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From Carbon Nanotubes to Phosphorus Snakes

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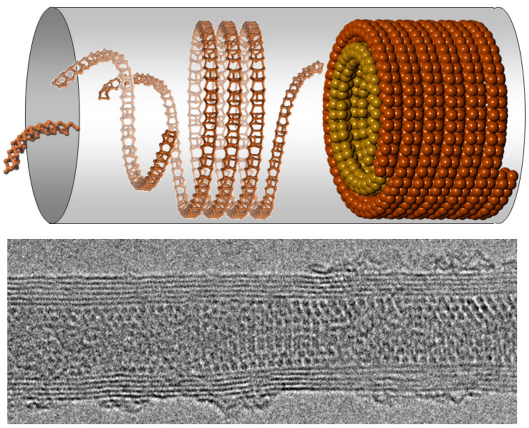

Figure 1. Top: Proposed formation mechanism of a helical phosohorus coil (Ref. [4]). Bottom: TEM micrograph of the P coil embedded in a nanotube.(Ref. [5]).

The discovery of carbon nanotubes (CNTs) in the late 20th century has impacted our world significantly [1]. CNTs are hollow cylinders of graphitic carbon with diameters ranging from 1-10 nm and lengths reaching up to 1 m. These quasi-1D structures are closely related to 0D C_{60} molecules and 2D graphene, are highly perfect on the atomic scale, and have excellent charge and heat transport properties. Similar to graphene and graphite, single- or multi-wall nanotubes are flexible yet very strong up to extremely high temperatures and resilient in harsh chemical environment. It took about two decades to study and harness the combination of ideal properties found in CNTs and to arrive at the current level of understanding. Enormous progress in the field has been achieved by scientists who dared to follow unconventional ideas. After a brief review of the journey that has brought us here, I will discuss two applications that are unique to nanotubes. An unusual application of the high tensile stretngth of nanotubes is the possibility of using twisted nanotube ropes to reversibly store nanomechanical energy [2]. As a superior counterpart of twisted rubber cords, twisted nanotube ropes have the potential to store permanently up to ten times more energy than Li-ion batteries within an unsurpassed temperature range. Other unusual applications arise from the constrained cylindrical volume inside CNTs, which may be filled with atoms or molecules that often arrange in a very different way than in free space. In this way, selenium or sulfur atoms may reconnect inside the nanotube to helical or linear chains that may become metallic [3]. In a similar way, phosphorus atoms may form previously unknown yet unusually stable coil structures [4,5]. Nanotubes even act as natural pressure containers that selectively drive particular chemical reactions, including a transformation of functionalized diamonoid molecules to a diamond nanowire inside a nanotube [6]. In all cases, predictive *ab initio* calculations provide a useful guidance to experimental studies.

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