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2nd Edition

Nanotechnology

FOR
DUMMIES®

Learn about:

- Using molecular replicators to build materials atom by atom
- Developing more energy-efficient vehicles
- Improving the environment
- All the ways nanomedicine can help us live longer

Earl Boysen

Nancy Boysen

Foreword by Desiree Dudley and Christine Peterson, the Foresight Institute



Nanotechnology For Dummies[®], 2nd Edition

Visit

www.dummies.com/cheatsheet/nanotechnology
to view this book's cheat sheet.

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Foresight Institute



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About the Authors

Earl Boysen spent 20 years as an engineer in the semiconductor industry and runs two web sites, UnderstandingNano.com and BuildingGadgets.com. Earl holds a Masters in Engineering Physics from the University of Virginia. He was coauthor of the first edition of *Nanotechnology For Dummies* and *Electronics For Dummies*. He also coauthored *The All New Electronics Self-Study Guide* from Wiley Publishing.

Nancy Boysen is the author of more than 60 books on technology topics (under the name Nancy Muir), including *Microsoft Project For Dummies* and *iPad All-In-One For Dummies*, and contributed to the college textbook *Our Digital World* from Paradigm Publishing. She is the senior editor for UnderstandingNano.com and runs two other web sites, TechSmartSenior.com and iPadMadeClear.com.

Dedication

To Nettie Boysen, Earl's mom, for providing the love and support that helped him to follow his dreams.

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Foreword

Realizing the Potential of Nanotechnology

What is nanotechnology? It's a big word: tiny in scale but infinitely immense in possibility. In the Silicon Valley era of tech bubbles and busts, you may have heard nanotechnology bandied about as the new thing, along with biotech, artificial intelligence, private space travel, and more.

But what does nanotechnology mean? Perhaps the most influential early reference to the field we now call nanotechnology was on December 29, 1959. That evening, one of the most famous and beloved physicists of all time, Richard Feynman, gave a dinner lecture at the California Institute of Technology entitled "There's Plenty of Room at the Bottom," where he discussed the potential in our increasing knowledge and ability to manipulate matter:

The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom . . . Put atoms down where the chemist says, and so you make the substance.

Feynman's visionary forecast was before its time; however, excitement about the field truly began to manifest with the invention of the scanning tunneling

microscope (STM) by Gerd Binnig and Heinrich Rohrer of IBM in 1981, and the field's first book, *Engines of Creation: The Coming Era of Nanotechnology*, written in 1986 by K. Eric Drexler. That year, Drexler and Christine Peterson formed the Foresight Institute, a nonprofit think-tank whose purpose is to advance the ethical development of beneficial nanotechnology.

Twenty-five years later, the field has blossomed. Billions of dollars go into nanotechnology research and development every year. More than a hundred major academic institutions, governmental organizations, research facilities, and advocacy groups in the world are dedicated to nanotechnology. We can see cells, atoms, and DNA at the sub-nanometer level with scanning electron and tunneling microscopes, measure and move molecules with atomic force and probe microscopes, "paint" with molecules using dip-pen lithography, and even snip and modify DNA using manmade DNA "walkers." We have begun putting the first labs on chips, identifying and even killing cancer cells with nanoscale techniques.

We have come so far. But have we reached a truly nanoscale control of matter? As so often happens, humanity has found that the devil is in the details: realizing the dream of molecular- and atomic-level precision is more difficult than its conception. Quantum physics and its mechanical effects become much more important on the nanoscale, and our understanding of the laws of nature at this scale is advancing but by no means fully comprehensive. Even with all our advances to date, processes for building truly precise three-dimensional structures through molecular manufacturing are still in-progress.

Lacking truly accurate understanding and precise application, media and industry have capitalized on the hopes and fears of a naive society fascinated by the potential in health, life extension, space travel, and green energy. *Nanotechnology* has become a much-hyped magical buzzword that glamorizes — or demonizes — today's production of imprecise nanoscale blobs.

However, despite real limitations, microscale and nanoscale progress to date is still impressive. The Information Age completely transformed our world by controlling those “blobs” of matter on a micronscale; the average cellular phone in your pocket today has more processing power than machines that filled entire basements in the 1980s. Articles and books that could take months to find can now be downloaded in moments; family members can call their loved ones from remote areas around the world; 911 emergency services can be at your car accident far faster than ever thought possible. Information sharing, communication, and real knowledge propagation that took weeks or months — or even years — can now be achieved faster than ever before because human beings had the courage to understand, develop, and implement new knowledge and technologies.

