsulated material within one of the nanotubes.

After allowing the mixture to settle, it was found that all the solid material seemed to have passed into the toluene layer. The aqueous and organic layers were separated by careful decanting. After sonication, droplets were removed from the toluene fraction and deposited on a carbon grid for transmission electron microscopy (TEM). A microscopic solid remained after removing the toluene by evaporation.

Low-resolution TEM studies reveal the particulate material to consist of multi-walled nanotubes and spheroidal carbon particles of 30–50 nm diameter; the latter tend to cluster. These are onion-like polyhedral particles, similar to those observed by Iijima[3] and Ugarte[4]. Some of the nanotubes (2–10 nm in diameter) are very long (>500 nm) and show evidence of encapsulated material (lithium chloride, oxide or possibly lithium metal). The nanotubes consist of 5–20 concentric layers and, unlike those produced by the vapour arc/plasma technique[1,2], are not always straight, but tend to form loops. The tubes collapse on prolonged irradiation (around 15 min) in the electron beam, forming irregular distorted tube-like structures. We believe that the formation of nanotubes during electrolysis may have important implications for continuous methods of nanotube production, as well as, for example, facilitating encapsulation of material within the nanotubes.

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Evaporation losing its strength

SIR — Over the past several decades, the observed increase in mean temperatures over much of the world has been a result of a disproportionate increase in night-time temperatures[1]. Here we show that, in the United States and the former Soviet Union, the evaporation of water, as measured by pan evaporimeters — simple devices consisting of a pan of water, a device to measure the water needed to return the surface to a predetermined level, and a rain gauge — has decreased. These decreases seem to be closely related to the same factors that are causing the trends in temperature.

Pan evaporation is a simple measurement of complex meteorological interactions. Although pan evaporation cannot fully represent lake evaporation and is even less indicative of ground evapotranspiration, analysis of observed trends in pan evaporation can provide considerable insights into current climate change and the impact this change may be having on agriculture and water resources.

A wide variety of evaporation pans have been used in both Russia and the United States since the nineteenth century[2,3]. Because pan type can affect the measurement, assessment of the homogeneity of the data is important before any trend analysis is carried out.