

Electron Energy Loss Spectroscopy Study of NbC Precipitates in an Ultra-Low Carbon Hot-Rolled Microalloyed Steel

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The role of the niobium in microalloyed steels is related to its ability to strength the steels by precipitation and for an effective retardation of the recrystallization kinetics by strain induced precipitation [1]. Many attempts have been made to characterize these particles. In this work, a detailed electron energy loss spectroscopy study of NbC precipitates in ultra-low carbon niobium microalloyed steel is presented. Preliminary reports of the work have appeared in References [2, 3].

250 kg of steel of controlled composition were induction melted and cast into metallic ingots of 101.6 mm × 150 mm, and deoxidized with aluminum in situ. The niobium addition was done as well (Table 1). The cast steel was hot rolled in a 50 ton two-high reversing mill in the temperature range of 1150° – 900° C. Precipitates were detected from polished and (electrolytic) etched and examined at high resolutions in a transmission electron microscopy (TEM) Phillips CM200 including backscattering electron detector, an *ultra thin window* energy dispersive X-ray spectrometer (EDX), and a parallel electron energy loss spectroscopy (PEELS). Using bright field images, the type, morphology, size, and distribution of the precipitates of the hot rolled Nb microalloyed steel were studied. The particles were semiquantitatively analyzed for the heavier alloying elements using EDX while PEELS was used for the lighter elements.

Figure 1 shows two loss energy spectra at the region of the carbon ionization edge (K: 284 eV), acquired at steel matrix regions (zone 1) and at internal regions of the precipitates (zone 2). In the region of the steel matrix there is a very low signal that corresponds to the carbon ionization edge, while in the zone where precipitates are present, the carbon edge stand out clearly. An analysis of the carbon ionization edge shape shows that this element is not free, but forming a compound (niobium carbide). Therefore, the carbon in the steel is localized predominantly in the precipitates.

Figure 2 shows two PEELS spectra at the region of the iron ionization edge (L_3 : 708 eV, L_2 : 721 eV) obtained in two zones, the steel matrix and the precipitates portion. A qualitative analysis confirms that the relative intensity of the peaks corresponding to the L_2 and L_3 edges is really different at both zones. Apparently there is a change in the Fe electronic structure at the interface [4]. However, this change can not be quantified and interpreted. When the carbide spectrum was acquired, the electron incident beam excites a wide region of the iron matrix far away of the carbide. Therefore, the spectrum region marked as precipitate zone is in reality a superposition of both regions. In order to differentiate them will be necessary to use a nanometric beam, which will be carried out in subsequent works. [5]

References

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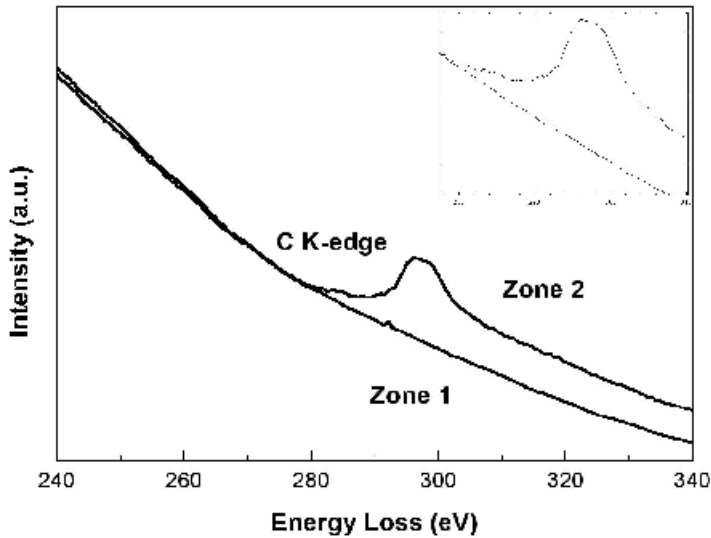


FIG. 1. PEELS spectra from the region of the carbon ionization edge in the steel matrix (zone1) and of the carbide (zone 2).

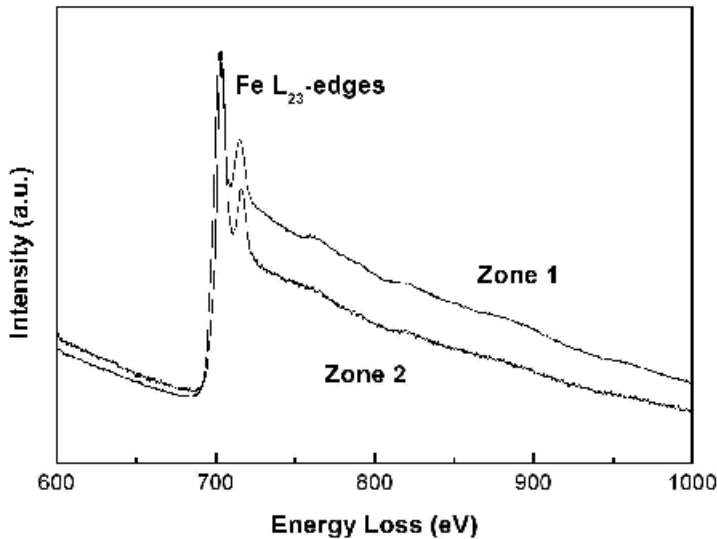


FIG. 2. PEELS spectra from the region of the iron ionization edge in the steel matrix (zone1) and of the carbide (zone 2).

TABLE 1. Composition of experimental Nb steel (Wt Pct).

	C	Mn	Si	S	P	Nb
Steel	0.019	0.45	0.038	0.026	0.013	0.048