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TEM Observations of Interphase Precipitation in Microalloyed Hot Strip Steels

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Fine carbonitride precipitation has long been recognized as an important strengthening mechanism in microalloyed steels. For many years, it was believed that only carbonitride particles formed in ferrite would contribute to strengthening. However, detailed TEM studies of the present authors have shown that, after industrial hot strip rolling, precipitation strengthening is only due to carbonitride particles that have formed in austenite during deformation and to interphase precipitation which accompanies the $\gamma \rightarrow \alpha$ phase transformation during cooling [1]. In principle, nucleation conditions can be identified from the electron diffraction pattern by determining the orientation relationship between the carbonitride particles and the surrounding ferrite matrix. When trying to distinguish the rather heterogeneously distributed interphase precipitation from the controversial post-transformation precipitation in ferrite, however, diffraction conditions have to be controlled very carefully in a double-tilt sample holder in order to identify interphase precipitation by the presence of only one variant, and precipitation in ferrite by the presence of all three variants of the same Baker-Nutting orientation relationship [2]. Thus, in Fig.1, interphase precipitation was found to be present not only in the area marked “A” where the particle sheets were aligned parallel to the electron beam (a rare event in principle, known as row formation), but also in the area marked “B” which exhibited a random particle distribution because the interphase precipitation sheets were inclined at some angle with respect to the electron beam.

In the present paper, TEM evidence is presented which proves that, in industrially processed hot strip steels, interphase precipitation sheets tend to align parallel to the rolling plane. As a result, interphase precipitation can easily be identified in TEM samples prepared from longitudinal or transverse sections, due to very frequent events of row formation. On the other hand, TEM samples prepared from normal sections (foil plane parallel to the strip surface) tend to exhibit the random morphology of interphase precipitation, increasing chances of observing post-transformation precipitation in ferrite by mistake.

The preferential alignment of the interphase precipitation sheets was noted after intensive studies of carbonitride precipitation in five different Nb, Nb+Ti and Nb+Ti+V microalloyed hot strip steels. Several examples and a statistical analysis of some of these observations in longitudinal and transverse sections are shown in Fig.2. The alignment can be understood with reference to the formation of pancaked austenite grains during hot strip rolling and the concept of “saturated-site nucleation” associated with the $\gamma \rightarrow \alpha$ phase transformation [3].


![FIG.1](image_url) Interphase precipitation under bright field conditions in (a), dark field conditions in (b). Diffraction pattern showing objective aperture with 200 carbonitride and superposed 110 ferrite reflection for dark field in (c). Magnification 90.000X.

![FIG.2](image_url) Interphase precipitation with row formation in longitudinal sections in (a), (b) and (c), transverse sections in (d), (e) and (f). Rolling plane is vertical and perpendicular to the plane of paper in all micrographs. Magnification 70.000X.