

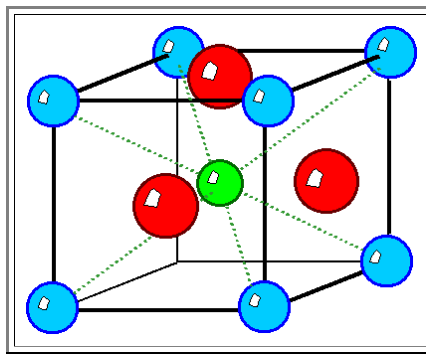
### 3.6.2 Ferro Electricity

The name, obviously, has nothing to do with "*Ferro*" (= Iron), but associates the analogy to ferro magnetism. It means that in some special materials, the electrical dipoles are not *randomly* distributed, but interact in such a way as to align themselves even *without* an external field.

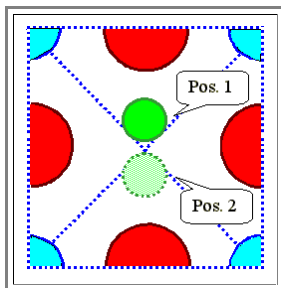
- We thus expect *spontaneous polarization* and a *very large* dielectric constant (**DK**).
- This should be very useful - e.g. for making capacitors - but as in the case of ferro *magnetism*, there are not too many materials showing this behavior.

The best known material used for many application is **BaTiO<sub>3</sub>** (**Barium titanate**).

- It has a simple lattice as far as materials with three different atoms can have a simple lattice at all. The doubly charged **Ba<sup>2+</sup>** atoms sits on the corners of a cube, the **O<sup>2-</sup>** ions on the face centers, and the **Ti<sup>4+</sup>** ion in the center of the cube.
- We have **8 Ba<sup>2+</sup>** ions belonging to **1/8** to the elementary cell, **6 O<sup>2-</sup>** ions belonging to **1/2** to the elementary cell, and one **Ti<sup>4+</sup>** ion belonging in total to the cell, which gives us the **BaTiO<sub>3</sub>** stoichiometry.
- This kind of crystal structure is called a **Perovskite** structure; it is very common in nature and looks like the drawing below (only three of the six oxygen ions are shown for clarity):



Often, the lattice is not exactly cubic, but slightly distorted. In the case of **BaTiO<sub>3</sub>** this is indeed the case: The **Ti** - ion does not sit in the *exact* center of the slightly distorted cube, but slightly off to one side. It thus has *two* symmetrical positions as schematically (and much exaggeratedly) shown below



- Each elementary cell of **BaTiO<sub>3</sub>** thus carries a dipole moment, and, what's more important, *the moments of neighbouring cells tend to line up*.

The interactions between the dipoles that lead to a line-up can only be understood with quantum mechanics. It is not unlike the interactions of *spins* that lead to ferro magnetism.

- We will not go into details of ferro electricity at this point. Suffice it to say that there are many uses. Traditionally, many capacitors use ferro-electric materials with high **DK** values. In recent years, a large interest in ferro-electrics for uses in integrated circuits has developed; we have yet to see if this will turn into new products.