Image Cover Sheet

CLASSIFICATION	SYSTEM NUMBER 511895
UNCLASSIFIED	

TITLE

Passivation of Laser-Treated Nickel Aluminum Bronze as Measured by Electrochemical Impedance Spectroscopy

System Number:

Patron Number:

Requester:

Notes: Paper #21 contained in Parent sysnum #511874

DSIS Use only:

Deliver to: CL

#511895 (21)

Passivation of Laser-Treated Nickel Aluminum Bronze as Measured by Electrochemical Impedance Spectroscopy

by R.D. Klassen[1], C. Hyatt[2] and P.R. Roberge[1]

[1]Dept. of Chem./Chem.Eng., Royal Military College of Canada P.O.Box 17000 Stn Forces, Kingston, Ontario K7K 7B4

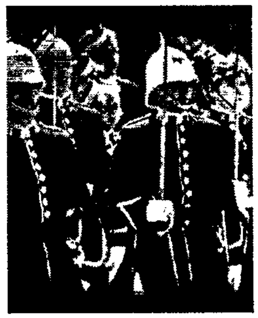
[2]Defence Research Establishment Atlantic, Dockyard Laboratory P.O. Box 99000 Stn Forces, Halifax, Nova Scotia B3K 5X5

ABSTRACT

Although laser welding and cladding of nickel aluminum bronze (NAB) surfaces involves a fraction of the energy input of conventional welding, a heat affected zone (HAZ) is still formed as well as an as-deposited zone. The main objective of this work was to determine whether the corrosion resistance of the HAZ due to laser treatment was different from the as-deposited zone or a surface without laser treatment. Electrochemical impedance spectroscopy (EIS) was employed to measure the corrosion rates of samples immersed in 3.5% neutral saline. The following specimens of a nickel aluminum bronze (Alloy D) were tested over an immersion time of 50 hours: (i) polished (not laser treated), (ii) laser-treated and polished, (iii) the as-deposited region of laser-treated and polished specimen, (iv) the HAZ region of a laser-treated and polished specimen and (v) laser-treated and unpolished.

A pseudo steady-state level of passivation was reached in all the samples within 40 hours. As expected, laser treatment increased the short-term rate of passivation and therefore improves the long-term resistance to corrosion. The HAZ region clearly passivated more slowly than the as-deposited region. The long-term susceptibility of part of the HAZ to corrosion was confirmed with SEM micrographs. Electrochemical impedance data illustrated a transition during the passivation process of the polished specimens that is consistent with the development of a film layer that restricts mass transfer. The welding oxide from the laser treatment produced a passivation film that is indistinguishable from that which eventually develops on polished specimens.

Passivation of Laser-Treated NAB as Measured by Electrochemical Impedance Spectroscopy

