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Growth kinetics of the $NbAl_3$ phase in the Al-Nb system produced by pack cementation

V. M. Silveira[1], N. Chaia[2], C. S. Barros[1], J. V. Luiz[1], K. E. Borowski[3], C. A. Nunes[1], G. C. Coelho[1]

[1] Lorena School of Engineering, University of São Paulo, Lorena, SP, Brazil
[2] Cecal Group, Lorena, SP, Brazil
[3] Université Paris-Est Créteil, CNRS, ICMPE, Thiais, France

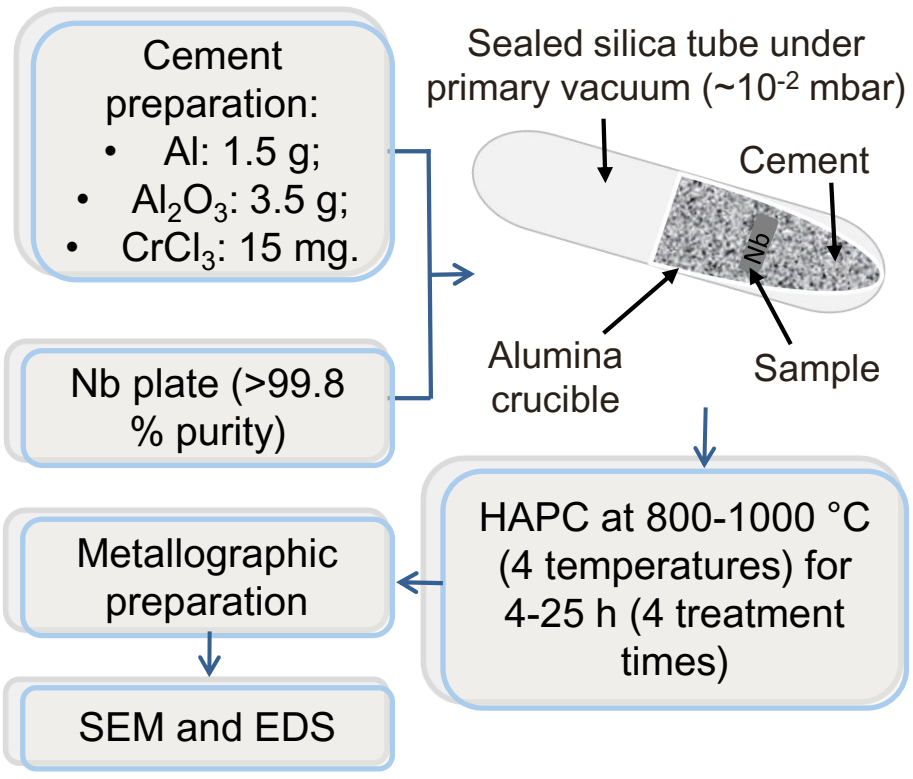
Introduction

Multicomponent systems containing refractory metals, such as Nb, together with Al are promising for high-temperature applications. Halide-activated pack cementation (HAPC) is a surface engineering technique used to produce protective coatings and investigate the growth of metallic aluminides [1,2]. Characterization of these layers provides kinetic data for the simulation of diffusion processes in multicomponent systems.

Objectives

To investigate the growth kinetics of the $NbAl_3$ intermetallic phase in the Al-Nb system produced by HAPC, aiming to determine its interdiffusion coefficients and associated activation energy.

Methodology



The growth of the $NbAl_3$ layer was controlled by solid-state diffusion and followed a parabolic law. The growth rate constants (K_p) were used to determine the interdiffusion coefficients $(\widetilde{D}_{int})$ using Wagner's approach [3]:

$$\widetilde{D}_{int}(N_{Al}^{i}) = \frac{\Delta x_i}{2t} N_{Nb}^{i} \sum_{\nu=2}^{\nu=i-1} \frac{V_m^i}{V_m^\nu} N_{Al}^{\nu} \Delta x_\nu + N_{Nb}^{i} N_{Al}^{i} \frac{(\Delta x_i)^2}{2t} + \frac{\Delta x_i}{2t} N_{Al}^{i} \sum_{\nu=i+1}^{\nu=n-1} \frac{V_m^i}{V_m^\nu} N_{Nb}^{\nu} \Delta x_\nu$$

