# Development of Advanced Overlay Weld Coatings for Application in Waste Incineration Environments

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## Introduction

Highly corrosive conditions are encountered in many industrial gasification and combustion processes that place high demands on the metallic components employed. Examples are plants for waste incineration, special refuse, bio mass, sludge etc. These charges contain high quantities of chlorine and sulphur compounds as well as heavy metals that have a strong corrosive effect based on attack from gaseous species and saline melts. Fig. 1 illustrates the mechanism of chlorine corrosion. To limit the extent of corrosive attack, many plants are operated at relatively low temperatures, although operation at higher temperatures would be more desirable from an economic point of view, especially in waste incineration plants with regards to increased efficiency. Additionally, certain process temperatures are not allowed to fall below specific limits to comply with legal requirements of emission protection.

The methods for protection against corrosion used so far such as galvanic nickel-plating, overlay welding or thermal spraying of nickel based alloys or the use of compound tubes (high-alloyed tube casing on ferritic heat exchanger tubes) do not allow a significant increase of the process temperature above 400°C. In the field of waste incineration, capacity for incineration has risen dramatically, due to the prohibition of the disposal of untreated waste, in force since July 2005 in Germany. Therefore the requirements for an efficient concept of corrosion protection that enable higher process temperatures combined with extended lifetime are growing.

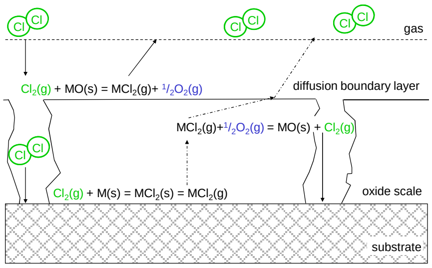


**Figure. 1: Mechanism of Cl-induced "active oxidation"**

## Coating Development

The aim of the present investigation is to develop overlay weld coatings suitable for the application of corrosion resistant coatings to waste incineration equipment. Overlay welding has many advantages over other conventional coating processes, these being high coating application rate, relatively low process and investment costs and ease of transportability of the coating equipment. At the same time, near-net-shape coating geometries can also be achieved. However, due to inter-mixing of the weld and parent metals, overlay welding can deliver coatings with alloy and/or phase changes. Hot cracking can also be an issue. Therefore, means to improve coatings through process and compositional factors are an important target of this project, together with the development of coating systems suitable for application in waste incineration plant. Coatings based on the ternary Ni-Cr-Si system have been chosen for the present application (see Figure 2).

Reference materials for coatings were Alloy 59 and Inconel 625. The substrate for the coatings is a ferritic-martensitic low chromium steel (St. 37).

| Sample Name | Composition (wt%) | Expected Phases |
|---|---|---|
| 11 | Ni-30Cr | γ-Ni |
| 12 | Ni-50Cr | γ-Ni + α-Cr |
| S | Ni-20Cr | γ-Ni |
| SA | Ni-20Cr-2Si | γ-Ni |
| SB | Ni-20Cr-5Si | γ-Ni |
| SC | Ni-20Cr-7Si | γ-Ni + $Ni_3Si$ |
| SD | Ni-20Cr-10Si | γ-Ni + $Ni_3Si$ |
| SE | Ni-20Cr-12Si | γ-Ni + $Ni_3Si$ |

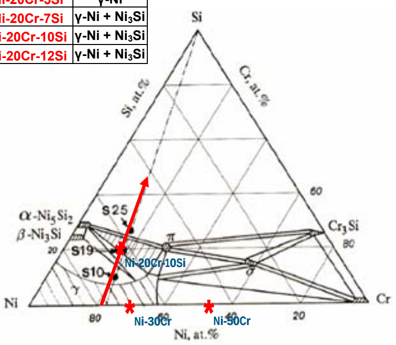


**Fig 2: Ni-Cr-Si phase diagram at 850°C with selected overlay welding coating compositions.**

## Exposures

Samples were exposed to the following gas atmosphere (*94,9 vol-% $N_2$, 5 vol-% $O_2$, 0,1 vol-% $Cl_2$*) at 500°C for a time of 100 h in a horizontal resistance wound furnace (see Figure 3). Corroded samples were embedded and examined metallographically. To examine the extent of attack and elucidate possible degradation mechanisms, samples were investigated using the EPMA. Element maps were generated and examples are shown in Figures 4, 5 & 6.

