# Carbon Nanotubes and the Sustainability Puzzle

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An international team of researchers receives over $4M to advance understanding of carbon nanotube synthesis and its potential for producing industrial materials more sustainably. The foundation's $1.9M Kavli Exploration Award in Nanoscience for Sustainability sparked an additional $2.2M from Carbon Hub to pursue this important research. The collaboration is led by Matteo Pasquali of Rice University.

"This project is timely and important. The fundamental nanoscience research we are supporting today could eventually help unlock a completely new solution to a vexing sustainability puzzle: the inherent emissions from making steel and other metals. The project also enables the development of new experimental and theoretical methods with wide-ranging applications in nanomaterials, energy, and more," said Jeff Miller, nanoscience program officer at The Kavli Foundation.

Manufacturing steel, aluminum, and copper generates over 10% of global greenhouse gas emissions, yet these materials are in high demand. Since net-zero goals require a tripling of the electricity grid, this will require hundreds of millions of tons of these strong and conductive materials (among their myriad other uses). Significant efforts are underway to reduce metal manufacturing emissions, but what if instead these materials could be replaced with a sustainable alternative?

When synthesized and assembled properly, carbon nanotube fibers can have strength to rival steel and conductivity comparable to copper, making them a promising and more sustainable candidate to replace conventional materials widely used in infrastructure. Raw materials to make nanotubes - natural gas and other hydrocarbons - can be accessed in vast quantities but currently are burned as fuels. As the world turns to non-carbon energy, this resource could become available to produce global quantities of nanotubes, replacing dirtier materials and generating clean hydrogen as a byproduct.

“We already know how to make these materials with the right properties; now we have to understand how to make them efficiently and sustainably, which requires a completely different level of understanding of the underlying processes,” said Pasquali. “Once we figure it out, we will unlock the power of carbon as a sustainable material, and we will make clean hydrogen as a valuable co-product.”

Before this vision can be realized, basic science questions about carbon nanotube synthesis must be addressed. At a Kavli Foundation convening in May 2023, participants from a wide variety of disciplines developed a path to start bridging the gaps in scientific knowledge that are preventing scalable use of carbon nanotubes. For example, attendees noted that carbon nanotube synthesis has typically been studied through reductionist approaches, where a single process is isolated and investigated in detail. These studies have allowed progress, but much faster progress towards opening the kinetic black box could be possible in a more expansive approach that could untangle and characterize the coupling between physical and chemical processes. These discussions led directly to funding this research project.

The approach of this project could also exemplify a path for other materials in the science of scale-up technologies.

“The Kavli Foundation was willing to fund a collaboration of academia and national labs across three continents,” said Pasquali. “This allows us to bring together in a single program all the leading groups and would have been very difficult to accomplish through traditional funding routes.”

Carbon nanotubes come in many shapes and sizes, with different properties to match. With this funding, researchers hope to gain a more nuanced understanding of the reaction dynamics that produce carbon nanotubes, and more specifically, how to most effectively yield high-quality carbon nanotubes. This includes creating new tools and analytical techniques to understand these complex reactions—including how temperature, pressure, and other conditions affect the products—and how to characterize the yielded carbon nanotubes.

The collaborative team includes Rice University scientists Pasquali, Boris Yakobson and Thomas Senftle as well as researchers from universities across the U.S., Europe, and Asia.

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