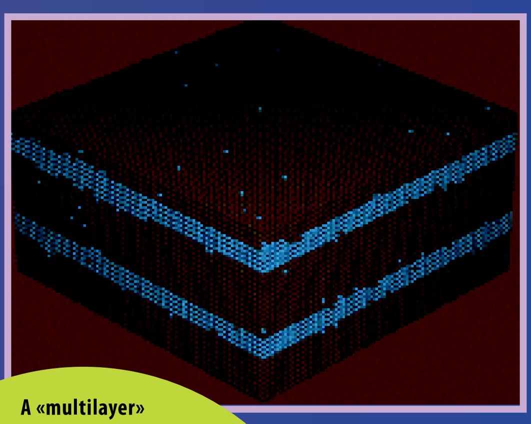
The crystal, magnetism and neutrons: from Néel to Fert

Néel invented the concept of antiferromagnetism and neutron diffraction proved him right. Whilst working on the production of artificial antiferromagnetic crystals, Fert and Grünberg discovered «giant magnetoresistance (GMR)». This has led to applications that have massive importance in our daily lives.



A «multilayer» artificial crystal,

produced like a layer cake for its giant magnetoresistance properties (GMR).

Giant Magnetoresistance or GMR is an amazing property:

(1) if the magnetic layers are magnetized in the same direction, the electric current flows (resistance is low)

(2) If the layers are magnetized in opposite directions however, the current falters (resistance is very high). We can use or modify the electronic properties of the individual layers of artificial crystals by adjusting their different layers.

The electronics industry produces more than 600 million GMR read heads every year. There may be one of them inside the MP3 player in your pocket.

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In a **magnetic crystal** the order of magnetic moments is superimposed on its atomic order. The atoms' magnetic moments can be likened to tiny compass needles.

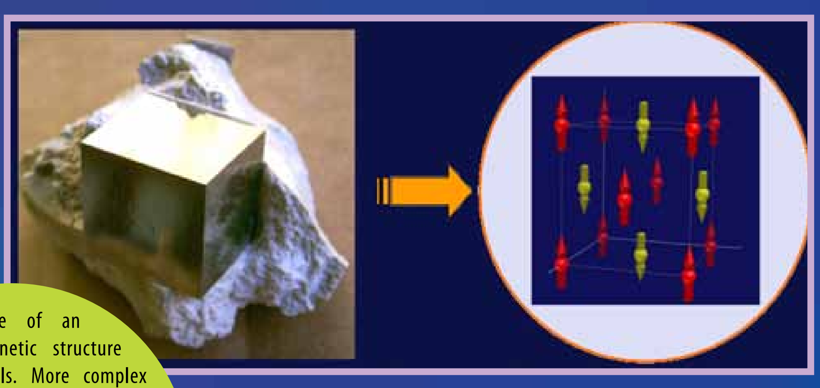
Just as X-rays have helped us to see the order of the atoms, so **neutrons let us observe the magnetic order**, for neutrons are themselves like tiny compasses: they possess a magnetic moment.

1970: Néel is awarded the Nobel prize

In 1932 **Néel discovered a specific new order**, the alternance of magnetic moments in one or the other direction, now known as **antiferromagnetism**. This explains the behaviour of certain magnetic materials but the idea went against the theories prevailing at the time. Seventeen years later, the observation of a manganese oxide crystal, using neutron technology, confirmed the existence of this type of order.

2007: Fert and Grünberg are awarded the Nobel prize

By stacking very fine layers (a few nanometres or millionths of a mm), with alternating magnetic and nonmagnetic layers, **Fert and Grünberg discovered and produced an artificial magnetic crystal**. This allowed them to control the resistance of the material. They had discovered the property of giant magnetoresistance. From then on even tinier read heads could be produced for the manufacture of very large capacity hard disks.



Example of an antiferromagnetic structure in cubic crystals. More complex orders can exist, in magnetite for example

The Nobel prize winner Louis Néel's model of **magnetite**, which he made out of wire and plugs, to help himself understand the structure of the mineral.

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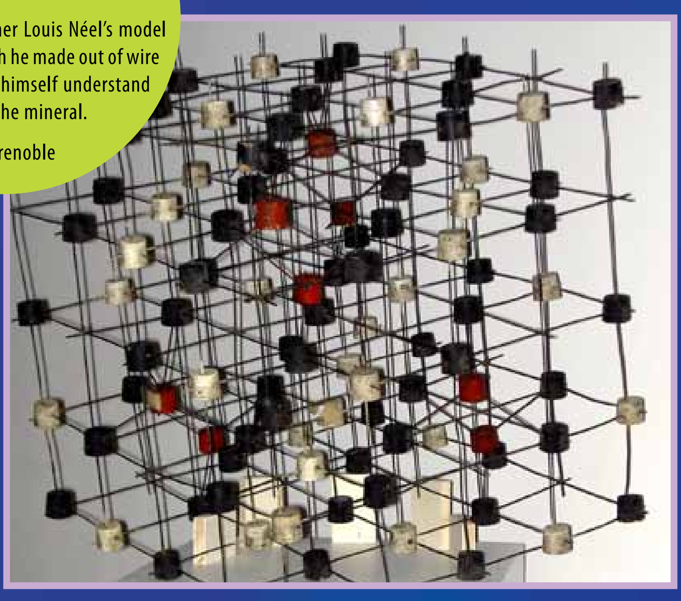

Compass networks

By examining the direction of the compass arrows we can see the different levels of crystal magnetic moments. Several arrangements are possible:

- Oriented randomly - this is disorder or paramagnetism
- All parallel - ferromagnetism
- More subtle: pointing alternately in one direction or the other - this is antiferromagnetism
- And there are many other possibilities...

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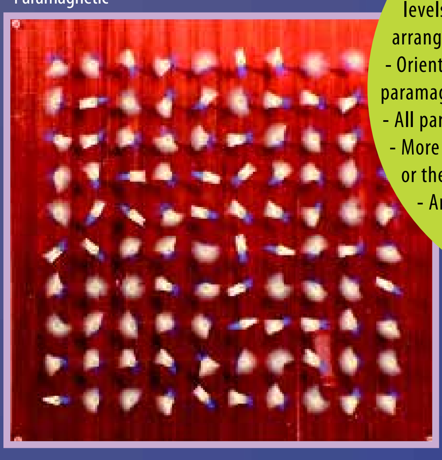
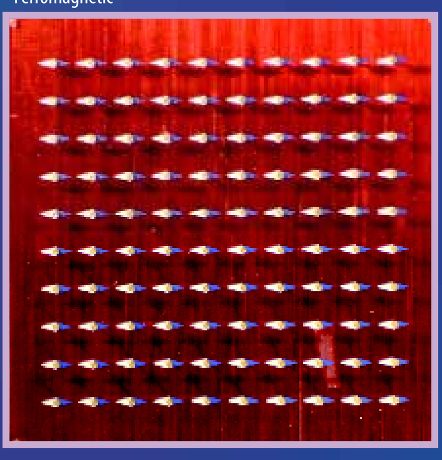
Paramagnetic



Ferromagnetic



Soft ferromagnetic alignment of compasses