

Nitriding – fundamentals, modeling and process optimization

Research Team:

Mei Yang
Richard D. Sisson, Jr.

Introduction

Gas nitriding is an important thermochemical surface treatment to improve the wear and corrosion resistance as well as the fatigue endurance. Compared to other surface treatment methods, gas nitriding is competitive due to its low cost and less distortion. However, the poor performance reliability of this process limits its wide applications. [1] The accurate process control is the effective way to ensure the properties reliability. To realize the accurate process control, the nitriding process parameters need to be pre-determined to meet the specifications.

Traditionally, trial and error method is used to define the nitriding process parameters to meet the specifications. This method is expensive, time consuming, and hard to control. An effective simulation tool is greatly in need to predict the nitriding parameters base on the specifications.

There has been ongoing effort on the simulation of the gas nitriding process since 1990s. However, most of the work has been done to simulate the gas nitriding process of pure iron [2] [3] [4] due to the limited thermodynamics and kinetics information available on the gas nitriding process of steels.

The objective of this project is to build up an effective model to simulate the gas nitriding process of steels based on the fundamental understanding of thermodynamics and kinetics.

Methodology

The project focused on three tasks:

Task 1: Develop a fundamental understanding of the gas nitriding process for steels.

Task 2: Develop a computational model to determine the nitrogen concentration in the steel in terms of:

- temperature
- atmosphere composition
- time
- steel surface condition
- alloy composition

Task 3: Verify the model by comparison with experimental results.

Salient Results

In this work, the customized Lehrer diagram which describes the phase stabilities in specified steel at different nitriding potentials and temperature is successfully constructed by computational thermodynamics for the first time. The accuracy of the customized Lehrer diagram has been verified and this proves the utility of using computational thermodynamics to develop the customized Lehrer diagrams for the specified steels.

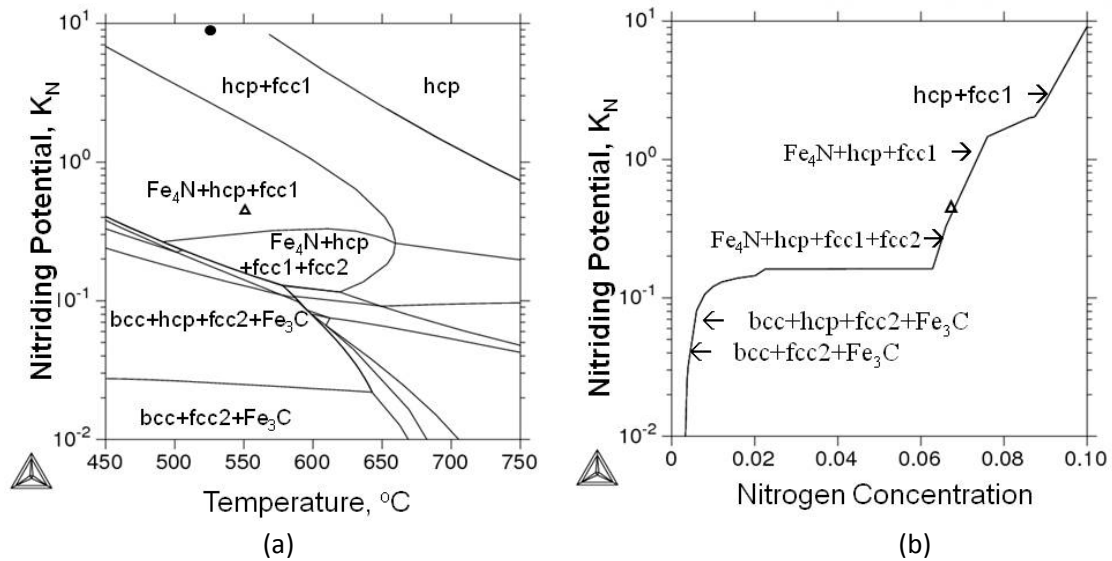


Figure 1. Lehrer diagram of AISI 4140 (a) and nitriding potential evolution with nitrogen concentration for AISI 4140 at 548°C (b). (Δ) represents nitriding condition, i.e. $K_n=0.43$, $T=548^{\circ}\text{C}$

