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# Low-temperature thermochemical treatments: metastable phases formation and opportunities for new developments

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Heat treatments have been widely employed by mankind since ancient times to tailor metal components properties. Similarly, thermochemical treatments have been used to modify the components surface properties. These treatments can lead to metastable phases formation, that are essential to achieve the desired performance. However, low-temperature thermochemical treatments have been investigated more recently, being currently applied most likely for stainless steels [1-2].

The most important and deleterious effect of applying "conventional" thermochemical treatments over stainless steels is the decrease of corrosion resistance on its treated surface. The corrosion resistance in such materials depends on the formation of a Cr-rich passive oxide layer on the steel surface and its occurrence is observed when at least 10.5 wt. % Cr is present in solid solution. The "conventional" thermochemical treatments lead to Cr compounds formation, such as chromium nitrides and/or carbides, diminishing the Cr content in the solid solution, thus decreasing corrosion resistance of the treated surface. Therefore, the motivation to develop low-temperature thermochemical treatments is to overcome this problem.

The low-temperature thermochemical treatments enable the improvement of stainless steels surface properties avoiding negative impacts in its corrosion resistance, or, in some cases, promoting improvements in terms of corrosion resistance [3]. This is possible due the fact that Cr is a substitutional atom and atoms introduced by thermochemical treatments, generally C, N or both, are interstitials, presenting consequently different mobility in the crystal lattice. Owing to this different behavior, it is possible to perform treatments choosing a temperature in which the substitutional diffusibility is negligible, whereas the interstitial one is significant. Therefore, high Cr content compounds cannot be formed due to kinetic limitations and, consequently, metastable phases are formed. As a result, Cr atoms remains in solid solution and the treated layer consists of a supersaturated solid solution of the introduced element, or of compounds containing a substitutional atom fraction equal to that of the treated steel and the introduced element, without reduction of the material matrix Cr content in solid solution. This condition is also known as *paraequilibrium* condition. By these means it is then possible to experience the stainless steel surface hardening, increasing its wear resistance and avoiding decreases in its corrosion resistance. Should further information concern the reader, an introduction on the subject can be found in [4].

Low-temperature thermochemical treatments are also applied for nickel alloys and, similarly to stainless steels, it is possible to obtain a treated layer of a C- and/or N-supersaturated solid solution. Due to the supersaturation, the crystal lattice parameter is increased, and these phases are thus known as expanded phases. The expanded phases are easily identified via X-ray diffraction by observing the component's diffraction peaks shift towards lower angles, as exemplified in Figure 1 for a low-temperature nitrided (300°C) martensitic stainless steel. The behavior of theses phases is very interesting for technological application, presenting generally high hardness and high corrosion resistance.

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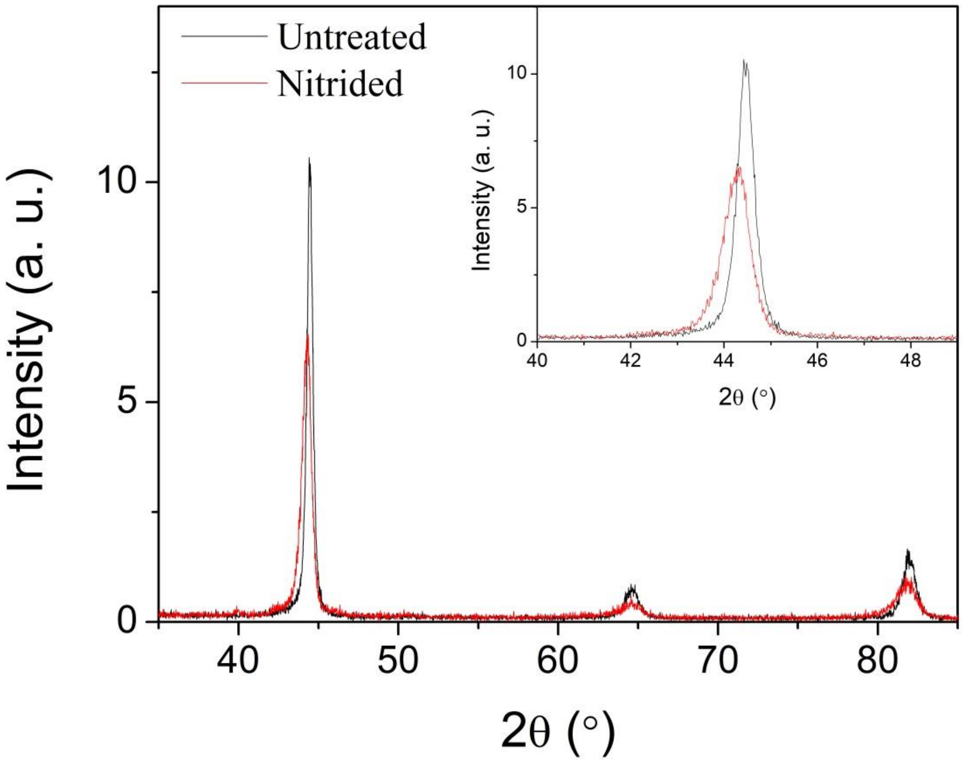


**Figure 1:** Example of X-ray diffraction patterns for untreated and low-temperature nitrided (300°C) martensitic stainless steel samples.

Based on phenomena behind these metastable phases formation as well as on the knowledge about low-temperature treatments, one can imagine that other commercial alloys, or alloys specially developed for it, are susceptible to be treated by such process, and can lead to the formation of new expanded phases or unknown *paraequilibrium* compounds. Since this research field is not vastly explored, one can expect important scientific and technological opportunities coming from the application of low-temperature thermochemical treatments for other metal alloys and thereby significant development should take place in this subject in the next years.

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