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NANOPATTERNING TECHNIQUES

Unconventional Nanopatterning Techniques and Applications by John A. Rogers and Hong H. Lee

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INTRODUCTION

Tools for nanofabrication are central to every field of nanoscience and nanotechnology. For research and initial development purposes, nanofabrication typically involves the use of specialized techniques to fabricate small collections of nanoscale devices, in processes that resemble a form of craftsmanship. Discoveries that emerge from such work will only yield valuable nanotechnologies, however, when they can be implemented with techniques that can be scaled for cost-effective manufacturing. As a result, the success of nanotechnology depends not only on versatile nanofabrication techniques for discovery in nanoscience, but also on approaches that offer low cost operation and high throughputs, suitable for mass production. In some cases, the techniques might rely on adapted versions of methods whose origins are in the microelectronics industry, such as photolithography and electron-beam lithography. In many others, including certain areas of photonics, microfluidics, biotechnology, and flexible electronics, new approaches are required, either to facilitate commercialization, to allow manipulation of unusual materials, or to enable challenging features sizes and structure geometries.

The need for unconventional nanofabrication techniques was recognized broadly in the early 1990s, even before nanotechnology was generally recognized as a separate field of study. During this time, new areas of research emerged around soft lithography, imprint lithography, and various types of self-assembly and scanning probe based patterning methods. The interest in these approaches is driven by their diverse, underlying scientific content, their conceptual novelty, and their technical capabilities for nanofabrication. Their ultimate success, however, is measured first by the extent of their adoption for research purposes and then by their use in manufacturing. Self-assembly and scanning probe techniques will be useful for some applications, but their limited patterning versatility (i.e., materials and geometries) and modest throughput, represent significant disadvantages. Soft lithography and

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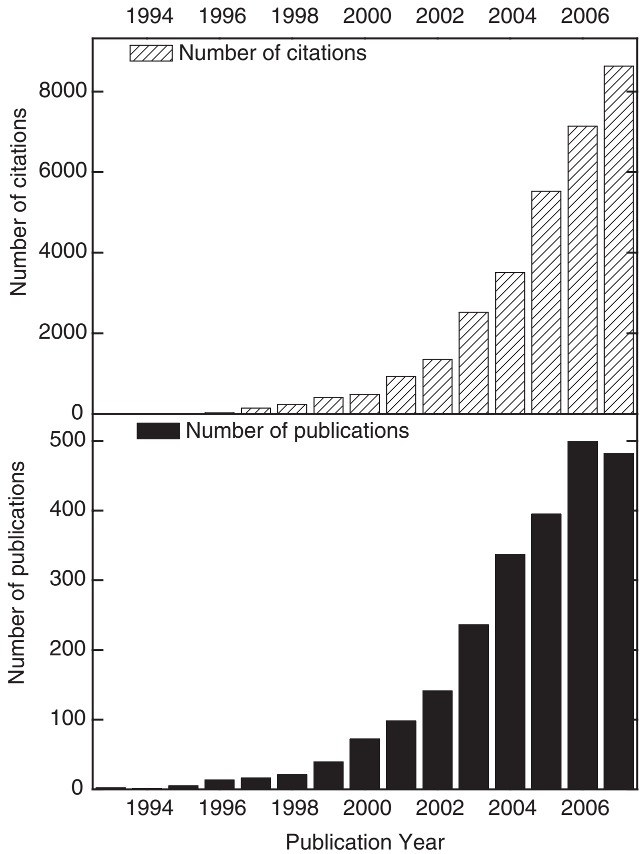

Figure 1.1. Numbers of scientific publications (bottom) and citations (top) for the fields of soft lithography and imprint lithography, since 1993.

imprint lithography avoid these problems and, in our view, have significant potential both for research and for realistic implementations in wide-ranging classes of applications. The growth of research in these areas has been explosive, starting with the introduction of microcontact printing, the first form of soft lithography, in 1993 and then imprint lithography in 1995. Figure 1.1 shows the numbers of papers in soft and imprint lithography, and citations of these papers as a function of time. These data indicate clearly the value of these methods for laboratory scale applications and research. This growth and the substantial development work on these methods at small and large companies also suggest an expansion of their use to prototyping and manufacturing.

This book covers unconventional methods for nanofabrication, with a focus on soft lithographic and related imprint lithographic methods, but also with a summary of some of the most promising self-assembly methods. The content is organized in two separate parts. The first deals with the principles and underlying science associated with a range of different techniques. In particular, the first chapter covers the classes of materials and surface chemistries that are most commonly used for the stamps, molds, and conformable photomasks of soft lithography. The next several chapters review established and new strategies for using these and analogous "hard" elements in procedures that range from transfer of solid materials to control of the flow of photons to molding of liquid or softened polymers to control of diffusion of chemicals or ions into and out of the substrate. The final chapter in this section demonstrates the power of self-assembly in procedures that rely on polymer phase separation. The second part of the book focuses on applications of these techniques in some of the most promising areas, as outlined in more detail in Chapter 11.

The content is intended for practitioners, for researchers developing new methods, and for students in specialized courses in chemistry, physics, biology, chemical engineering, materials science, electrical engineering, or mechanical engineering. The sizes of these communities are growing rapidly, due to the high level of importance of the methods to broad areas of nanotechnology, information technology, biotechnology, and related fields. We hope that this book will help expand even further the reach of these methods and that this expansion will facilitate their further development, potentially culminating with their broad-based use in bridging the gap between nanoscience and nanotechnology.