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Global methods for characterizing phase transformations

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Abstract – To characterize phase transformations and their kinetics, it is necessary to know, at each time the nature of each phase, as well as their distribution and volume fraction. No experimental technique alone is capable of providing these two types of information. The nature of phases is, indeed, a local parameter, whereas the distribution and volume fraction are more global parameters. It is important to use, in parallel with local techniques, global experimental techniques, that investigate the response of the whole sample to a stimulus. The aim of this talk is not to give an exhaustive list of all global experimental techniques, but to focus on a few examples of recent studies dealing with the characterization of phase transformations.

To characterize phase transformations and their kinetics, it is necessary to know, at each time: (i) the nature (crystallography, chemistry, morphology..) of each phase, as well as, (ii) their distribution and volume fraction. No experimental technique alone is capable of providing these two types of information. The nature of phases is, indeed, a local parameter (nanometer sclale), whereas the distribution and volume fraction are more global parameters (micrometer scale).

Electronic microscopy is the most commonly used technique to investigate local information (see figure 1). Another local (and booming) technique is tomographic atom proble, which gives access to the nature and position of atoms. For such techniques, the analysed zone is of the order of a few nm^3.

The main drawback of these techniques remains in the difficulty to obtain global information, requiring thus long and numerous experiments coupled with heavy statistical treatment (e.g. to reach precipitate size distribution). Moreover, such properties like phase fractions are simply impossible to get with such techniques.

This is why, in parallel, it is important to use global experimental techniques, that give an average on a very large number of objects. Global techniques are based on the response of a given material to a stimuli that can be:

- thermal: (i) the energy to reach a given temperature (calorimetry), or (ii), the voltage arising from a sample submitted to a temperatures gradient (thermoelectric power – see figure 2) is measured.
- electrical: the level of electric resistance of a sample can be measured (resistivity)
- mechanical: the deformation of the sample is measured under (i) low amplitude and cyclic stress (mechanical spectroscopy) or (ii) large amplitude stress (hardness, mechanical testing).
- radiative: the interaction between the sample and a radiation (X-rays, neutrons, electrons…) is studied.

The aim of this communication is not to give an exhaustive list of all global experimental techniques, but to focus on a few examples of recent studies dealing with the characterization of phase transformations, namely (i) the determination of the solubility limit of copper in iron, (ii) the tempering of martensite and (iii) a precipitation sequence in aluminium alloys.

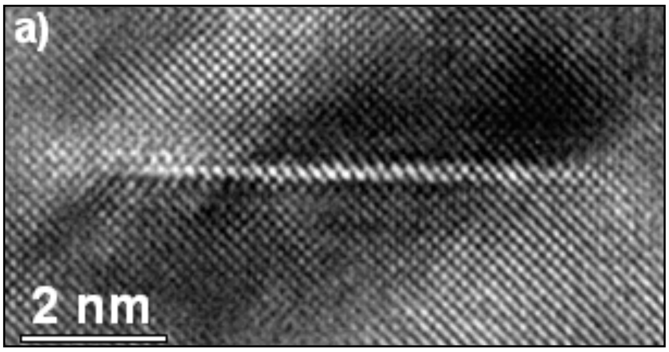

Figure 1: Local technique: HRTEM
(Monoatomic platelets of NbN [1]).

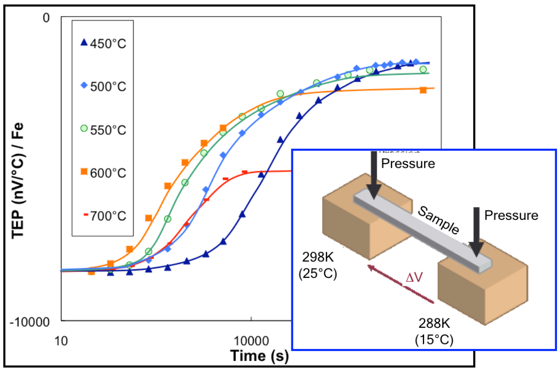

Figure 2: Global technique: Thermoelectric power
(Cu precipitation in Fe [2])

References

[1] Perez (M.), Courtois (E.), Acevedo (D.) et al., Phil. Mag. Lett., vol. 87, 2007, p. 645-656
[2] Perez (M.), Perrard (F.), Massardier (V.) et al., Phil. Mag., vol. 85, no 20, 2005, p. 2197-2210