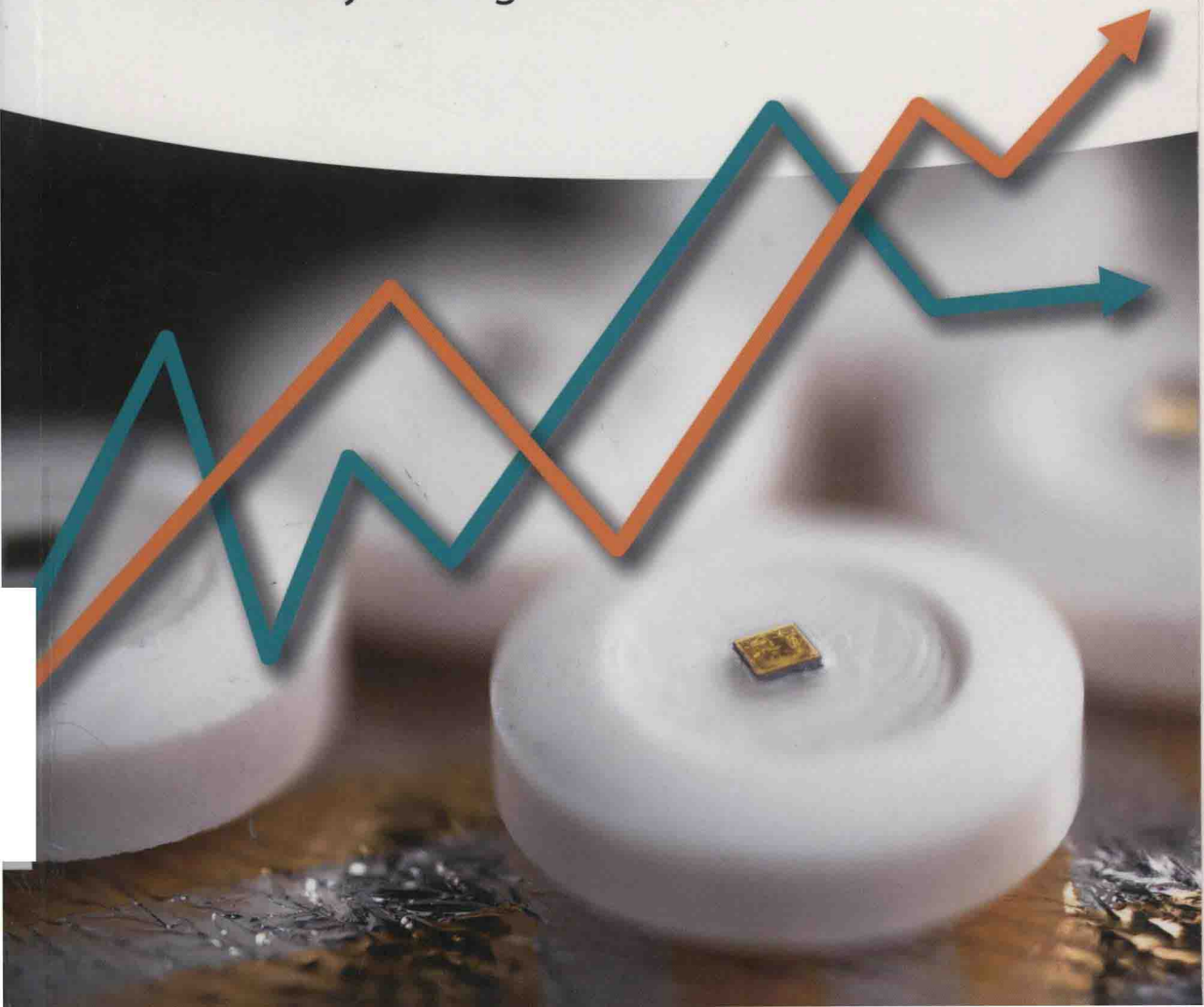


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Michael Tomczyk

# Nano**nn**ovation

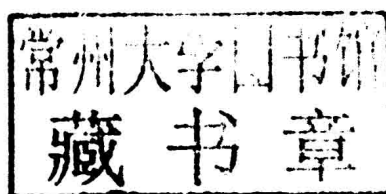
What Every Manager Needs to Know



*Michael Tomczyk*

## **NanoInnovation**

What Every Manager Needs to Know



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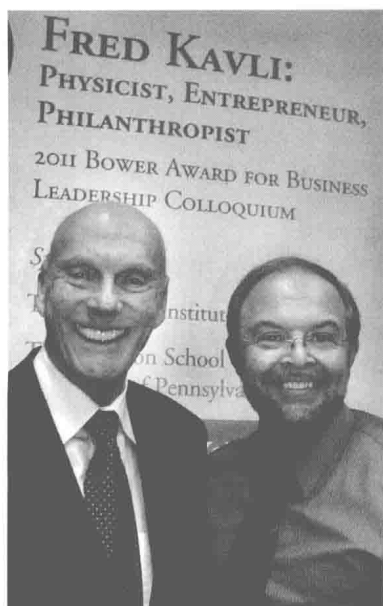
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**This book is dedicated to**

**Fred Kavli (1927–2013)**

**Founder and Chairman, The Kavli Foundation**

*This book is dedicated to the late Fred Kavli. I was privileged to meet Fred in 2011 at the Wharton School when he was being presented with the Franklin Institute's Bower Award for Business Leadership. He provided the following quotation for this book, although sadly he did not live to see it published:*



**Figure 1** Fred Kavli and Michael Tomczyk.

“We cannot predict the future and foresee all the revolutionary developments that nanotechnology will bring us, but it gives us confidence that our rate of development and discovery will follow the logarithmic curve and maintain an ever-increasing rate of expansion and discovery to bring us a future that is so revolutionary that we cannot even imagine it today anymore that we could imagine the revolution that the transistor would bring when it was discovered in the 1940’s.”

*Fred was a Norwegian (and naturalized American) entrepreneur, inventor, and philanthropist who used his wealth to fund the Kavli Foundation, Kavli Prize, and Kavli Institutes, including the Kavli Institute for Bionano Science and Technology at Harvard University. As you can see from this photo, the octogenarian retained his enthusiasm throughout his life and is a wonderful example of a world-class innovation champion.*