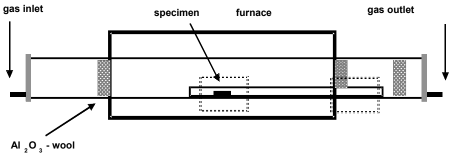
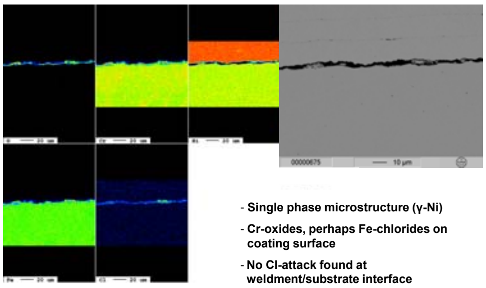


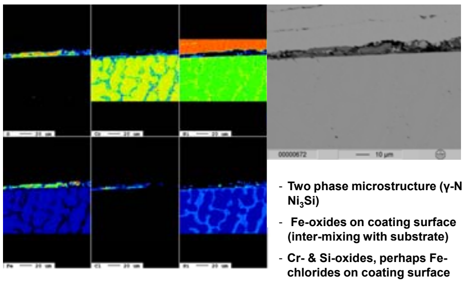
**Figure 3: Furnace set-up for corrosion experiments.**

## Overlay weld coating performance – EPMA Investigation



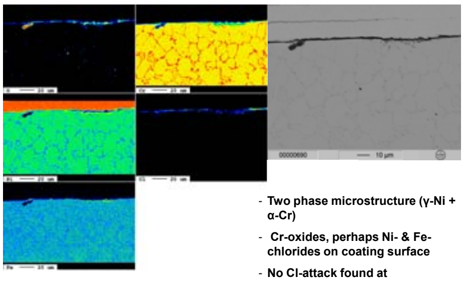
- Single phase microstructure (γ-Ni)
- Cr-oxides, perhaps Fe-chlorides on coating surface
- No Cl-attack found at weldment/substrate interface

**Figure 4: EPMA element maps for Ni-20Cr after 100 hour exposure at 500°C.**



- Two phase microstructure (γ-Ni + $Ni_3Si$)
- Fe-oxides on coating surface (inter-mixing with substrate)
- Cr- & Si-oxides, perhaps Fe-chlorides on coating surface
- No Cl-attack found at weldment/substrate interface

**Figure 5: EPMA element maps for Ni-20Cr-10Si after 100 hour exposure at 500°C.**



- Two phase microstructure (γ-Ni + α-Cr)
- Cr-oxides, perhaps Ni- & Fe-chlorides on coating surface
- No Cl-attack found at weldment/substrate interface

**Figure 6: EPMA element maps for Ni-50Cr after 100 hour exposure at 500°C.**

## References & Acknowledgements

- R. Bender, M. Schütze, *Mat. Corr.*, **54**(9), 652 - 686 (2003)
- H Schroer, C.; Spiegel, M.; Grabke, H.J.; Schriften des FZ Jülich: Reihe Energietechnik Band 5,2 789 - 798 (1998)
- Schülein, R.; Eiteneuer, F.; Dampferzeugerkorrosion; Verlag Saxonia Standortentwicklung; 321-347 (2005)
- Weber, T.; Bender, R.; Schütze, M.; Hochtemperaturkorrosion in chlorhaltiger Verbrennungsatmosphäre - Schutzkonzepte für metallische Werkstoffe, Optimierung der Abfallverbrennung 1, K.J. Thomé-Kozmiensky (Ed.), TK-Verlag, Neuruppin, 581-598 (2004)
- Lee, Y.Y., McNallan, M.J., Met. Trans Y., **18A**, 1099-1107 (1987)

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## Outlook

The best candidates will be exposed to a second, more aggressive atmosphere (*76,75 vol-% $N_2$, 8 vol-% $O_2$, 0,25 vol-% HCl*) at 500°C for times up to 1000 h and will be embedded in an artificial ash mixture that simulates real process deposits.

Further improvements in the overlay welding process and coating chemistry will lead to more reliable and cost effective coatings making them a viable option for waste incineration applications and ultimately lead to increased efficiency.