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Non-metallic Inclusions Acting as Potential Nuclei for Acicular Ferrite in Different Steel Grades

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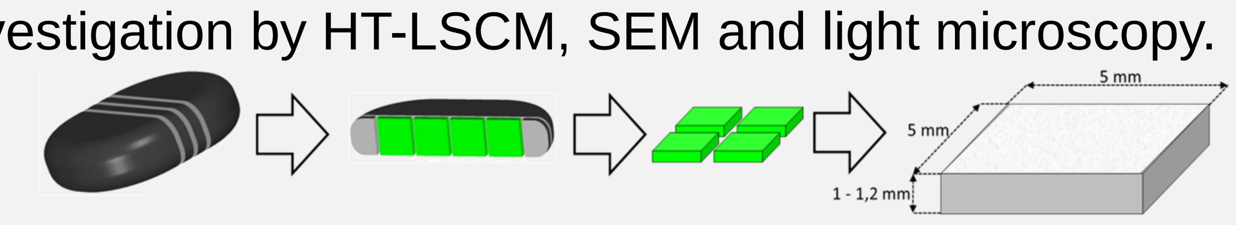
Motivation

Acicular ferrite (AF) is a special form of phase transformation. Because of its needle shaped, chaotic and fine microstructure AF increases strength and fracture toughness at low temperatures. Non-metallic inclusions (NMI) are essential acting as nucleation sites for AF. Therefore their nucleation potential was investigated by HT-LSCM, metallographic methods and Scanning Electron Microscopy (SEM). The analysis includes a medium carbon steel with varying Cr, Ni, Mn and a Mg-modification as well as a high carbon steel with different Ti contents. The results of the following questions are answered in the poster.

1) Are there influences of a Mg-modification on the nucleation behaviour of NMIs?
2) Is it possible to produce acicular ferrite in high carbon steels with 0,65% C?

Sample Preparation

Samples melted in a Tammmann furnace were cut and prepared metallographically for the subsequent investigation by HT-LSCM, SEM and light microscopy.

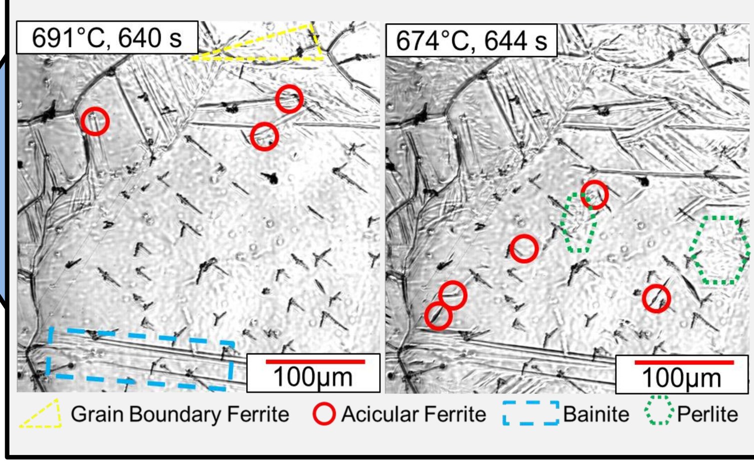


HT-LSCM

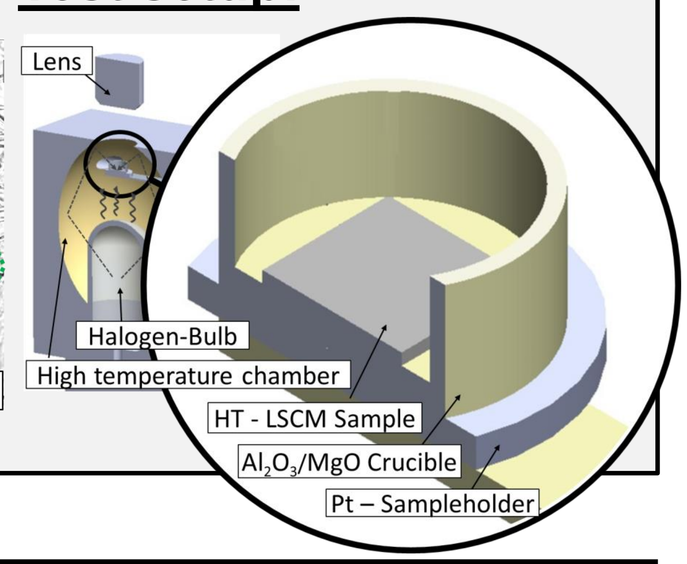
Hightemperture – **L**aserscanning **C**onfokal**m**icroscope

Because of its high flexibility in temperature control and the possibility of an in-situ observation the HT-LSCM was chosen for heat treatment studies.