## Preface

In 2000, I was giving a series of presentations to industry and academic groups on radical innovations that have the potential to reshape the future, and one of these innovations was nanotechnology. At the time, there was a lot of hype around “nano,” but I had the sense that most people didn’t really understand what was really going on in the field. So I began asking my audiences, “Who can name one product that uses nanotechnology?”

To my amazement, most people couldn’t name a single product. This happened year after year. In the fourth year, one hand went up and someone said, “carbon nanotubes.” At the time, I knew there were already more than a thousand products that used nanotechnology. Obviously, the business community needed to know more about nanoinnovation. At the same time, many of my colleagues in business were expressing frustration over the media hype and constant flow of “breakthrough” announcements that were causing a lot of confusion and misinformation. Finally, I decided to write a book that tells what’s “really happening” in nanoinnovation – the book you’re reading now.

I started by interviewing nano-insiders in business, government, science, and academia. Thanks to contacts shared by friends like Michael Terlaak and others and by using LinkedIn and other networking resources, I was able to interview more than 150 nano-insiders. Over time, I got to know many of the most prominent nano pioneers. I invited them to provide updates on their research at an annual event I hosted at the Wharton School called the Emerging Technologies Update Day.

Virtually everyone I contacted was eager to participate and to help convey the “real story” of nano. In addition, people in many countries worked behind the scenes to answer questions, provide details, and secure permission for nanoscale images. Some laboratory technicians took nanoscale photos especially for this book. Others provided me with background summaries of nanotech projects and details that are not yet public.

