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TEM Characterization of Complex Nanoprecipitates in Single-Phase V-Nb bearing Automotive Steels

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Micro-alloyed single-phase nanoprecpitated steels are a new generation of Advanced High Strength Steels (AHHS), mainly developed for light-weight automotive applications. These modern steel grades can present a tailor-made combination of high strength, ductility and complex formability performance, which stem from the lean compositional design and thermomechanical controlled processing (TMCP), which produce an essentially single-phase ferritic matrix strengthened by second-phase nanoprecipitates. These nanoprecipitates are mainly carbides (M_xC_y) and/or carbonitrides (M_x,(C_y,N_{1-y})), where M may be V, Nb, Mo, Ti or a combination [1, 2]. These Face-Centered Cubic (FCC) carbides/carbonitrides are the crucial aspect of these steel grades hardening. Concerning their developing orientation relationship, some of these nanoprecipitated particles present Kurdjumov-Sachs (K-S) in austenite and Baker-Nutting (B-N) in ferrite, whereas others do not follow such established orientations, which indicate their nucleation and growth in austenite [3, 4]. However, their complex chemical composition and ultra-fine size require advanced experimental facilities to fully characterize.

In the current research, a cold rolled micro-alloyed single-phase V and Nb-bearing automotive strip steel with a ferritic microstructure, is studied to assess its potential use for automotive applications. The experimental approach followed focusses on a detailed characterization of the complex nano-precipitates evolution in the matrix via TEM coupled with EDS microanalysis. Initial observations provide indication that the studied precipitates appear to deviate from established Baker-Nutting (B-N) orientation relationship in ferritic matrix (SADP on Fig. 1), which can confirm that the larger (<100 nm) precipitates are nucleated and grown in austenite [3]. Furthermore, fine (<100 nm) and ultra-fine (<10 nm) precipitates are identified, and the majority of them present a V/Nb wt.% ratio equal to 1.2 – 1.8 approximately, verified by TEM-EDS examination. The shape of smaller precipitates can be characterized as sphere-like, whereas the geometry of larger precipitates present a complex curved tetrahedron-like morphology, as can be understood via the tilted (Fig. 1) and non-tilted (Fig. 2) bright field TEM micrographs of the same working area. The studied SADP and Moiré patterns reveal that the precipitates develop misfit angles $\theta < 5^o$ with the matrix