HT-LSCM Video:

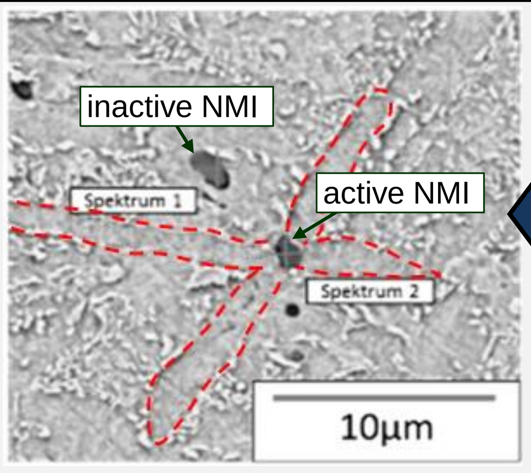


Test setup:



SEM/EDS – Analysis

The samples were analysed automatically (determination of inclusion landscape) and manually (chemical composition and morphology of active non metallic inclusions).



Metallography

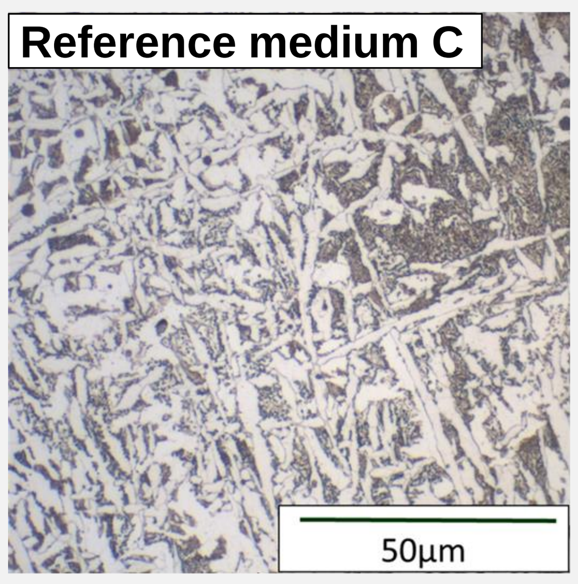
A computer based determination of the austenite grain size and the amount of acicular ferrite in the microstructure evaluate the influence of the varying chemical composition as well as different heat treatments on the AF formation.

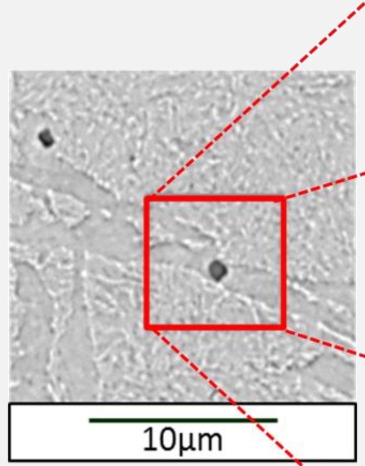
Nucleation Behaviour in Medium Carbon Steels

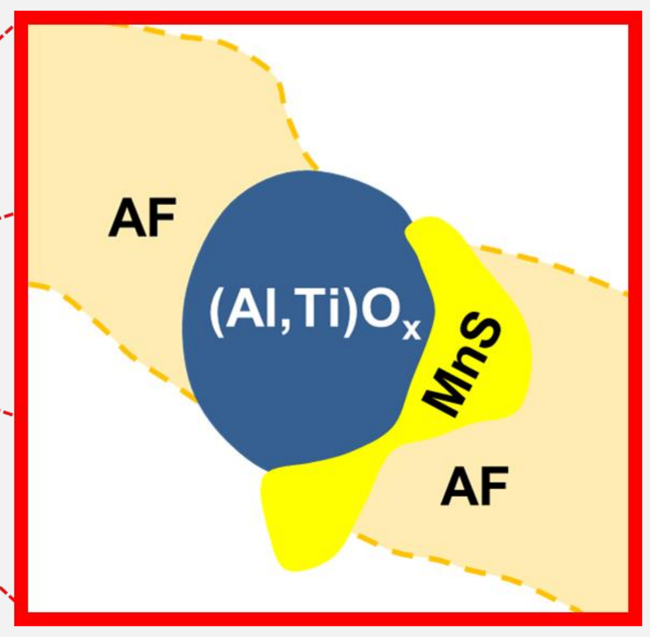
The five investigated medium carbon steel samples (reference alloy: 0,2% C - 1,5% Mn - 0,05% Ti) showed differences regarding their acicular ferrite amount due to varying alloying contents and due to inclusion modification caused by the use of a MgO crucible. By applying the explained analysing methods a comparison of the results leads to different nucleation potentials of non-metallic inclusions for acicular ferrite.

