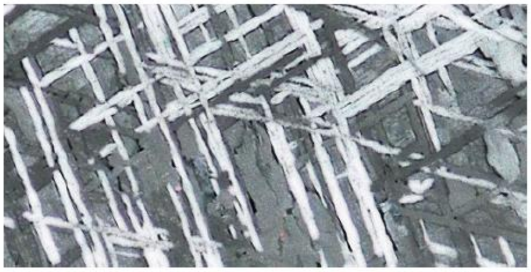
The Widmanstatten, or Thomson Pattern/Structures and How They Form in Meteorites From the Minerals Taenite and Kamacite.



Typical Widmanstätten pattern on an etched iron-nickel meteorite

Widmanstätten: Pronounced "Vidmanstayten"
<u>Note: At the beginning there are technical terms that will be explained in the document. Please skip to page 2 first for explanations.</u>**

Widmanstätten patterns, also called Thomson structures, are figures of long nickel-iron (Ni:Fe) crystals, found in the octahedrite iron meteorites and some pallasites (gorgeous Olivine crystals of peridot in the (Ni:Fe, or Fe:Ni).
They consist of a fine interleaving of Kamacite and taenite bands or ribbons called lamellae. Commonly, in gaps between the lamellae, a fine-grained mixture of kamacite and taenite called plessite can be found. The light regions are the low Nickel Kamacite. Widmanstätten patterns can also be found in some steels, usually unwanted because of being so hard, as well as[1] titanium and zirconium alloys.

<u>History</u>

- **In 1808 the pattern was discovered by Count Alois von Beckh Widmanstätten, the director of the Imperial Porcelain works in Vienna. He did not publish his findings, claiming them only via oral communication with his colleagues. Carl von Schreibers, the director of the Vienna Mineral and Zoology Cabinet, after further study named the structure after Widmanstätten.**
- **However, it is now believed that full credit for the discovery should actually be assigned to William Thomson, MD, and minerologist (British, known as Guglielmo Thomson in Italy) as he published the same findings four years earlier.**
- **Working in Naples in 1804, Thomson treated a meteorite with nitric acid in an effort to remove oxides. Shortly after the acid made contact with the metal, the same pattern appeared.**
- **Due to Civil wars and political instability in southern Italy Thomson could barely maintain contact with colleagues in England, and his courier was murdered. His findings were only published in French in the *Bibliothèque Britannique*.**
- **Due to the Napoleonic wars, Thomson fled to Sicily and in November of that year, he died in Palermo at the age of 46. In 1808, his work was again published posthumously in Italian from the English manuscript. The wars, travel across Europe and early death delayed his contributions for many years.**

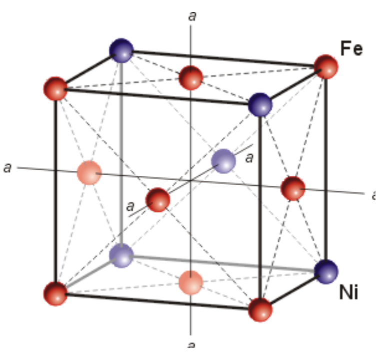
<u>The formation of the Meteorite Structures:</u>

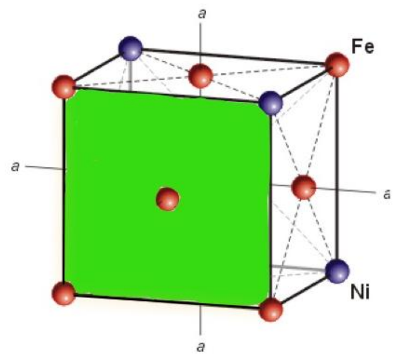
The macro- and microstructure of iron meteorites provide valuable insights into both the inner structure of our planet and the history of our solar system. High speed collision events in the asteroid belt send the meteorites careening toward Earth. <u>With cooling rates on the scale of a few degrees per million years, phase transformations (changes in the crystals) can occur under ideal conditions.</u> This cannot be done by us because we cannot duplicate the slow cooling. Many researchers are trying to create the meteor Widmanstätten/Thomson structures using computer models but this is still in its infancy. Preserving meteorite fragments helps to understand the origin of the universe.

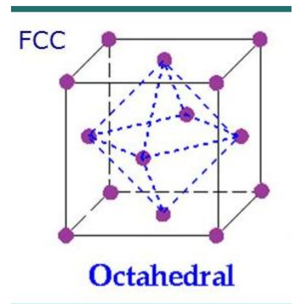
Thomson/Widmanstätten patterns are created as the meteorite cools; at high temperatures both iron and nickel have face-centered lattices/crystals. When the meteorite is formed it starts out as entirely <u>molten</u> taenite (greater than 1500 ˚C) and as it cools past 723 ˚C (some sources say 900C depending on the Nickel content) the alloy changes into crystalline taenite and kamacite begins to form. As the meteorite cools below 723 ˚C the Thomson structures form but temperature, pressure, and composition of the meteorite are also factors.

Taenite:

Taenite (Fe,Ni) is a mineral found on Earth mostly in iron meteorites and is a major constituent in them. In octahedrites (crystal structures of 8 sides i.e. like an octahedron) it is found in bands interleaving with kamacite forming Widmanstätten patterns.
Taenite may contain from 20 to 40% Nickel although Mindat puts it at 25 to 65%.
The structure is gamma-(Ni, Fe) <u>in the cubic system</u> so it is Face Centered Cubic or FCC (left figure).

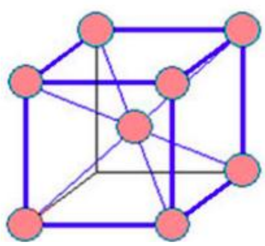






The middle diagram shows one face of the crystal to show the FCC type. Inside there is an 8 sided set of crystal planes. These form an octahedron from the atoms on the faces. An FCC structure has close packed octahedral planes. These minimum atomic spacing planes are the faces that allow Kamacite to grow into Taenite to create the Widmanstätten/Thomson structure. FCC crystals can be thought of as stacked octahedral planes.

Kamacite:



This mineral is an alloy of iron and nickel which is found on Earth only in meteorites. Kamacite has 5-10 wt% Ni, and in the cubic system is body centered cubic (BCC). In the image the center atom within the cube can be seen.

In other words the proportion of iron:nickel is between 95:5% and 90:10%. The mineral has a metallic luster, is gray and has no clear cleavage plane. It is also sometimes called balkeneisen.

<u>Summary of How Kamacite Grows into Taenite</u>

From the above discussion Taenite essentially has a FCC lattice and Kamacite has a BCC lattice as an overview. At high temperatures both iron and nickel are face-centered, and iron meteorites are essentially all taenite. As the temperature drops, kamacite begins to exsolve (separate out), expelling nickel into the taenite and forming thin lamellae (bands) of almost pure iron. The most common variety of iron meteorite is called "octahedrite" because the kamacite lamellae are oriented along the octahedral faces of the taenite. The crystallographic plane that dominates in the kamacite lamellae/bands has a close atomic spacing with a misfit of about 3 per cent from Taenite. This is good enough to allow the two minerals to join and Kamacite to grow into Taenite but not small enough to prevent some misfit later on. The 3 percent is a calculation.

<u>Why Does the Widmanstätten/Thomson Structure or Pattern have Dark and Light Regions?</u>

When the polished meteorite surface is etched or "attacked" by weak Nitric acid the high Nickel Taenite does not etch very much so it stays dark. The Kamacite with its 1) lower Nickel content and 2) different structure does become etched and becomes lighter in color. There are some new astonishing images using tinted acids.