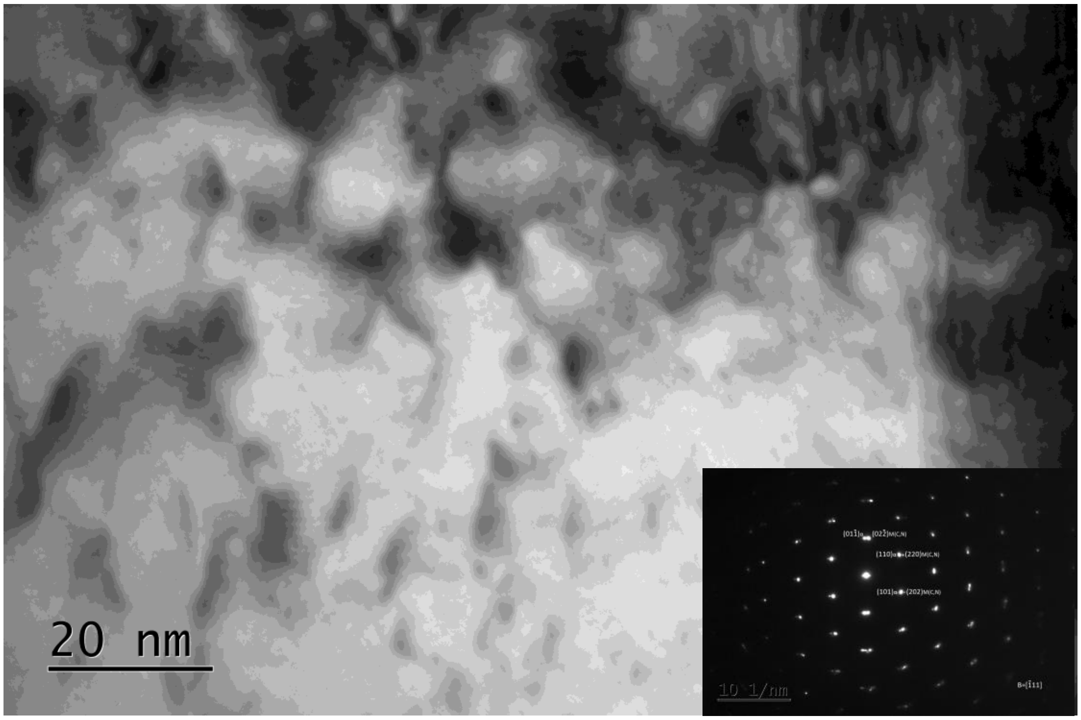

Figure 1. BF TEM micrograph coupled with SADP (tilted) present the morphology, size, coherent strain field and orientation relationship (near to $\{110\}_{\alpha}//\{220\}_{M(C,N)}$ and $[-111]_{\alpha}//[-111]_{M(C,N)}$) of nanoprecipitates in ferritic matrix.

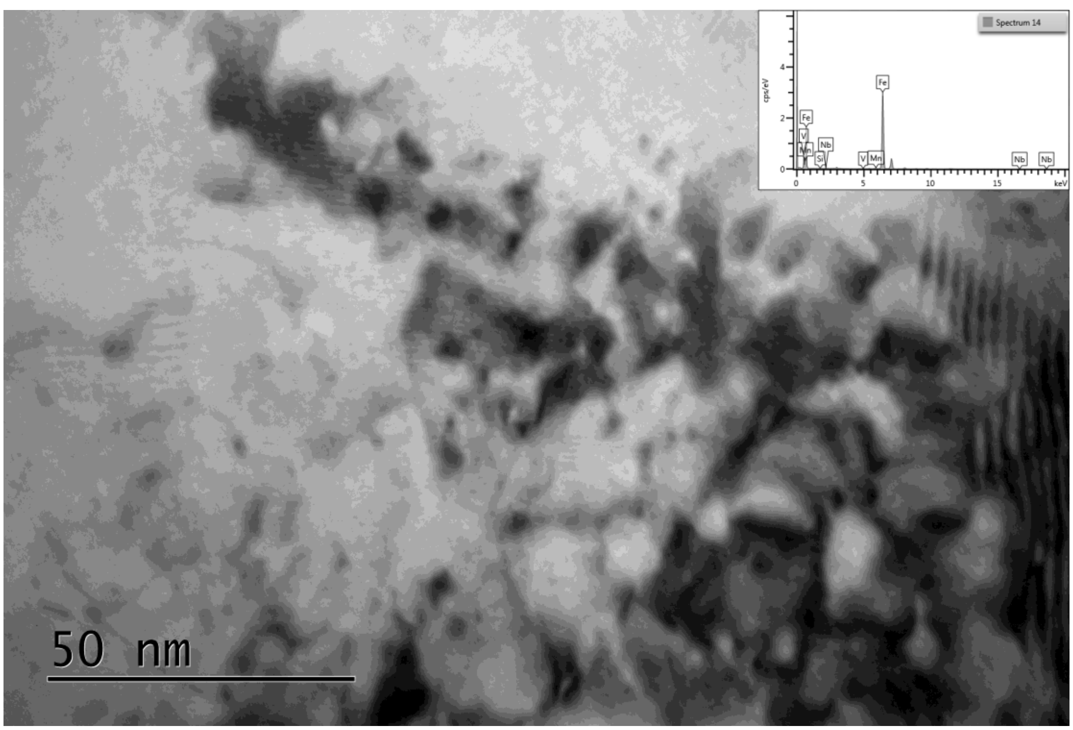

Figure 2. BF TEM micrograph (without tilt) coupled with an associated EDS spot microanalysis trace recorded in area A, that presents the variety of the nanoprecipitates, characteristic Moiré patterns development within ferrite, as well as chemical composition, which present a V/Nb wt.% ratio equals to 1.5 approximately.

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