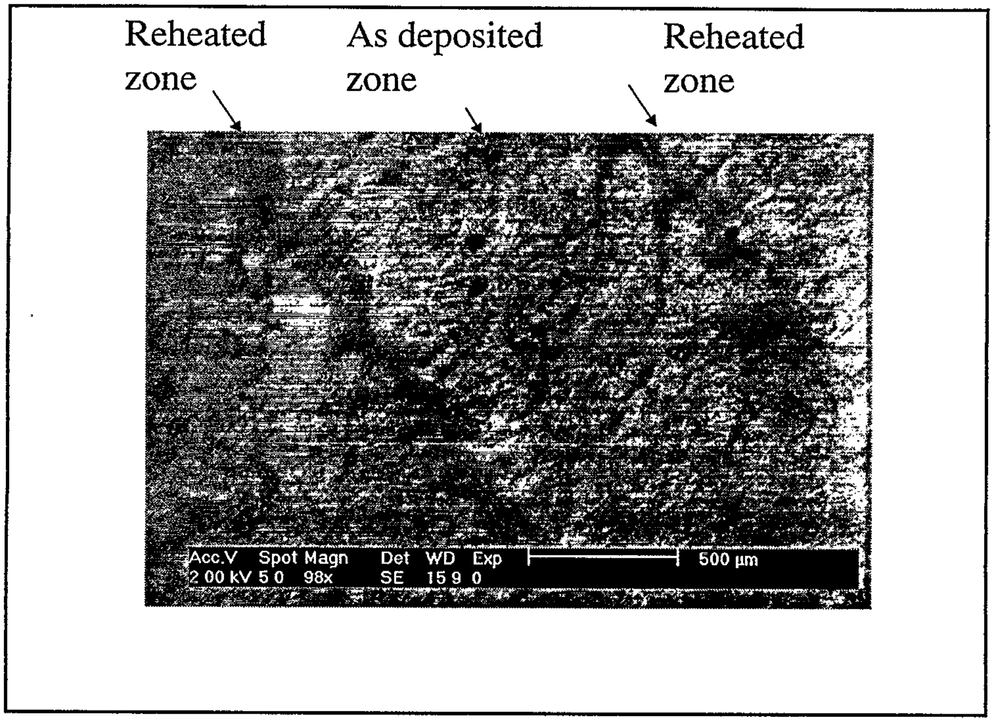


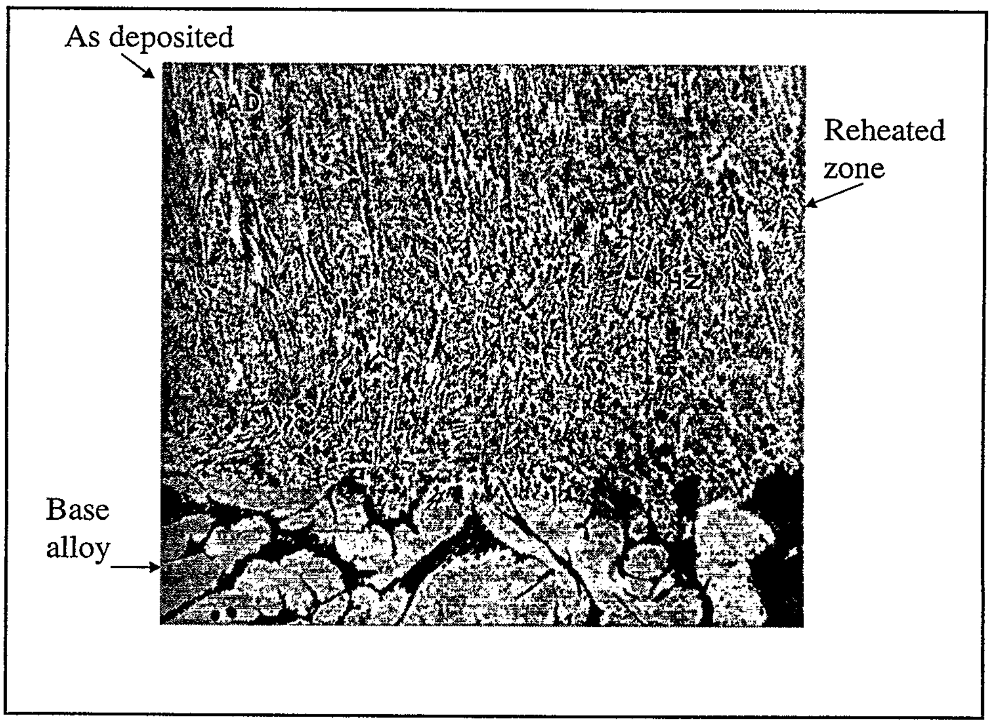
Bob Klassen, Calvin Hyatt and Pierre Roberge

Previous work

- Schussler and Exner had found, via Auger analysis, that the passivation of a NAB (un-clad) was due a layer of disordered aluminum oxide that was about 9 nm thick.

- The passivation time for laser-clad NAB was shorter than for an un-clad NAB (Taylor et al.).

