**Mechanisms and theory**

**Metallic**[**microstructure**](http://en.wikipedia.org/wiki/Microstructure)

The key to understanding the mechanism behind hardness is understanding the metallic [microstructure](http://en.wikipedia.org/wiki/Microstructure), or the structure and arrangement of the atoms at the atomic level. In fact, most important metallic properties critical to the manufacturing of today’s goods are determined by the microstructure of a material. At the atomic level, the atoms in a metal are arranged in an orderly three-dimensional array called a [crystal lattice](http://en.wikipedia.org/wiki/Crystal_lattice). In reality, however, a given specimen of a metal likely never contains a consistent single crystal lattice. A given sample of metal will contain many grains, with each grain having a fairly consistent array pattern. At an even smaller scale, each grain contains irregularities.

There are two types of irregularities at the grain level of the microstructure that are responsible for the hardness of the material. These irregularities are point defects and line defects. A point defect is an irregularity located at a single lattice site inside of the overall three-dimensional lattice of the grain. There are three main point defects. If there is an atom missing from the array, a [vacancy defect](http://en.wikipedia.org/wiki/Vacancy_defect) is formed. If there is a different type of atom at the lattice site that should normally be occupied by a metal atom, a substitutional defect is formed. If there exists an atom in a site where there should normally not be, an [interstitial defect](http://en.wikipedia.org/wiki/Interstitial_defect) is formed. This is possible because space exists between atoms in a crystal lattice. While point defects are irregularities at a single site in the crystal lattice, line defects are irregularities on a plane of atoms. [Dislocations](http://en.wikipedia.org/wiki/Dislocations) are a type of line defect involving the misalignment of these planes. In the case of an edge dislocation, a half plane of atoms is wedged between two planes of atoms. In the case of a screw dislocation two planes of atoms are offset with a helical array running between them.[[5]](http://en.wikipedia.org/wiki/Hardness#cite_note-4)

Dislocations provide a mechanism for planes of atoms to slip and thus a method for plastic or permanent deformation. Planes of atoms can flip from one side of the dislocation to the other effectively allowing the dislocation to traverse through the material and the material to deform permanently. The movement allowed by these dislocations causes a decrease in the material's hardness.

The way to inhibit the movement of planes of atoms, and thus make them harder, involves the interaction of dislocations with each other and interstitial atoms. When a dislocation intersects with a second dislocation, it can no longer traverse through the crystal lattice. The intersection of dislocations creates an anchor point and does not allow the planes of atoms to continue to slip over one another. A dislocation can also be anchored by the interaction with interstitial atoms. If a dislocation comes in contact with two or more interstitial atoms, the slip of the planes will again be disrupted. The interstitial atoms create anchor points, or pinning points, in the same manner as intersecting dislocations.

By varying the presence of interstitial atoms and the density of dislocations, a particular metal's hardness can be controlled. Although seemingly counter-intuitive, as the density of dislocations increases, there are more intersections created and consequently more anchor points. Similarly, as more interstitial atoms are added, more pinning points that impede the movements of dislocations are formed. As a result, the more anchor points added, the harder the material will become.