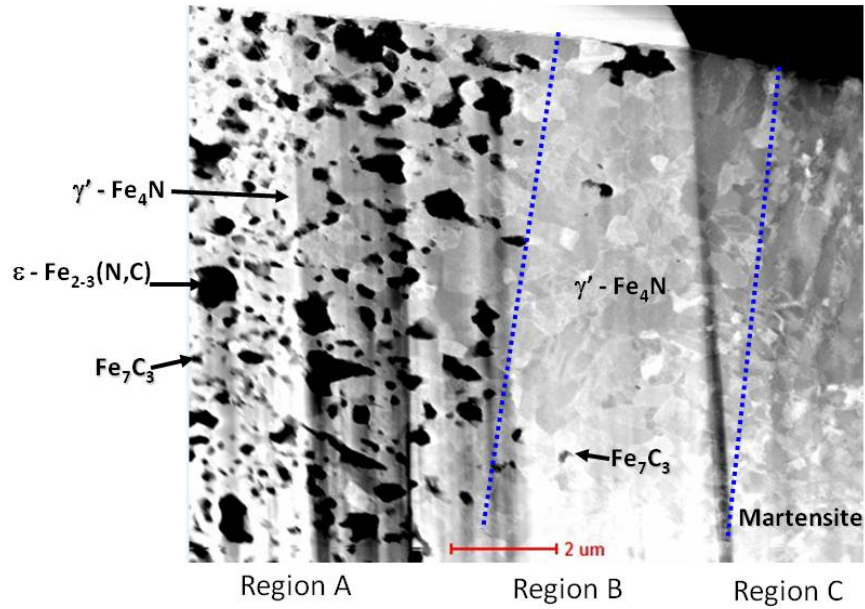


Figure 2. High angle annular dark field TEM micrograph from the nitrided case of AISI 4140 (nitriding condition is $K_n=0.43$, $T=548^\circ\text{C}$ for 50 hours)

Based on the steels Lehrer diagrams, the compound layer growth model is proposed to simulate the gas nitriding process of steels. By using this model, the properties of the nitrided steels based on the phase constitution, surface nitrogen concentration, nitrogen concentration profile, case depth, as well as growth kinetics can be simulated through variation of process parameters (temperature, time, and the nitriding atmosphere).

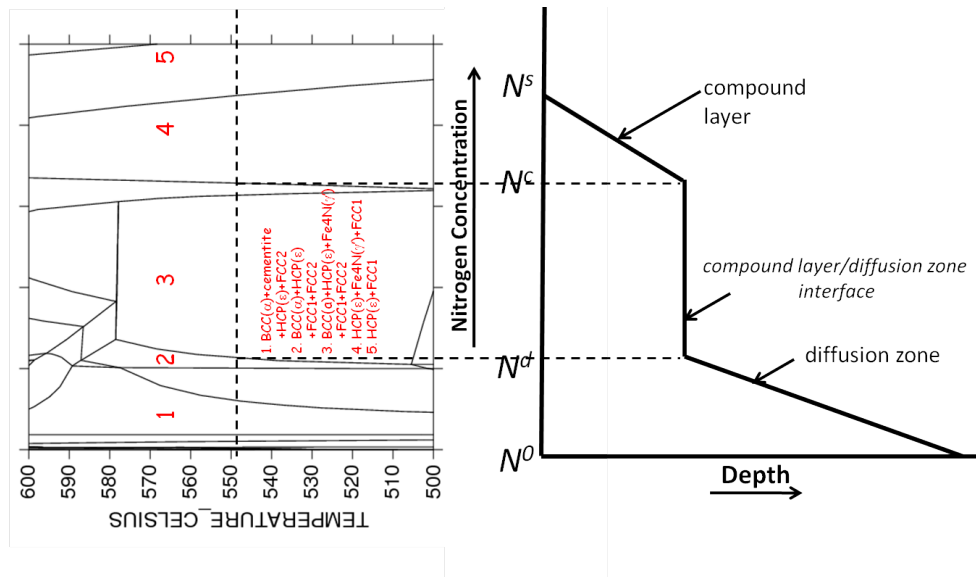


Figure 3. Relation between the isopleth (left) and nitrogen concentration/depth for the nitride layer growth model (right) of nitrided AISI 4140

