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TEM Characterization of Retained Austenite Stabilization on TRIP Steel

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Third generation advanced high strength steels exhibit outstanding mechanical properties in tandem with the goals of higher productivity, zero carbon footprint and in service structural integrity. Study of paraequilibrium phase transformation through electron microscopy techniques, is vital to transfer modern physical metallurgy principles into upcoming production technologies and further downgauging in engineering applications [1]. Ongoing microscopical research on automotive steels with multiphase microstructure, containing retained austenite, shows that tailored thermal cycles combined with novel chemical compositions could exhibit the desired micro and nano constituents to yield enhanced mechanical properties [2].

An experimental thermal simulation was carried out on a cold-rolled and annealed low C, Mn, Al and high Si TRIP steel. Starting with ferrite-perlite microstructure, austenitisation took place at 900^{o}C for 120s soaking time, followed by isothermal quenching, employing critical cooling rate of 30-50^{o}C/s, on a molten metal bath at temperature ranging between 250^{o}C - 450^{o}C for 300s followed by water quenching at ambient. Standard metallographic preparation techniques and ion milling was employed, before examination of the microstructure via Scanning and Transmission electron microscopy. Bright field TEM imaging, electron diffraction and EDS spot microanalysis, employing parallel or convergent beam modes, took place on a TEM Jeol 2100HR unit operating at 200kV. The purpose of this experimental study is to perform a detailed microscopical characterization of metastable retained austenite, assess and quantify attained volume fractions, spatial distribution, crystallographic indexing, local chemical compositions, and finally to bring about a thorough understanding of paraequilibrium solid state phase transformations on the nanoscale.

This research highlighted the retention of metastable interlath austenite, in nanofilm morphology, during isothermal holding in 300^{o}C-400^{o}C via the formation of low temperature bainitic ferrite. Secondary electron micrographs (Fig.1) show the obtained morphologies of interlath and blocky austenite and paraqeuilibrium phases of bainitic ferrite and martensite formation in a ferritic matrix. Populations of interlath retained austenite in bright field electron micrographs (Fig.2) appear chemically and mechanically stabilized with nanofilm morphology and an apparent thickness distribution of 10nm to 200nm phenomenon thickness. Indexed electron diffractions (Fig.2) confirm the presence of face centered cubic structure of retained austenite and EDS microanalysis indicates sufficient carbon diffusive partitioning on austenite up to 1-1.5% wt. along with other critical alloy elements. At 250^{o}C the substructure appears mixed with partially transformed twinned austenite to martensite and lenticular bainitic ferrite, in contrast with undeformed retained austenite formed at 400 ^{o}C. The present study offers useful insight into the mechanisms of stabilization of nanofilm retained austenite through microscopical characterization of phase transformations. It is envisaged that such information could be useful for designing next generation multiphase advanced high strength steels utilizing TRIP effect, through improved industrial processing of upcoming production technologies.

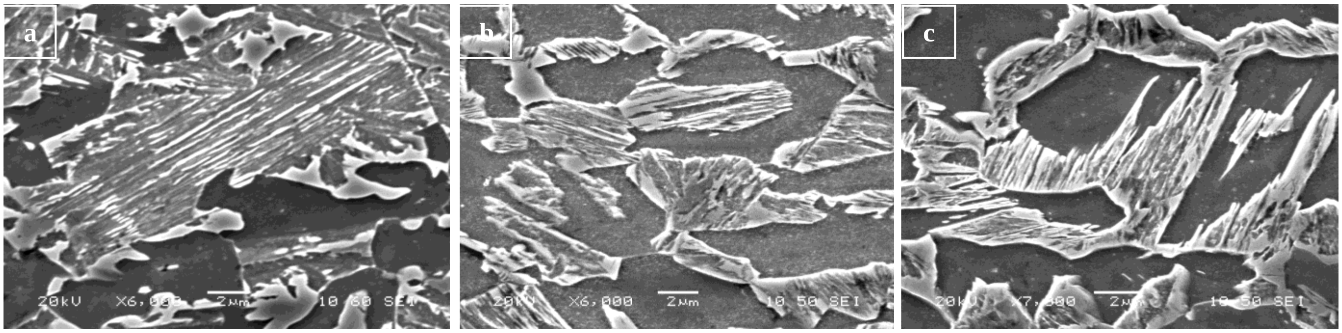

Figure 1. Secondary electron micrographs showing bainitic lath formation, film-like and blocky retained austenite on a ferritic matrix, for isothermal bainitic quenching at 400°C (a), 300°C (b), 250°C (c).