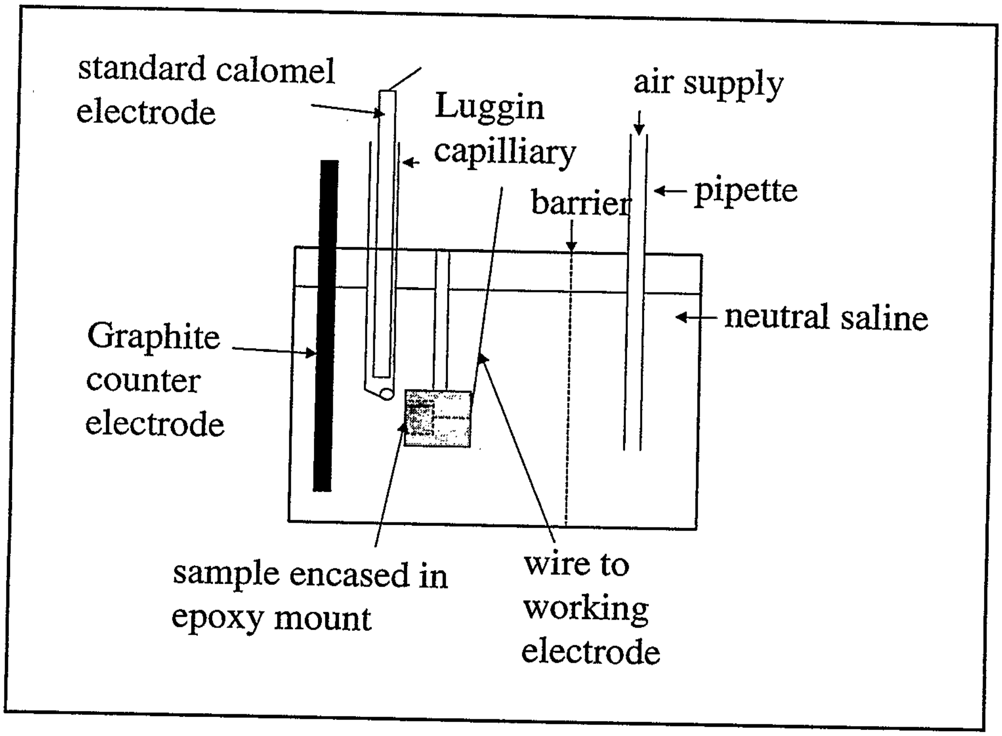

Reheated zone
As deposited zone
Reheated zone
Acc.V Spot Magn Det WD Exp
500 µm
2 00 kV 5 0 98x SE 15 9 0

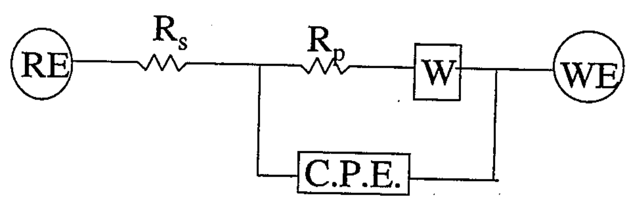

As deposited
Reheated zone
Base alloy

NAB samples

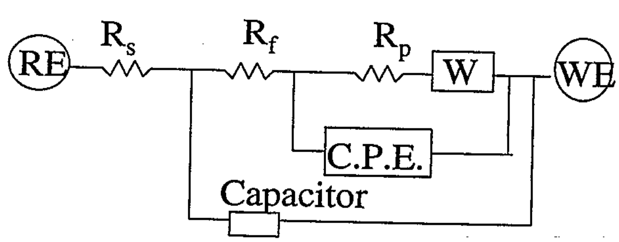
- base alloy, polished
- laser-clad, unpolished
- laser-clad, polished
- laser-clad, polished, as-deposited region only
- Gleeble specimen (reheated zone simulation), polished

Alloy	Designation (UNS)	Specimen Composition Cu	Al	Ni	Fe	Mn
base	C95800	81	9.1	4.4	4.1	1.1
wire	CuNiAl	80.8	9.0	4.6	3.9	1.2
Gleeble	C95800		9.2	4.7	3.4	0.77

