Preface

We are in an age where, in the Western world at least, we all take high technology pretty much for granted. Many of us use and even depend on mobile phones, laptops, PDAs and other miniature electronic devices during our daily lives. What has made this all possible are advances in semiconductor technology, at the centre of which is the humble transistor. Next to the discovery of penicillin, the invention of the solid-state transistor was arguably one of the most important developments for mankind over the past century, as it has had far-reaching consequences across all aspects of life.

As the scale of electronic devices continues to decrease, and approaches the nm level, it is becoming more and more important to understand the details of current flow in reduced dimensions. This book is intended as an introductory overview of transport phenomena from the macroscale right down to the atomic level. There are two means by which nm-scale devices can be fabricated — by top-down or bottom-up technologies. The top-down approach has been used with obvious success by the semiconductor industry for several decades now and the bottom-up approach is being pioneered by researchers in the field of nanotechnology. Whilst current indications are that bottom-up nanotechnologies will not completely replace top-down technologies, the two will almost certainly become complementary. In any event, it will still be essential to have a sound understanding of transport at the nanoscale. We begin in Chapter 1 by looking at transport in familiar devices: resistors and transistors, and how, despite any ideas we may have to the contrary, their electrical characteristics are determined by

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events at the quantum level. We then dedicate Chapter 2 to gaining a practical understanding of the quantum nature of current flow, i.e. the relationship between current and voltage and the origins of electrical resistance. In Chapter 3, we look at the boundary between the quantum and macroscopic regimes — known as the mesoscopic regime, and look at how geometry, size and microstructure start to play an important role in determining resistance at the nanoscale. In Chapter 4, we look at the techniques used to probe the electrical properties of structures and devices at the nanoscale — scanning probe microscopy. In fact, it was the development of scanning probe microscopes that jump-started the field of nanotechnology. In Chapter 5, we look at some of the detrimental effects of current flow: heating and electromigration in nanowires. This is particularly important due to the fact that while transistors in microprocessors continue to shrink, so too must the interconnects which join them together. The resilience of small wires to the flow of current for prolonged periods is not the same as for large (i.e. micron-scale) wires. In the final chapter, we take a look at the field of molecular electronics, which has gained a lot of interest in recent years due to the promise it holds for novel circuit functions. This text is intended to serve as a useful introduction to quantum mechanics, scanning-probe microscopy and electronic transport.

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