One of my most important challenges was to make this a dynamic publication. When I began this project, I noticed that a lot of nanotechnology books offered snapshots of innovations that quickly grew out-of-date, so I tried to take a slightly different approach. My goals were to make this a starting point, not an endpoint or snapshot. So I tried to design this as a dynamic living document that

you the reader can use as a basis to continue your own investigations. Most of the nanoinnovations you'll learn about here will continue to evolve over time, and you can easily track their progress on the Internet and in science and business media.

Another goal of this book is to give credit to some truly impressive pioneers, and tell their stories in their own words where possible – because many of the most significant breakthroughs are the result of extraordinary personal effort. It's fascinating to learn, for example, how Ned Seeman gleaned a breakthrough idea from a woodcut on the wall of a pub while enjoying a beer, or how Tony Atala redesigned inkjet printers to “print” human organs. I also invited business entrepreneurs to discuss how they developed their ventures – including failures as well as successes.

This is not just a book about what's happening in nanotechnology – this is also a book about what you can make happen. You don't have to be a scientist to be a nanoinnovator, or to champion nanotechnology. I know this, because early in my career I was fortunate to play a role in developing and launching the world's first home computer (the Commodore VIC-20). I was not an engineer. I went to college in Oshkosh, Wisconsin and studied literature and journalism. After military service as a US Army officer, I earned an MBA from UCLA, fell in love with home computers, and played a lead role in developing and launching the first home computers at Commodore. My love affair with emerging technologies helped me to become a pioneer in home computing and kept me involved in innovation throughout my career, including 18 years at the Wharton School as Managing Director of the Emerging Technologies Management Research Program, the Mack Center for Technological Innovation, and the Mack Institute for Innovation Management. As my own story confirms, there are many paths that allow you to get involved in innovation.

Most of the nanotech pioneers you'll meet in this book did not start out specializing in nanotechnology. They come from physics, chemistry, biology, engineering, business, environmental technology, and other fields. Most are self-taught. For many researchers, nanotechnology was so new and different that it forced them to think in new and different ways. Their stories are fascinating.

One of the things we learn from their stories is that anyone can be a nanoinnovation *champion*. If you're in a company, you can support and cultivate an innovation culture that includes the manipulation of atoms and molecules in the R&D toolkit. If you're in marketing, think about how nanoinnovations will compete with existing technologies and change your industry. If you're managing a business, think about how nanotechnology will affect your organization, your industry, and your competitive markets. If you're a parent, encourage your children to study science and technology – especially nanotechnology. If you're a teacher, push to integrate nanotechnology in your school curriculum. Learn about nanotechnology and scan the horizon for emerging technologies and applications. If you're in a country that is out of the nanoinnovation mainstream, find ways to educate students and seed the nanoinnovation process. Focus on

how nanotechnology can solve problems in your country, especially problems for which there are no other solutions.

As you read this book, keep thinking about how nanoinnovation will change your world. Will a new material made from carbon nanotubes or graphene replace plastic, steel, or aluminum? Will nanosensors create a “sensor revolution” where almost anything can be detected? Will nanomedicine cure diseases that have been stubbornly resistant to cures for decades or centuries? Will we be growing our own hearts and livers to replace failing, damaged, or even aging organs? Will we wrap buildings in nanoskins to regulate environmental conditions? Will we change the structure of materials by mimicking innovations created by Nature, such as creating a new type of dry adhesive by imitating the footpads of a lizard, or engineering a material based on the nanostructure of a butterfly’s wing?

The answer is, these wondrous things are already happening. The revolution in nanotechnology is changing our lives, wherever we live on the planet. Many of these nanoinnovations are happening out of sight and are hidden from view in research laboratories. Some innovations are discussed only in specialized science, engineering, or medical journals. This book throws light on hidden corners of science and technology, just as nanoimaging systems reveal nanoscale objects that are smaller than visible light waves. It also gives you a portfolio of ideas and themes that belong on your radar screen, if you want to keep current on what will be happening in the coming decades, in nanotechnology and other areas.