Sample	$CR_{500°C}^{800°C}$ [°C/min]	AF [%]
reference medium carbon	**200**	**≥ 70%**
+ Cr, + Ni	20, 200	0
Mg-modified	**200**	**≥ 70%**
- Mn	100, 200	9
- Mn, + Ni	150, 200, 250	1

Reference medium C

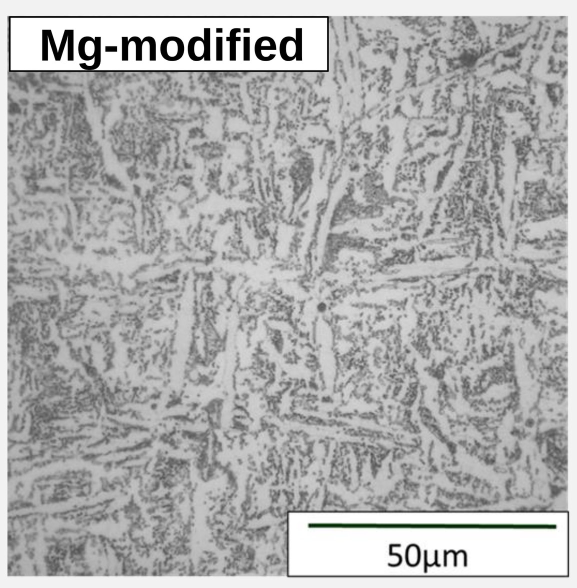


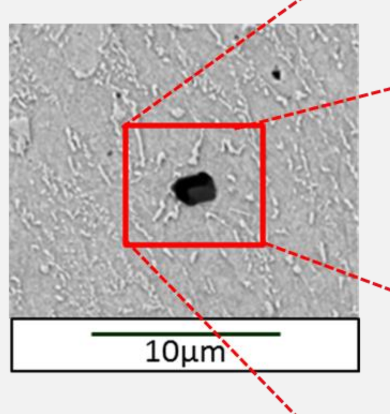


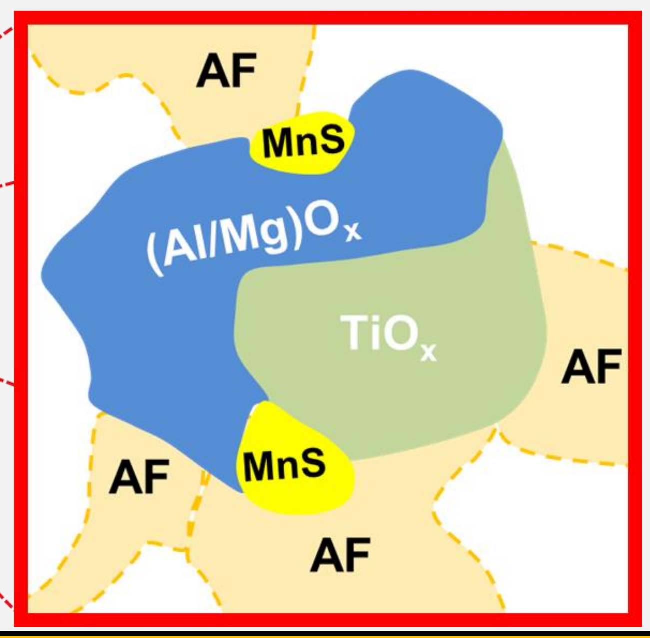


Reference medium carbon: The non-metallic inclusions of the reference sample show a high potential for acicular ferritic nucleation. Manual SEM/EDS measurements show particles like **$(Ti,Al,Mn)O_xS_y$ - 38%**, **$(Ti,Al,Mn)O_x$ - 14%**, **$(Ti,Al)O_x$ - 10%** and **$(Ti,Mn)O_x$ - 10%** as the most effective nucleation sites of 100% investigated NMI.

