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# Microstructure and property evolution of Fe-N ferrite undergoing early-stages of precipitation

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## Abstract

The precipitation-hardening phenomenon is well-known in nitrogen-supersaturated ferrite and its precipitation sequence has received extensive attention. Thus far the  $\alpha''$ -Fe<sub>16</sub>N<sub>2</sub> phase has been known as the main hardening precipitates in the alloy upon ageing at low temperatures. Here we report that distinct precursors (pre- $\alpha''$ ) of the  $\alpha''$ -phase exist and they also play a crucial role in the precipitation-hardened alloy. Using (in-situ) high-resolution transmission electron microscopy, property characterization and first-principle energy calculations in association with varying thermal processes, it is shown that lying on the  $\{001\}_\alpha$  planes, the pre- $\alpha''$  precipitates have a plate-like morphology and are the major hardening precipitates in natural aged Fe-N ferrite. They are stable without much change even after tempering at 60 °C for 2 h. Furthermore, the plate-like pre- $\alpha''$  precipitates typically consist of needle-like domains, due to energy minimization. The in-situ observations demonstrate that the precipitation sequence upon ageing is as follows: N-supersaturated  $\alpha$ -Fe  $\rightarrow$  N-rich clusters  $\rightarrow$  pre- $\alpha''$  (GP zones)  $\rightarrow$   $\alpha''$ , where GP zones stands for Guinier-Prestone zones. The pre- $\alpha''$  precipitates can have even more significant effects on properties of the alloy, as compared with the well-known  $\alpha''$  precipitates.

**Keywords:** Fe-N alloys; GP zone;  $\alpha''$  phase; Precipitation; Transmission electron microscopy; Property

## 1. Introduction

Age-hardening phenomena are often observed in N-supersaturated ferrite or martensite,

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