These are exciting times to be involved in science, technology, and business. There have never been so many innovations poised to change our lives, from robots that walk and fly to genetic solutions that will save and prolong our lives. Everything is changing, from how we use mobile social media to communicate, to how we process and package food, to how we use energy. Most of these innovations are visible, but the science and technology that drives them is invisible, and that’s why we need to know more about nanoinnovation.

I invite you to join me and millions of others who are helping to drive progress through nanoinnovation. Together, we can make the future happen faster.



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I am extremely grateful to the many nano-insiders who devoted time to participate in interviews, discuss their research, share their personal stories, and read portions of my book to ensure I “got it right.” Many nano-insiders generously provided referrals and introductions to colleagues who allowed me to expand my network of nanotech professionals in science, business, government, and media.

I especially want to thank Michael Terlaak, founder of the Nanotechnology Research Foundation in San Diego, who provided referrals to numerous colleagues at the beginning of my research. This helped jump-start the interview process. Lynn Foster also opened his contact network to me and provided some excellent insights. My friend and colleague Brent Segal, cofounder of Nantero, provided a wonderful entree to critical issues in nanotechnology – by inviting me in 2007 to help organize and serve on the senior leadership of the IEEE/IEC project developing standards for the use of nanomaterials in electronics.

Several university colleagues at the Wharton School and University of Pennsylvania played an important role in my “academic development.” I want to thank Jerry Wind, Saikat Chaudhuri, and the Mack Institute’s Core Group for giving me an informed vantage point on a wide array of emerging technologies during my more than 18 years at the Wharton School. I joined Wharton in 1995 to help launch the Emerging Technologies Management Program, which in 2001 became the Mack Center for Technological Innovation and in 2013 became the Mack Institute for Innovation Management. Throughout these changes I was privileged to provide managerial leadership as Managing Director, which kept me thinking constantly about radical innovations including nanotechnology.

I started writing this book while studying for my master’s degree in environmental studies at the University of Pennsylvania. The research methodologies I learned during my graduate studies were immensely valuable. Yvette Bordeaux, who chaired the Master of Environmental Studies (MES) program at the University of Pennsylvania, helped me tailor my graduate studies to include nanotechnology in my curriculum, including a superb course on nanotechnology taught by Dr. Jody Roberts from the Chemical Heritage Society. My graduate advisor Stan Laskowski was extremely helpful and supportive.

I'm especially grateful to my editors at Wiley-VCH: Heike Noethe, my terrifically patient and absolutely awesome editor, and Martin Preuss who championed the book when I first presented the concept and got me started on the project. Dr. Noethe was patient, encouraging, generous, professional, constantly enthusiastic, and supportive. As an author, I couldn't ask for a better editor/publisher.

Having started my career as a journalist, I greatly appreciated the availability of Google, Google Scholar, LinkedIn, Gmail, and other tools that gave me instant access to emerging innovations and allowed me to contact virtually any nano-insider I wanted to interview, including some of the world's leading scientists and business leaders.

My mega-thanks and gratitude go to the more than 150 nanotechnology insiders who participated in interviews and provided information, insights, and images, graciously sharing their experiences to help make this book accurate, relevant, and "real." Many of these pioneers and champions have already made tremendous contributions to the field of nanotechnology, and continue to help drive nanoinnovation forward. Others are toiling 24/7 in laboratories and offices to turn possibilities into solutions. Their enthusiastic participation in this book project allowed me to include observations and opinions that can only come from insiders who truly know what's really happening in nanoinnovation. I also want to thank those who provided or facilitated the use of the images and diagrams included in this book. Thank you again to these remarkable nanoinnovators and champions, with apologies to anyone I may have inadvertently excluded from this very extensive list or whose affiliations/titles may have changed since this list was updated:

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