2006

The effect of manganese and chromium on the selective oxidation of low carbon strip steels for tinplate applications

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THE EFFECT OF MANGANESE AND CHROMIUM ON THE SELECTIVE OXIDATION OF LOW CARBON STRIP STEELS FOR TINPLATE APPLICATIONS

A thesis submitted in fulfilment of the requirements for the award of the degree

DOCTOR OF PHILOSOPHY

from

UNIVERSITY OF WOLLONGONG

by

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2006

I, Paton Wilson, herby certify that the work embodied in this thesis is the result of original research and has not been submitted for a higher degree to any other University or Institution.

Paton Wilson

Acknowledgements

I would like to express the deepest gratitude to my supervisor, Dr Zhixin Chen for his guidance and support throughout the project. Much appreciation also goes to Professor Druce Dunne for his assistance. The support of my industrial supervisors, Chris Killmore and Stuart Laird is greatly appreciated.

Thanks also go to Dr David Wexler for TEM training and assistance, Phil Renwick for his assistance in TEM sample preparation techniques, Dr Charlie Kong for guidance in the use of FIB, Nick Mackie for SEM training and assistance, Greg Tillman for metallographic sample preparation and imaging, Mark Thompson for his support with industrial gas annealing experiments, and lastly final year students Greg Reece and Pierre Greig for there contribution to the project.

This project would have not been possible without the financial support of the Australian Research Council (ARC).

Importantly much appreciation goes to Bluescope Steel for their technical and financial support, supply of materials and use of equipment.

Finally I would like to thank Belinda, my family and friends for their continuous support.

Abstract

The ‘edge defect’ is a band of low reflectivity that occurs near the edge of batch annealed steels that have been tinplated. The tinplate product that contains this defect must be scrapped because of the poor aesthetical properties and the reduced corrosion resistance in the affected areas. This defect was known to be caused by surface precipitates formed during batch annealing of the steel strip substrate. This research aims to identify the surface precipitates and the factors that can be modified to reduce their formation in an effort to develop an alloying and/or processing strategy which eliminates the occurrence of the ‘edge defect’.

In this investigation the ‘edge defect’ was characterised using scanning electron microscopy (SEM) and transmission electron microscopy (TEM) which demonstrated that surface $MnCr_2O_4$ spinel precipitates were responsible for the ‘edge defect’ although two different oxides, (MnFe)O and $MnCr_2O_4$ spinel, were observed on the steel surface. The formation of the surface (MnFe)O and $MnCr_2O_4$ spinel was due to the selective oxidation of manganese and chromium during batch annealing. The effects of manganese, chromium and annealing temperature on selective oxidation were also investigated and it was found that the $MnCr_2O_4$ spinel precipitate size and distribution were directly affected by the content of the chromium in the steels. The higher the chromium content of the steel the coarser the surface $MnCr_2O_4$ spinel particles. The annealing temperature has a similar effect on the average size of the $MnCr_2O_4$ spinel. Within the range of this investigation the higher the annealing temperature the coarser the surface particle size.

The surface precipitates across the width of industrial batch annealed steel strip were characterised using SEM and TEM which established that the diameter of the surface oxide precipitates decreased from the edge to the centre of the steel strip. However, for the steel strip which exhibits the ‘edge defect’ the maximum size of the surface precipitates does not occur at the edge, rather about 20-100 mm from the edge. This has been interpreted as the result of the transition of internal selective oxidation to external selective oxidation suggesting that the steel sheet’s exhibiting the ‘edge defect’ are exposed to relatively higher oxygen potentials.

This investigation has identified that lowering the annealing temperature, reducing the chromium level in the steel and reducing the oxygen potential of the annealing environment will reduce the formation of the $MnCr_2O_4$ spinel. Therefore the 'edge defect' may be reduced by modifying these parameters during tinplate production. The minimisation of this defect will reduce production costs and improve product consistency for tinplate production.

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List of Abbreviations

AES	Auger Electron Spectroscopy
BCC	Body Centred Cubic
EDS	Energy Dispersive X-Ray Spectroscopy
FCC	Face Centred Cubic
FIB	Focussed Ion Beam Miller
GDOES	Glow Discharge Optical Emission Spectroscopy
LHS	Left Hand Side
RHEED	Reflection High-Energy Electron Diffraction
RHS	Right Hand Side
SEM	Scanning Electron Microscopy
SIMS	Secondary Ion Mass Spectrometry
SNMS	Secondary Neutrals Mass Spectrometry
TEM	Transmission Electron Microscopy
XPS	X-Ray (excited)-Photoelectron Spectrometry
XRD	X-Ray Diffraction