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Real- and Quasi-Atomic Layer Etching for Ultra-High Resolution Patterning

With the development of computers and other electronic devices arises the need for them to be faster and more powerful. The solution for the latter is considered to be using more *transistors* (a basic circuit component in electronics) in the processor. Fitting more of them in the same space on the chip would require reducing their size. However, if the transistors get small enough, some quantum effects would interfere with the device properties and such effects need to be considered when designing and fabricating the devices. That can be done with the help of *Nanoscience*.

Nanoscience is the study of *nanoscale* objects, with a size of one millionth of a millimeter or 10^{-9} meters, their properties and ways of fabricating them, in addition to any effects that may affect the fabrication processes. Among the fabrication techniques is *etching* - “digging a hole” in the material used. The techniques are typically divided in two groups - *wet etching*, using a liquid chemical to remove the exposed material, and *dry etching*. A widely used member of the latter group is *reactive ion etching* which uses *plasma* containing *ions*, *radicals* and other particles. The *ions* are accelerated towards the material being etched and they can knock out an atom (or a few) by collision (*sputtering*) or remove material by chemical reaction.

Another dry etching technique is *atomic layer etching* (ALE). In this process the surface of the material is *activated* by the particles of a gas sticking to the material surface then bombarded with ions so that they can remove the activated material (which was made easier by activation). If the ions do not have enough energy to remove inactivated material, then the etching would stop after the activated material is removed which should be a layer with the thickness of one atom. The process is often cyclic – repeating the *activation* and etching a number of times, which allows us to control the etch depth very precisely and allows the etch depth to be as little as the size of an atom. However, often ALE is not the only process happening in the etch step – reactive ion etching and sputtering could happen in parallel in which case the etching process is known as quasi-ALE. On the other hand, if ALE is the only etching process happening then the process is called real ALE or pure ALE.

One particular use of etching is in *patterning* if a predefined pattern is to be etched into a certain material. Often there is a mask layer on top of the one we would like to etch that already covers the areas we don’t want to be etched, so the places we want etched are exposed. With the shrinking size of the *transistors* some “holes” that should be etched during fabrication had become quite shallow and *reactive ion etching* may not be able to etch that little material. In that case, ALE is the solution.

The main focus of this project was the development of ALE optimizing the relevant parameters of the process. The goal was to develop real ALE or if that is not possible, quasi-ALE with minimized contribution to the etch depth of the unwanted etching processes.

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