Crystals and metallurgy

Metals and their alloys are known as polycrystalline solids – for they are formed by a multitude of crystals. The defects within and between the crystals explain much of the behaviour of a metal.

Bronze figurine (West Africa); Danakil steel knife (Ethiopia), brass and copper reliquary (Kota, Gabon).
Col Museum de Grenoble

The first traces of metallurgy can be found in the use of bronze 5000 years ago in the Middle East. Around 1200 BC, the early Anatolians discovered that iron heated with charcoal is harder than bronze. It was not until the early 19th century, however, that new metals such as aluminium could be isolated from their environment. Given the huge technical advances made this century in the treatment of ferrous metals, it is said that we are now living in the «golden age» of steel (which is a combination of iron and carbon).

A piece of metal is made up of a group of crystallites (known as grains); they are interlinked and vary in size from a centimetre to a nanometre in length (one billionth of a metre).

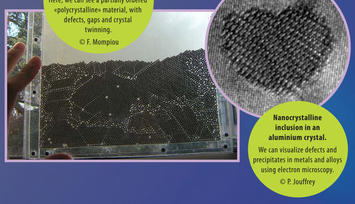
Metallurgy: from the age of bronze to the golden age of steel

Metallurgy is the science that studies the structure and properties of metals and alloys. It has its origins 3000-5000 years ago in the bronze and iron ages. Metallurgists are also interested in the technologies used for the production, treatment and casting of metals, and of steel in particular.

The age of materials with controlled «defects»

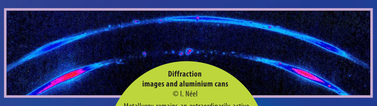
Metallurgists spend their time on the development and shaping of materials, for use in the automobile, aeronautical and nuclear industries for example. Electron microscope and X-ray diffraction techniques are used to determine the order in which the crystals are arranged, and to understand the processes involved during the elaboration (solidification, precipitation) and use (corrosion, ageing process, distortion) of metal alloys.

Whilst hardness can be associated with the structure of a crystal, it is often the **defects that determine the mechanical properties of metals and alloys.**



We can picture the order of atoms and defects in a material using a stack of metal balls in a box. Here, we can see a partially ordered «polycrystalline» material, with defects, gaps and crystal twinning.
© F. Mompiou

Nanocrystalline inclusion in an aluminium crystal.
We can visualize defects and precipitates in metals and alloys using electron microscopy.
© P. Jouffrey



Diffraction images and aluminium cans
© L. Néel

Metallurgy remains an extraordinarily active sector of research – the twentieth century has seen an explosion in the use of aluminum for example. Aluminium is everywhere – what do the traditional Italian coffee machine, kitchen paper, aircraft wings and jet engines have in common? Aluminium! Only the defects differentiate the different aluminiums . X-ray diffraction allows scientists to distinguish deformed crystals (larger spots) from the recrystallized crystals (thinner spots).