Carburisation of Fe-X (X = Si, Mo, V) diffusion couples

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Abstract

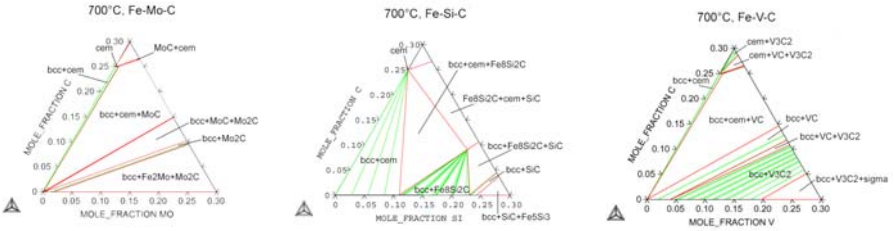
Accurate values of solubilities of alloying elements such as X = Si, Mo, and V in cementite $(Fe,X)_3C$ are important for reliable simulations of diffusion controlled phase transformations in steels.

This paper presents a new approach for experimental studies of such solubilities in carbides. Diffusion couples of Fe/Fe-4Si, Fe/Fe-7Mo, and Fe/Fe-20V (in at.%) were prepared and heat treated at 900 °C or 1200 °C for 1 month. Subsequently, they were carburised at 700°C in a strongly carburising $CO-H_2-H_2O-H_2S$ gas mixture with a carbon activity of a_C = 100 for 10 h. Such conditions generally lead to cementite formation on surfaces of iron and low alloyed steels. The subsequent decomposition during the high-temperature corrosion process "metal dusting" can be suppressed for reasonable time periods by adding small amounts of H_2S to the gas atmosphere.

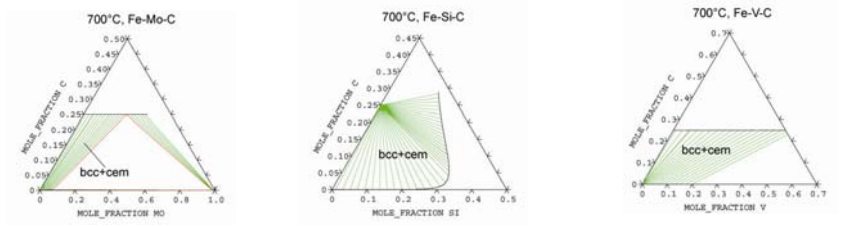
As expected, the growth of cementite was found to depend on the concentration of the alloying element X in the diffusion couple. The cementite layers extend laterally from the pure Fe side up to a position in the diffusion couple corresponding to a concentration of X which is assumed to represent its solubility limit in $(Fe,X)_3C$.

Concentration profiles in the diffusion couples were determined quantitatively by electron probe microanalysis (EPMA) after the first heat-treatment and after the carburisation treatment as well. These experimental results fit well with profiles calculated with DICTRA. Cross-sections of the carburised diffusion couples were characterised by means of light optical microscopy (LOM). Additional precipitates were identified using electron backscatter diffraction (EBSD). The experimental results are discussed with respect to Thermo-Calc calculations of stable and metastable phase equilibria in Fe-Si-C, Fe-Mo-C, and Fe-V-C. Simulations of diffusion controlled phase transformations using DICTRA were performed to support the discussion of possibly different regimes of cementite growth .

Thermo-Calc calculations (SSOL Database): ternary systems Fe-Mo-C, Fe-Si-C, and Fe-V-C



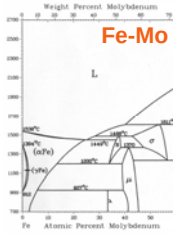
Thermo-Calc calculations (SSOL Database): ternary systems Fe-Mo-C, Fe-Si-C, and Fe-V-C (metastable equilibria bcc + cementite)

