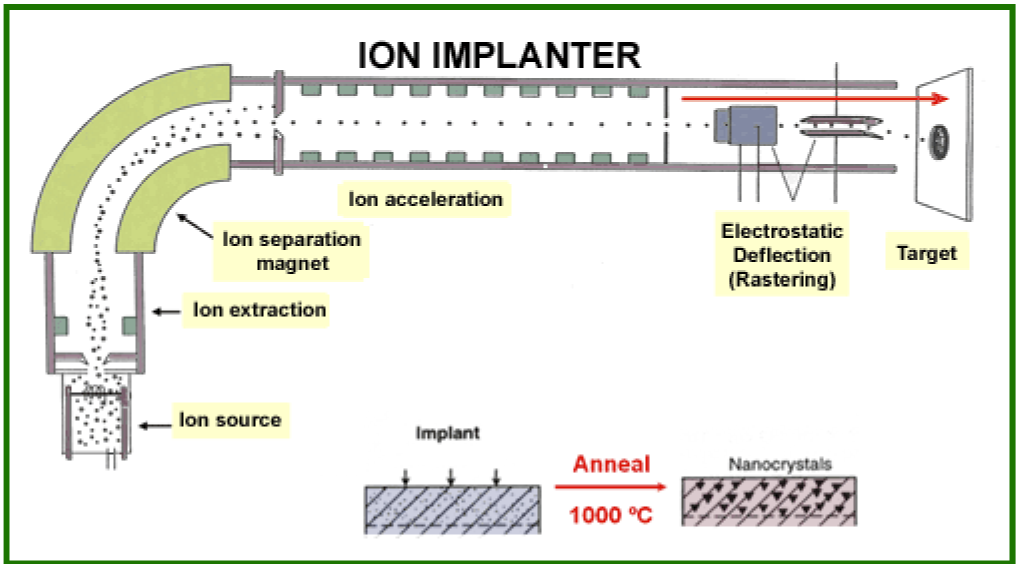

Schematic of an ion implantation system

Ion Implantation Method

Ion beam implantation is a process that changes the physical and electronic properties of a material by forcibly embedding different types of ions[1] into the material. The technique dates back to the 1940's when it was developed at Oak Ridge National Laboratory as part of the Manhattan Project.[2] Since then the technique has found a variety of applications in materials processing. In the 1970's the use of ion implantation to modify the electrical properties of semiconductors, metals, insulators and ceramics became extremely popular. In recent years the continued miniaturization of the individual transistors in integrated circuits has made ion implantation a standard technique for production of computer chips.

A typical ion implanter consists of an ionization chamber where ions are created and an accelerator where they are boosted up to speeds high enough to penetrate the target material to the desired depth. The technique is best suited to materials like semiconductors where small numbers of implanted particles can cause major changes in the material's electrical or physical properties.

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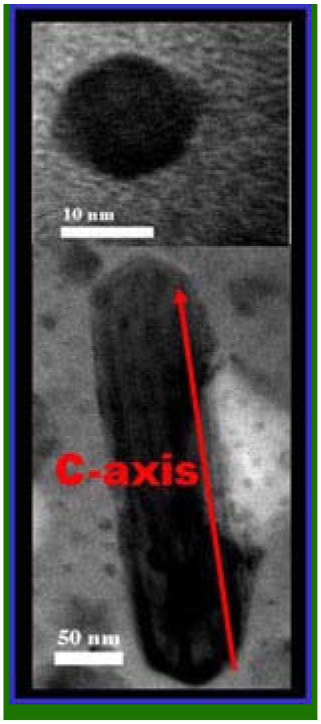
[1] Ions are atoms with a net electrical change. Normally, atoms are electrically neutral. The number of positively changed protons in the nuclei are balanced by an equal number of electrons surrounding it. But under fairly common situations, atoms can loose some of their electrons or pick up some extras, making them either electrically positive or negative.

[2] Ion implantation was one the approaches that was explored in the effort to separate the different isotopes of uranium so the fissionable isotope could be used to build an atomic bomb.

Nature’s quickest change artist

In order to create vanadium dioxide nanocrystals, the Vanderbilt researchers began with electrically charged ions of vanadium and oxygen. They accelerated them through a vacuum and slammed them like tiny bullets into targets of silicon dioxide. Because the smaller oxygen ions penetrate the target material more easily than the larger vanadium ions, the researchers had to accelerate the oxygen and vanadium ions at different energies so that they would penetrate the same depth into the material: The oxygen ions are given a kick of 120 KeV while the vanadium ions are boosted to 300 KeV. [3]



Courtesy of Richard Haglund

Vanadium dioxide nanocrystal sphere and rod made by ion implantation.

Vanadium dioxide contains two oxygen atoms for every vanadium atom. So the researchers also had to embed twice as many oxygen atoms in the material as they did vanadium atoms. When the ions penetrate the silicon dioxide they loose their excess electrical charge, changing them into neutral atoms.

Once the desired quantities of vanadium and oxygen atoms were implanted, the researchers placed the target in a furnace and heated it to 1,000 degrees Celsius (1,800 degrees Fahrenheit). The heat provides the energy that the excess vanadium and oxygen atoms need to begin forming vanadium dioxide crystals. After two minutes at this temperature, crystalline spheres about 10 nanometers in diameter were formed. At first, they formed spheres about 10 nanometers in diameter. When the target was kept in the furnace for longer periods, the spheres grew into tiny rods, reaching 50 nanometers in diameter and up to 200 nanometers in length after 30 minutes of annealing. At that point, the implanted oxygen and vanadium atoms have been largely used up and the nanorods stop growing.

[3] KeV stands for 1,000 electron volts. An electron volt is a measure of energy used in atomic and nuclear physics. It is the amount of energy that an electron gains when it moves through a potential difference of one volt. It is a very small unit of energy in everyday terms, but it is large enough to accelerate ions to very high speeds.