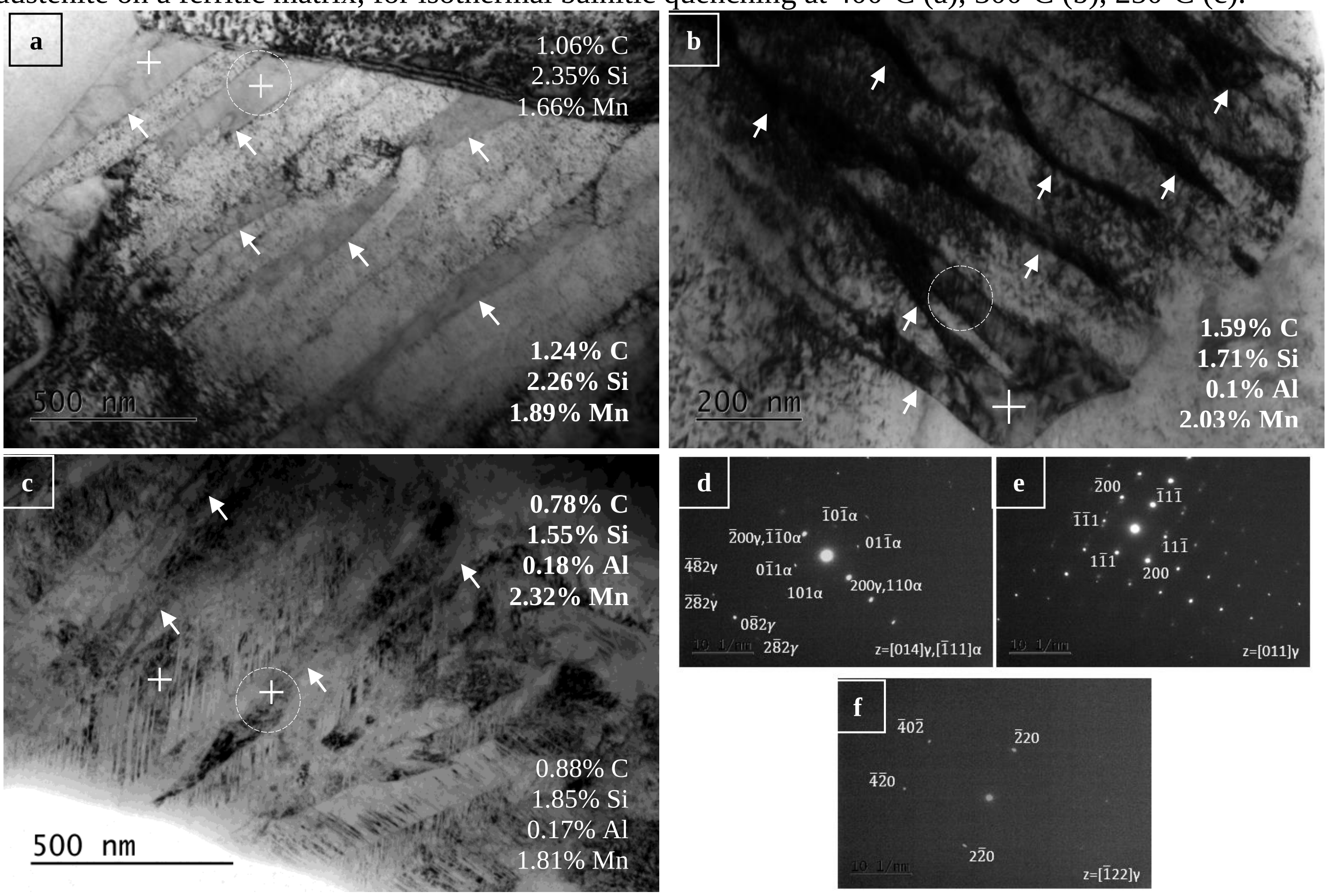

Figure 2. Bright field TEM micrographs showing mostly stabilized nanofilm retained austenite (arrowed) by bainitic ferrite growth, for isothermal bainitic quenching at 400°C (a), 300°C (b), 250°C (c) respectively, accompanied by electron diffractions (d), (e), (f) respectively (performed on the circled area) and EDS spot microanalysis (area marked by cross). All EDS microanalysis are in wt%, with Fe balance and an +/- 0.1wt% standard error. On electron diffractions, γ and α stands for austenite (FCC) and ferrite (BCC) respectively.

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