NANOFABRICATION PROCESS AND NANODEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a divisional of U.S. patent application Ser. No. 12/625,077 which was filed Nov. 24, 2009, and is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] This disclosure relates to processes for patterning and etching a substrate to form a complex three dimensional surface topography defined by a plurality of nanometer scale critical dimensions and devices manufactured using such processes.

[0003] Lithography (e.g., photolithography) is known and used for fabricating nanofluidic devices, integrated circuits, and the like. As an example, a typical nanofluidic device may include a fluidic channel with a nanometer scale depth for the manipulation and analysis of biomolecules, such as nucleic acids and proteins.

[0004] Currently, photolithography is one method that is used to fabricate such nanofluidic channels. For instance, a photoresist layer may be deposited onto a substrate and then exposed to a light pattern created using a photomask. The portions of the photoresist that are exposed to the light are either rendered resistant to a developer (i.e., when a negative photoresist is used) or soluble in the developer (i.e., when a positive photoresist is used). In either case, the developer removes the portions of the photoresist that are soluble to thereby expose the underlying substrate. The exposed portions of the substrate are then etched to a nanometer scale depth which may be enclosed to form a fluidic channel. Thus, one iteration of applying the photoresist, exposing the photoresist to the light pattern, and etching the substrate forms a mono-depth channel in the substrate. Traditional lithography is therefore planar with respect to the features formed in a single iteration. Additional channels or channel depths can be formed using additional iterations but require precise alignment of the subsequent photomasks relative to the channels formed in prior iterations. Features from different iterations must overlap to form a continuous channel, while nanoscale alignment limitations can result in inadvertent over- or under-etching of the overlapping region that limits device design and functionality.

[0005] The inherent dimensional limitations on serial patterning and alignment limit the geometry, number and size of the channel depths that can be formed and prevent the fabrication of some complex three dimensional surface features. Indeed, since the utility of a nanodevice is in general proportional to its complexity and dimensionality, current devices provide relatively limited ability to manipulate biomolecules or other analytes of interest.

SUMMARY OF THE INVENTION

[0006] An exemplary nanodevice that may be fabricated using a disclosed nanofabrication processes includes a substrate having an elongated channel that includes a plurality of nanoscale critical dimensions arranged as a stepped gradient across the elongated channel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The various features and advantages of the disclosed examples will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

[0008] FIG. **1** illustrates an example of a nanofabrication process.

[0009] FIG. **2** illustrates sequential views of selectively etching a photoresist etch mask and substrate according to a nanofabrication process.

[0010] FIG. **3** illustrates an example of a nanodevice having an elongated channel with a stepped gradient across a width of the channel.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0011] FIG. **1** illustrates an example of nanofabrication process **20** that may be used with a photoresist that is disposed on a substrate to form a nanodevice. As will be appreciated from the following description, the nanofabrication process **20** may be adapted to form a variety of different types of nanodevices that are unavailable using conventional techniques. In a few examples, the nanofabrication process **20** may be used to form a nanofluidic device, integrated circuit, nanomolding tool, resonator, or other device that would benefit from the ability to form complex three dimensional surface topographies defined by a plurality of nanometer scale or nanoscale critical dimensions. As an example, the terms "nanometer scale" or "nanoscale" may refer to a critical dimension or characteristic dimension of up to about one-hundred nanometers. In comparison, larger dimensions of up to one micrometer may be referred to as "submicrometer" and dimensions exceeding one micrometer and up to about one-hundred micrometers may be referred to as "micrometer scale."

[0012] The exemplary nanofabrication process **20** includes an exposure step **22**, a developer step **24**, and a transfer step **26**. As will be described, the transfer step **26** may optionally include the action **28** of controlling an amount of oxygen gas in an etchant gas mixture used to etch a photoresist and substrate. The following description of the nanofabrication process **20** will be made with reference to a substrate and a photoresist layer disposed on the substrate. The type of substrate and photoresist materials may vary, depending on the application. However, some examples may utilize a fused silica substrate having a surface roughness of approximately less than 5 angstroms and a polymeric photoresist. As an example, the photoresist may be MEGAPOSIT SPR 700 1.2. The photoresist may be applied in a known manner, such as by using a spin coat technique. In some examples, the photoresist may be applied at an angular acceleration of 8,000 revolutions per minute and then baked at around 95° C. for about 2 minutes. The resulting photoresist thickness may be about 1070±10 nanometers.

[0013] Turning first to the exposure step **22**, a user of the nanofabrication process **20** exposes the photoresist to a gray-scale radiation pattern of varied intensity. The term "gray-scale" refers to a controlled radiation intensity over some area of the pattern. As an example, lower intensity radiation does not penetrate as deeply into the photoresist as higher intensity radiation. Thus, the pattern can be designed to imprint a