Mg-modified







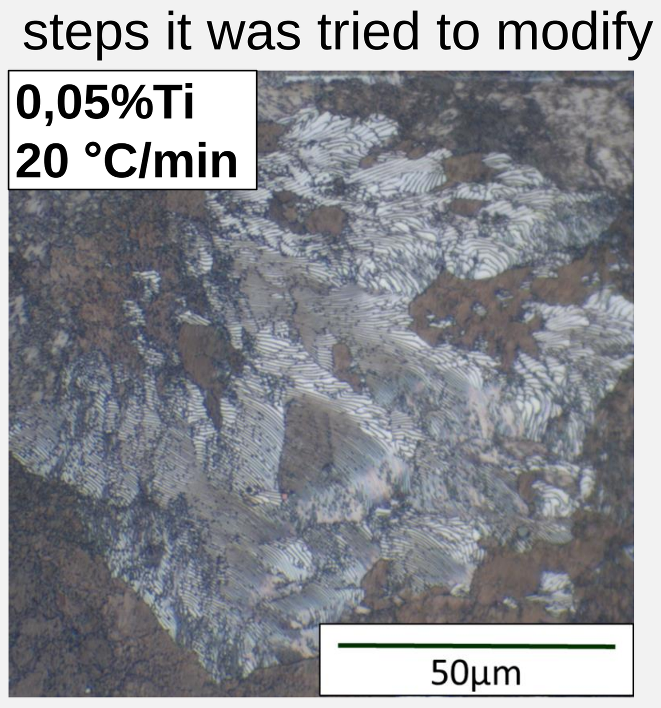
Mg-modified: A magnesium-modification by producing the sample in a MgO-crucible does not decrease the high nucleation potential of the NMI. **$(Ti,Al,Mn)O_x$ - 41%**, **$(Ti,Al,Mn,Mg)O_xS_y$ - 16%**, **MnS - 8%** and **$(Ti,Al,Mg)O_x$ - 8%** are the predominant detected active inclusion types. Mg is found to contribute to inclusion modification throught the formation of MA-spinels.

Nucleation Behaviour in High Carbon Steels

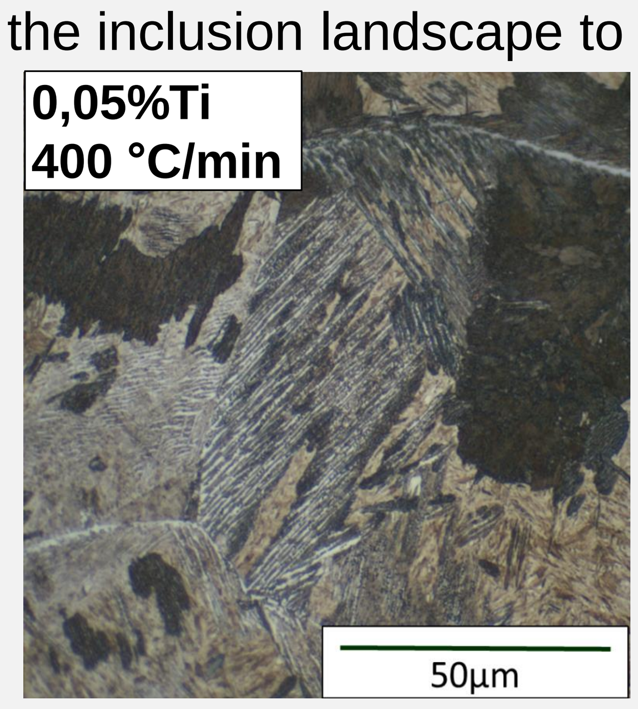
Sample	$CR_{500°C}^{800°C}$ [°C/min]	AF [%]
reference high carbon	200, 400	0
+ 0,02% Ti	200, 400	0
+ 0,05% Ti	**20, 200, 400**	**0**

By increasing the titanium content in the high carbon steel samples (reference alloy: 0,65% C - 1% Mn - 0,5% Si) in two steps it was tried to modify the inclusion landscape to a more favorable nucleation behaviour for AF.

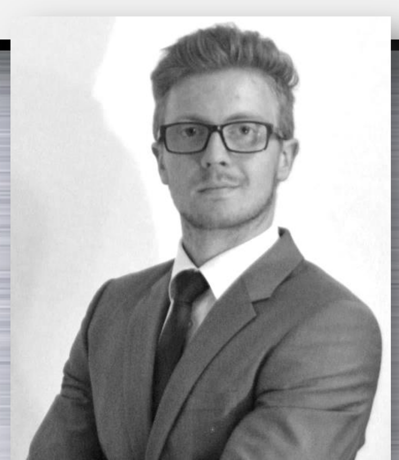
0,05%Ti 20 °C/min



0,05%Ti 400 °C/min



+ 0,05% Ti: Although the inclusion landscape includes **$(Ti,Mn)O_xS_y$-**, **MnS-** und **$(Ti,Al)O_x$**-particles, which are very active in theory and in the medium carbon steel no acicular ferrite is formed. The alongside figures show that the ferritic potential at 0,65% carbon is too small for a acicular ferritic transformation. At various cooling conditions the sample transformed perlitic (20 °C/min) and perlitic/bainitic (400 °C/min).



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