BIOMEDICAL NANOSTRUCTURES

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PART I

Nanostructure Fabrication

CHAPTER 1

Nanofabrication Techniques

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1.1 INTRODUCTION

Interest in the study and production of nanoscaled structures is increasing. The incredibly small sizes of nanoscaled devices and functionality of nanoscaled materials allow them to potentially change every aspect of human life. This technology is used to build the semiconductors in our computers; nanoscaled materials are studied for drug delivery, DNA analysis, use in cardiac stents, and other medical purposes. Layers of molecules can be placed on machine parts to protect them from wear or aid in lubrication; monolayers of molecules can be added to windows to eliminate glare. Although we are already greatly affected by this technology, new advances in nanofabrication are still being made.

Microelectromechanical systems (MEMS) and nanoelectromechanical systems (NEMS) have the potential to perform tasks and study the human body (BioMEMS and BioNEMS) at the molecular level. BioMEMS have existed for decades and were first used in neuroscience. In the 1970s, Otto Prohaska developed the first planar microarray sensor to measure extracellular nerve activity [1]. Prohaska and his group developed probes used for research in nerve cell interactions and pathological cell activities in the cortical section of the brain [1]. In the future, NEMS and other nanoscaled structures may be able to perform more advanced tasks. This technology may allow us to cure diseases or heal tissues at the molecular level. Computers may be even more powerful, while taking up less space.

Many of the fabrication methods for nanoscaled devices used today are actually based on previously conceived methods. Others take advantage of new technologies to make nanoscaled structures. Still others combine several

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different methods to produce new technologies. This section will describe several technologies commonly used in nanofabrication. These methods produce a large variety of structures from fibers, to columns, to layers of materials that are a single molecule thick.

1.2 PHOTOLITHOGRAPHY

Originally, lithography was a printing method invented in 1798 by Alois Senefelder in Germany. At that time, there were only two printing techniques: relief printing and intaglio printing [2]. In relief printing, a raised surface is inked and an image is taken from this surface by placing it in contact with paper or cloth. The intaglio process relies on marks engraved onto a plate to retain the ink [2]. Lithography is based on the immiscibility of oil and water. Designs are drawn or painted with an oil-based substance (greasy ink or crayons) on specially prepared limestone. The stone is moistened with water, which the stone accepts in areas not covered by the crayon. An oily ink, applied with a roller, adheres only to the drawing and is repelled by the wet parts of the stone. The print is then made by pressing paper against the inked drawing.

Optical lithography began in the early 1970s when Rick Dill developed a set of mathematical equations to describe the process of lithography [3]. These equations published in the "Dill papers" marked the first time that lithography was described as a science and not an art. The first lithography modeling program SAMPLE was developed in 1979 by Andy Neureuther (who worked for a year with Rick Dill) and Bill Oldman [3].

Photolithography is a technique used to transfer shapes and designs onto a surface of photoresist materials. Over the years, this process has been refined and miniaturized; microlithography is currently used to produce items such as semiconductors for computers and an array of different biosensors. To date, photolithography has become one of the most successful technologies in the field of microfabrication [4]. It has been used regularly in the semiconductor industry since the late 1950s; a great deal of integrated circuits have been manufactured by this technology [4]. Photolithography involves several generalized steps, cleaning of the substrate, application of the photoresist material, soft baking, exposure, developing, and hard baking [5]. Each step will be explained briefly below.

1.2.1 Cleaning of the Substrate

During substrate preparation, the material onto which the pattern will be developed is cleaned to remove anything that could interfere with the lithography process including particulate matter and impurities. After cleaning, the substrate is dried, usually in an oven, to remove all water [3].