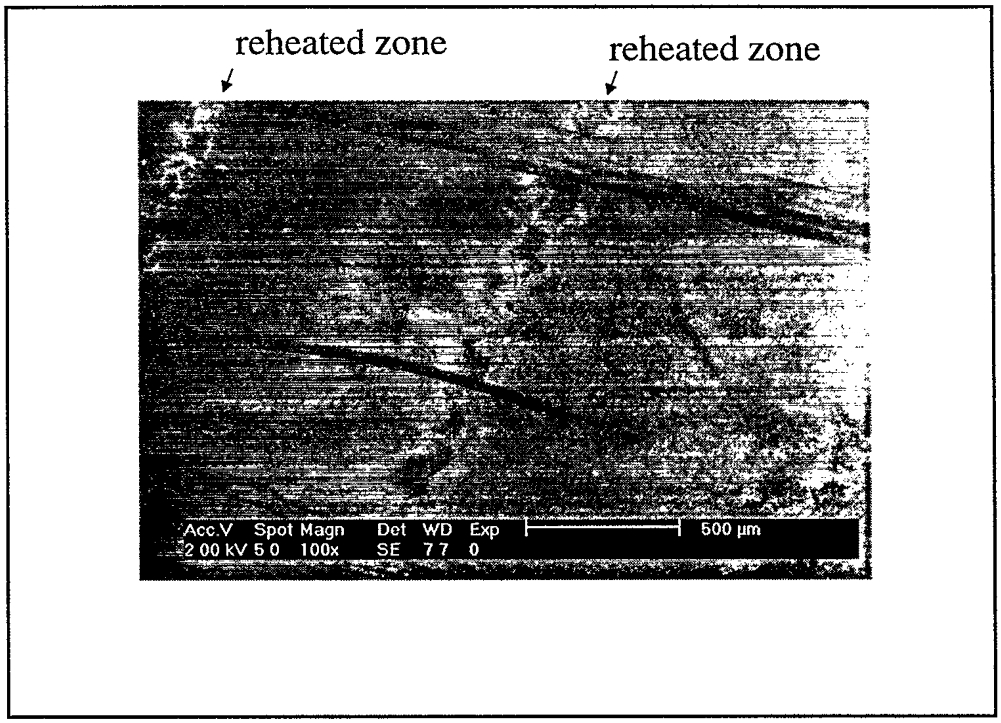


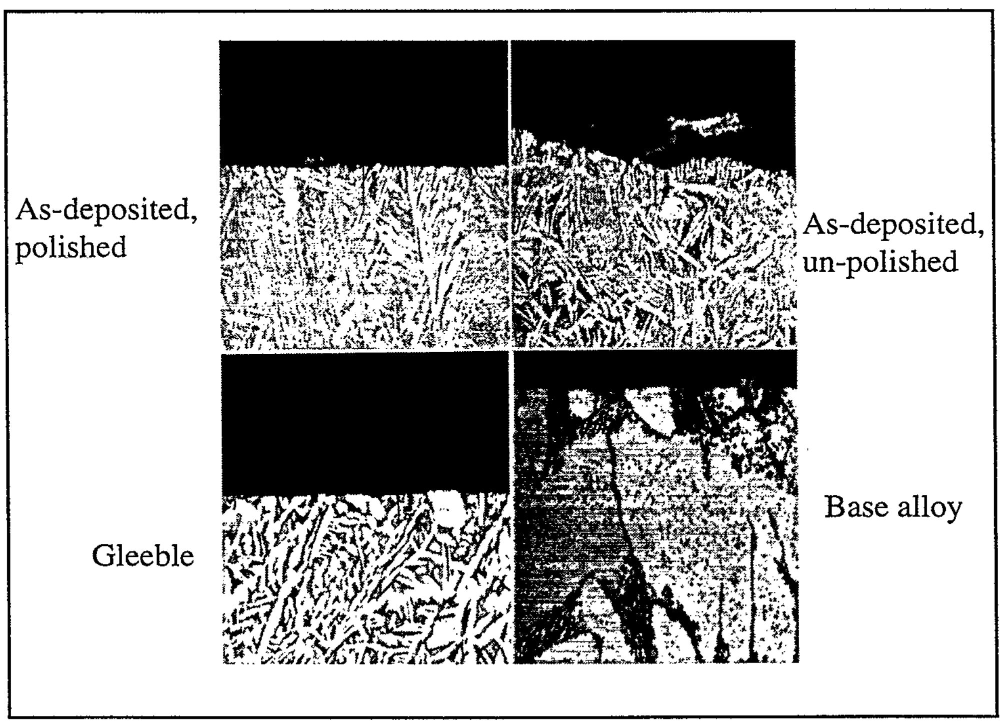


