

# Influence of interdiffusion zones on the performance of coatings against coking and metal dusting

C. Geers, M.C. Galetz, M. Schütze  
e-mail: geers@dechema.de  
Funded by: BMWi via AiF  
Period: 01.01.2009 - 31.12.2012

## Metal Dusting



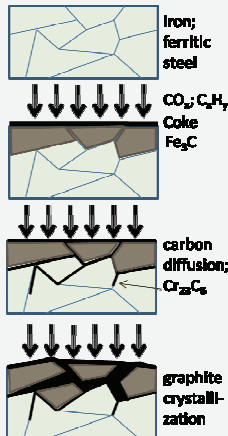
uncoated low alloy steel (1%Cr; 0.4%Mo) after 100 hrs under metal dusting conditions at 650°C ( $H_2$ -24%CO-2% $H_2O$ )

### Metal Dusting Conditions

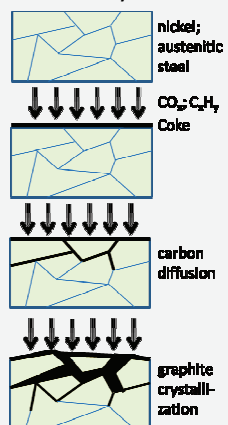
- temperatures between 400-900°C
- atmospheres with high carbon activity  $a_C \geq 1$ ;
- low  $p_{O_2}$

### Metal Dusting Mechanisms

#### mechanism for ferritic steel

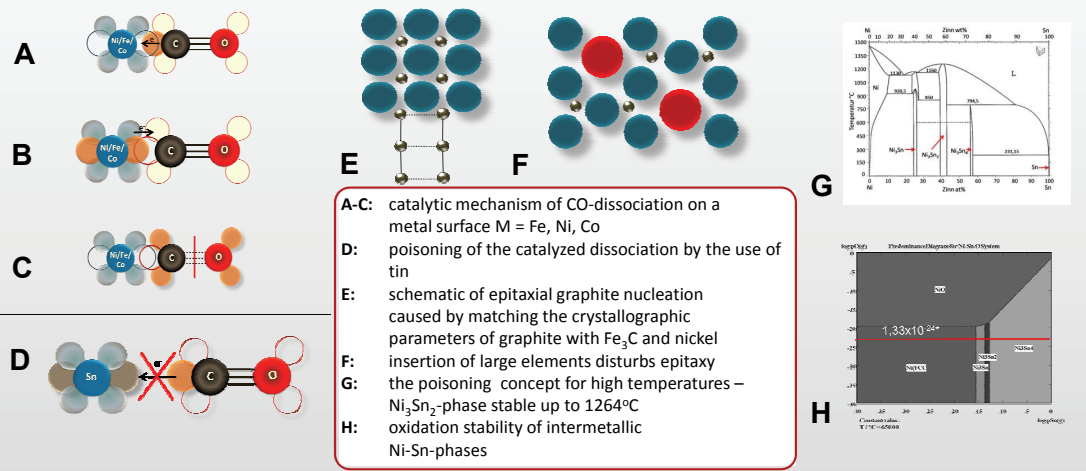


#### mechanism for nickel and nickel base alloys

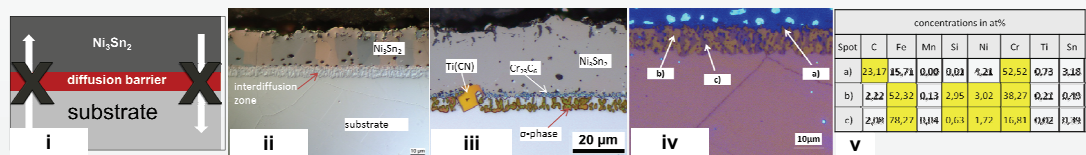


This work is financially supported by the German Ministry of Economics via AiF under IGF contract no. 16294N which is gratefully acknowledged.

## Functional Coating Approach



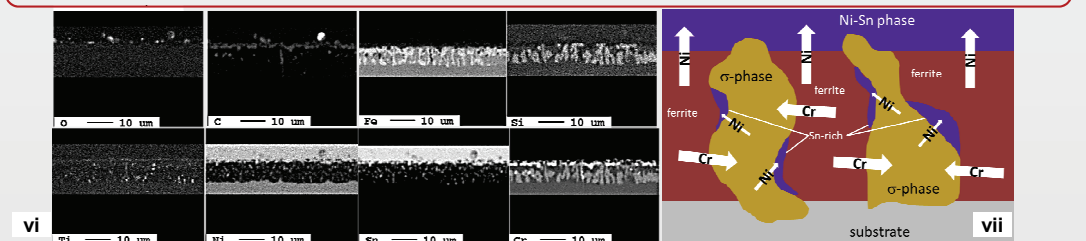
## Coating Stability



The functional coating concept shown above relies on the constant chemical composition of the coating during operation time. Consequently, three different diffusion processes have to be controlled during operation time (i): no carbon is to diffuse through the coating to the substrate alloy; no substrate components should diffuse into the intermetallic coating; and no coating components, especially tin, should diffuse into the substrate.

The  $Ni_3Sn_2$ -phase is inert to carburization, coking and metal dusting. Carbon is not able to diffuse through the coating. Nickel and iron from the substrate can diffuse into the intermetallic coating in alloys with a chromium content lower than 15 wt%. This interdiffusion causes phase transformations from  $Ni_3Sn_2$  to  $Ni_3Sn$  or  $(Ni_{3-x}Fe_x)Sn_2$  with  $0 < x < 1.5$ . These transformations lead to stresses and reduce the coating stability.

For substrates with a chromium content greater than 15 wt% the intermetallic nickel-tin coating was found to be chemically stable for more than 3000hrs (ii). This can be associated with the high stability of the interdiffusion zone as is described in the following:



The interdiffusion zone between the intermetallic coating and the substrate was intensively investigated for alloy 800, AISI 321 and alloy 600. For all three alloys, the interdiffusion zone was found to be a diffusion barrier consisting of chromium carbides,  $\sigma$ -phase as well as  $\alpha$ -ferrite for the austenites (viii). Figures ii, iii, iv and vi show this zone in a cross-section of a nickel-tin coated alloy 800 specimen after 500 hrs exposure under metal dusting conditions at 620°C ( $H_2$ -24%CO-2% $H_2O$ ) produced using differential interference contrast (ii), electrochemically etched in 10M NaOH (iii), ZnSe-PVD coated (iv). Figure vi shows the element maps measured using EPMA. In table v EPMA-spot measurements of the positions highlighted as a-c) in figure iv are listed; a) matches the  $Cr_{23}C_6$ -phase, b)  $\sigma$ -phase and c)  $\alpha$ -ferrite. The formation of these precipitates in the interdiffusion zone occurs due to the rapid depletion of nickel during the coating process in this zone. The nickel is consumed in the intermetallic nickel-tin coating leaving behind an iron-chromium rich layer (schematically shown in figure vii). This  $\sigma$ -phase rich layer was found to be a reliable diffusion barrier which stabilizes the chemical composition of the intermetallic coating for more than 3000hrs under metal dusting conditions.

