Part IV
Nanoscale Materials Processing with Ion Beams

The fact that ion beams are electrically charged not only makes them well suited as probes for characterisation, (discussed in the previous part) but also makes possible their use for modification on an nanometre scale. This strong interaction makes possible extremely localised deposition of energy into the electronic and atomic structures of the target – often so the energy is delivered to a single atom.

The extreme localisation of the deposited energy is made use of for proton beam writing lithography and in focused ion beam technology (FIB). These two techniques, although they both use focused ion beams, because of the different energies and mass of the ion beam used, work on quite different physical principles with very different and in many ways complementary characteristics. FIB is a very standard workhorse tool in nanoscience, where it is used as a nanometre-scale material deposition and cutting torch, which makes it useful for modifying prototype integrated circuits by depositing metal and insulating layers as well as cutting out specimens for transmission electron microscopy. Proton beam writing, on the other hand, is capable of rapidly writing nanometre-scale patterns in thick polymer layers and even writing patterns of defects that can be used for tasks as diverse as tissue engineering, prototyping lab-on-a-chip devices, and making colour-tunable optoelectronic devices in nanoporous silicon.

Broad-beam ion bombardment is also very important in nanoscience and technology. Ion irradiation by a plasma forms the basis of plasma etching and deposition. This is a workhorse technique that is used for a range of purposes in nanofabrication, from making 3D patterns in hard materials like silicon by anisotropic etching in combination with masking, to depositing refractory metals like tungsten and platinum, as well as cleaning wafers by “ashing” resist polymers in an oxygen plasma. Most significantly, ion implantation can be used in a bottom-up way to form nanoparticles in materials in which, because of quantum confinement and coupling, they modify the fluorescence and other optical properties of the materials.