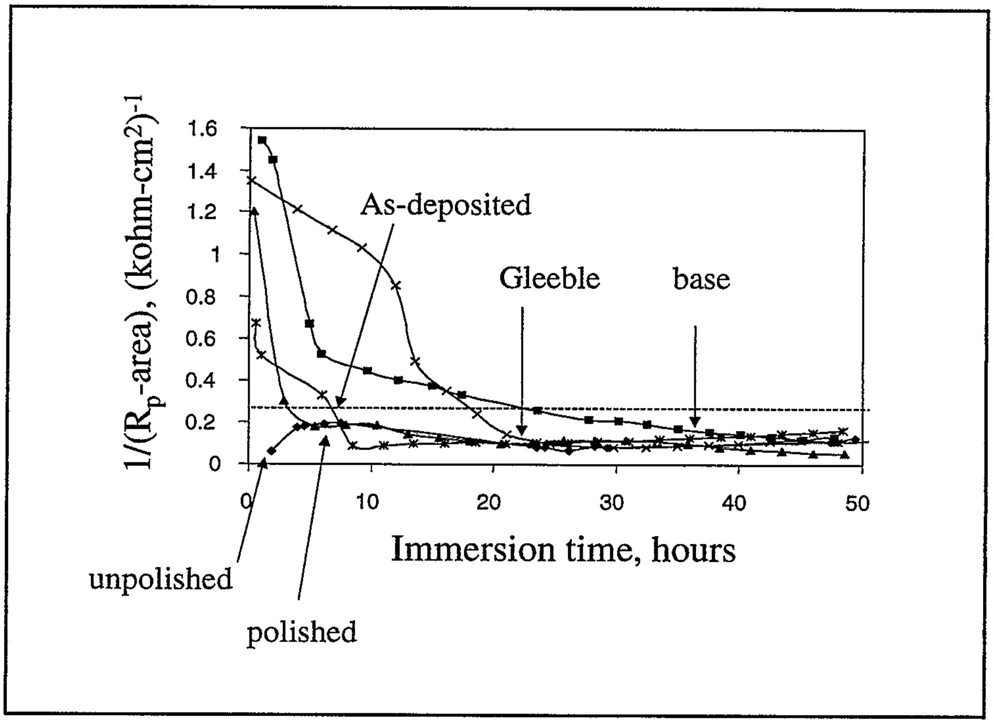
Mixed kinetic and diffusion control circuit