But this world-changing progress is merely the microscale; time has already started to show that we can do better. And even more is possible. Imagine a world in which a family of four can take a trip to the moon for the price of a Sunday drive — because the materials and fuel are so light, strong, and inexpensively made. Imagine a world in which nanoscale devices can go in and help rebuild your grandmother's heart, or your own arteries. A world in which chemical pollution no longer exists.

You may think “that sounds like science fiction.” Well, that it is. In 1995, best-selling author Neal Stephenson wrote about this kind of world in a Hugo Award-winning book called *The Diamond Age*. And that world is truly a different world than the one we live in now. But this kind of grand, forward-thinking vision has always inspired human progress. Ideas are first whispered or hastily scrawled by those starry-eyed dreamers who dare to imagine something more, something better. In the history of human civilization, the curious inventors, the doers, the makers, and the courageous leaders are the ones who dare to try, to understand, to be inspired, to create, to build: to take those far-off dreams and make them real. The road to truly great dreams is often a long one, and humanity almost always takes more time, energy, work, and earnest collaboration than imagined to fully build and travel this road, — especially to travel it well.

Nanotechnology For Dummies, 2nd Edition, guides the reader through a bright path of progress and possibility, on a road that will eventually lead to all that nanotechnology promises. This book also serves as an entrée into the basic concepts, achievements, problems, and prospects in this exciting field. We hope the knowledge will inspire you to help us create a better world.

— Desiree Dudley and Christine Peterson
— Foresight Institute

Introduction

If you are one of the many who has read headlines about nanotechnology and the incredible things it is making possible in our world, you've probably bought this book to find out what the fuss is all about. Nanotechnology has been touted as both a Holy Grail of science that can cure all ills and a dangerous manipulation of matter that could cause the end of our world. So just what is nanotechnology and what could it make possible?

Nanotechnology For Dummies, 2nd Edition, helps you get a good grounding in nanotechnology history, concepts, and applications while clearing up some of the hype. As you work your way through its chapters, you will discover some fascinating facts about nanotechnology past, present, and future.

About This Book

Nanotechnology is probably the most promising branch of science today. It holds out the possibility of clean air, cheap energy, and longer life. In fact, almost every industry today is using or considering nano for their business, and most countries have some level of nanotechnology research and development.

Although nanotechnology can be a complex topic, we've made every effort to give you a good overview of its many aspects while not driving you to distraction with jargon and technical talk. We explore not only the concepts behind nanotechnology but also how it's being applied in the real world. We even take several glimpses

into the future to explain all the things that nano may help make possible.

If you are looking at nanotechnology as a career, an investment opportunity, or a scientific field of study, or are just curious, this book will provide you with answers.

Finally, because nanotechnology is a fast-moving field, note that we provide updated information for our readers on our web site, www.UnderstandingNano.com.

Foolish Assumptions

While writing this book, we assumed that you would have at least a passing interest in science, but we didn't assume that you are a scientist. We therefore tried to put things in simple terms and define technical terms when they first appear as well as in a glossary.

We also assumed that most of you have access to the Internet, so we've included throughout the book URLs of sites you may want to visit for more information or updates. In case you would prefer not to type the URLs to access these sites, we've provided links to each site on our web site at www.UnderstandingNano.com/nanotechnology-links.html.

Finally, we assumed that you want to go right to the information that's most useful to you, so we wrote this book in a way that doesn't require you to read it in any particular order. Jump in wherever you like!

How This Book Is Organized

This book is conveniently divided into several handy parts to help you find the information you need.

Part I: Nanotechnology Basics

The chapters in Part I introduce you to nanotechnology: what it is, where it came from, and the people who made key discoveries to advance the science. We also include chapters about nano materials, techniques used in manipulating those materials, and tools that every nanotechnologist should have in his or her nano toolkit.

Part II: Nano Applications

Nanotechnology is a science that has applications in almost every area of life, from health care to manufacturing, space travel to improving our environment. In Part II, we explore what's being done, developed, or just imagined in various industries and settings.

Part III: Nanotechnology and People

Nanotechnology may be relevant to you in a few keys ways. In Part III, we explore the ethical, safety, and regulatory issues that may have an effect on how you interact with nanotechnology products or processes in