Results and Discussion

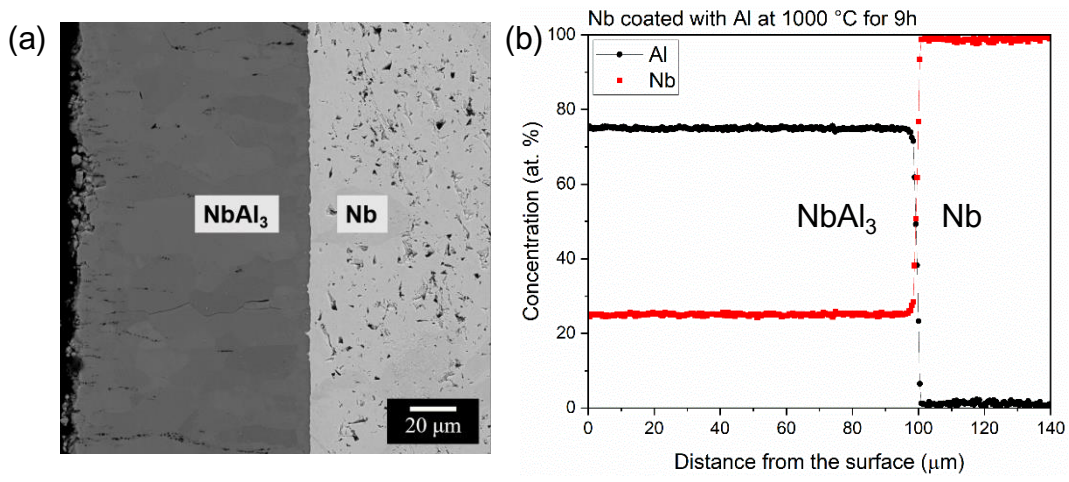
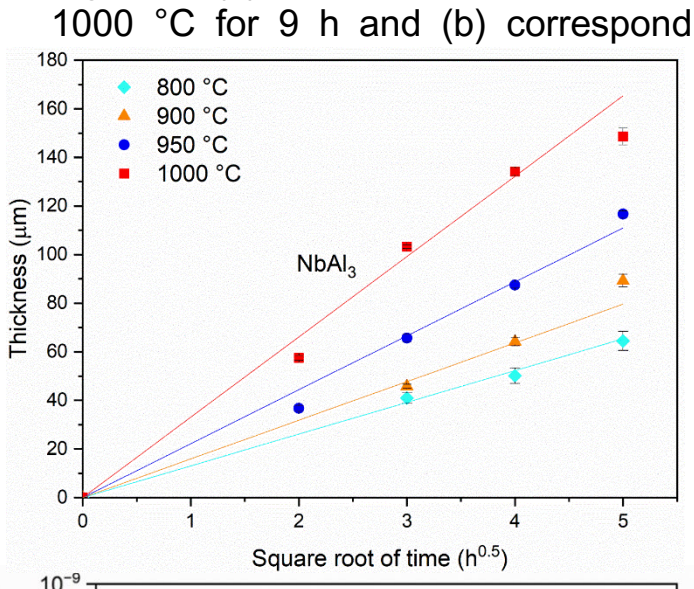


Figure 1. (a) Cross-sectional SEM image of Nb aluminized at 1000 °C for 9 h and (b) corresponding EDS concentration



$$\Delta x_i^2 = 2.K_p.t$$

Figure 2. Growth kinetics of $NbAl_3$ at 800, 900, 950, and 1000 °C

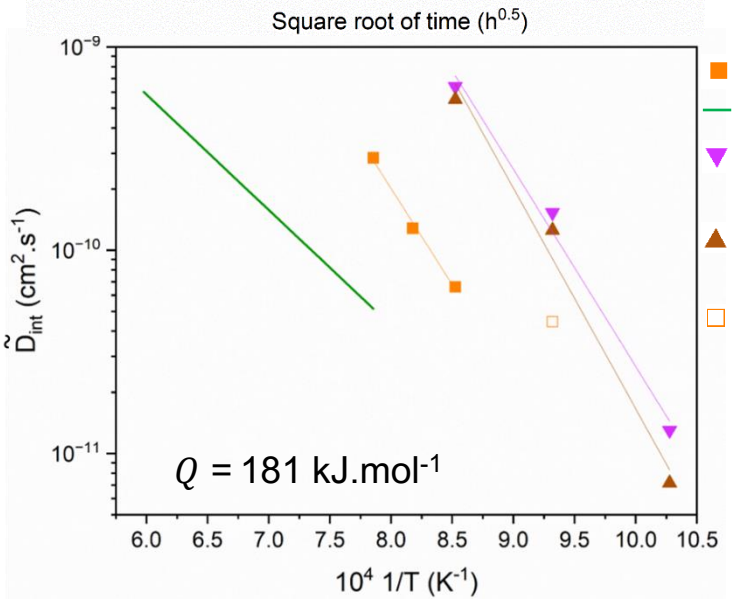


Figure 3. Arrhenius plot of $\widetilde{D}_{int}$ for $NbAl_3$

Conclusions

- The HAPC technique enabled the production of semi-infinite diffusion couples and the experimental determination of interdiffusion coefficients in the $NbAl_3$ phase;
- The growth of the $NbAl_3$ phase approximately followed a parabolic law, indicating diffusion-controlled growth in the solid state;
- The interdiffusion coefficients $(\widetilde{D}_{int})$ ranged from 10^{-11} to 10^{-10} cm^2·s^{-1}, with an activation energy of 181 kJ·mol^{-1} (900-1000 °C);
- The results provide kinetic parameters for modeling and developing aluminide-based coatings for high-temperature applications.

References and Acknowledgments

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