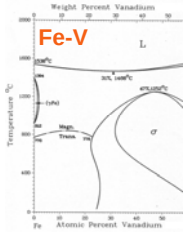


Binary systems

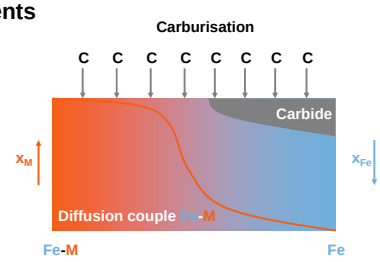
The preparation of diffusion couples was carried out by heat treatment of pure Fe samples bonded with Fe-4Si, Fe-7Mo or Fe-20V samples. The binary phase diagrams provide information for defining the heat treatment. The Si-diffusion couple was heat treated at 900°C in order to obtain a continuous Si-profile over the whole specimen.

Because of the expected higher solubility in cementite a higher Mo- and V-content had to be chosen. In order to achieve a sufficiently flat profile the heat treatment was performed at 1200°C. The composition step associated with the α/γ transition at this temperature was not detrimental.



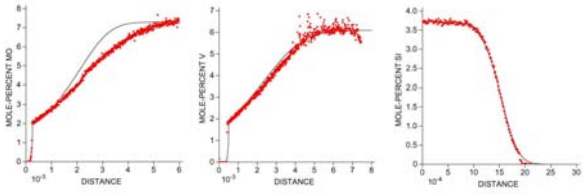


Experiments

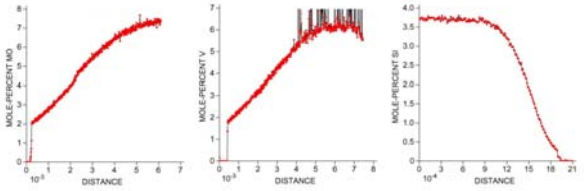


Diffusion couples after 1 month heat treatment (without carburisation): EPMA results vs. DICTRA simulations

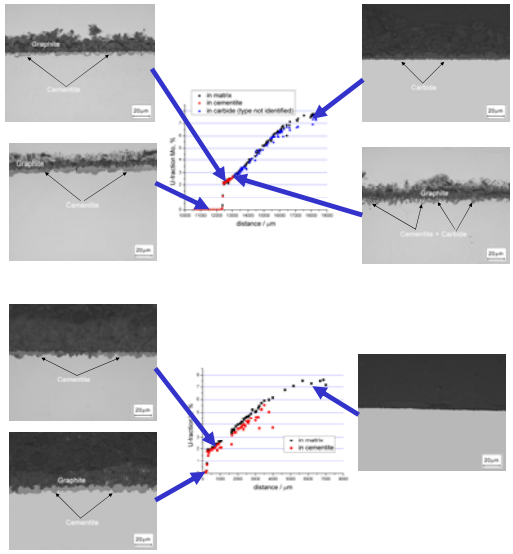
Fe-Mo, 1200 °C **Fe-V, 1200 °C** **Fe-Si, 900 °C**



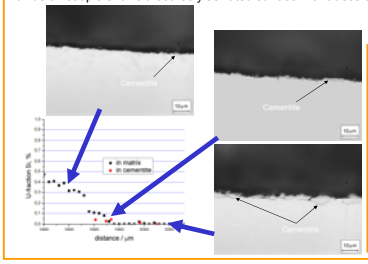
DICTRA simulations: changes of composition profiles during 10 h treatment at 700 °C (carburisation condition)



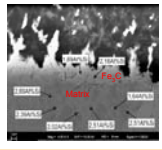
Carburised diffusion couples



Diffusion couple with Si after carburisation : at compositions up to 2 at. % Si the diffusion couple shows a coarsely serrated surface with traces of small particles of cementite.



The binary Fe-2Si sample was carburised to measure the Si-content in cementite.



Growth regimes

Simulation of V diffusion in a ternary Fe-5V-5C alloy at 700°C. This composition is within the two phase region α-Fe+Fe_3C. At this content the formation of cementite starts with a fast reaction without partitioning of V, followed by the slow reaction with partitioning. This is shown by DICTRA simulations.