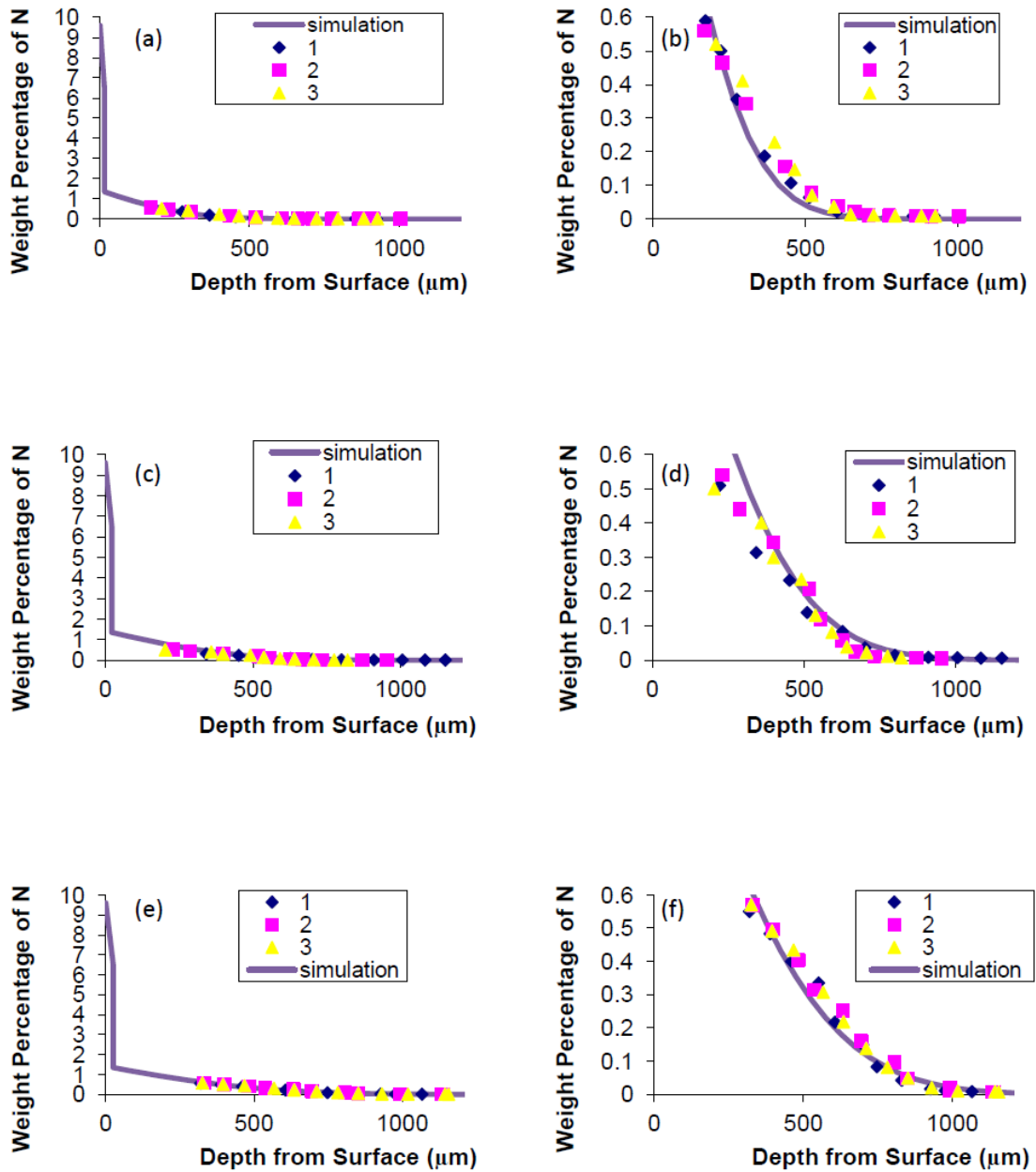


Figure 4. The simulation results for nitrided AISI 4140 in comparison with the OES measured nitrogen concentration profiles: the complete nitrogen concentration profile for 14 hrs(a), 30hrs(c), and 45hrs(e); the nitrogen concentration profile in the diffusion zone for 14 hrs(b), 30hrs(d), and 45hrs(f).

(nitriding condition is $T=550^{\circ}\text{C}$, $K_n=8$)

References

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2. Somers, M.A.J. and E.J. Mittemeijer, *Layer-Growth Kinetics on Gaseous Nitriding of Pure Iron - Evaluation of Diffusion-Coefficients for Nitrogen in Iron Nitrides*. Metallurgical and Materials Transactions a-Physical Metallurgy and Materials Science, 1995. **26**(1): p. 57-74.
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