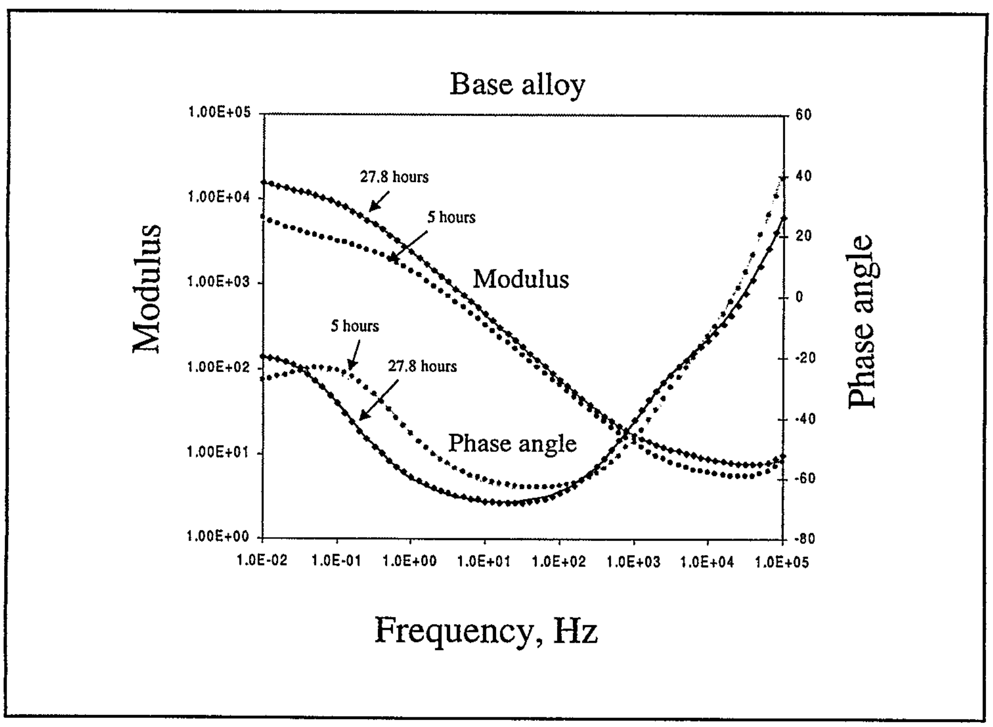


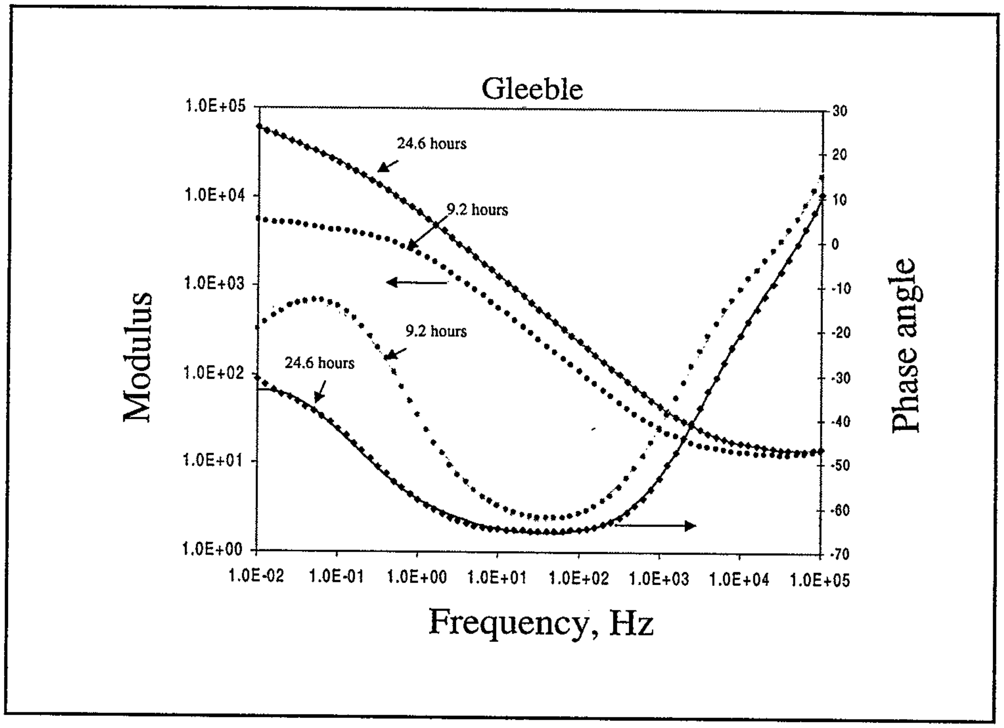
Filmed metal circuit.

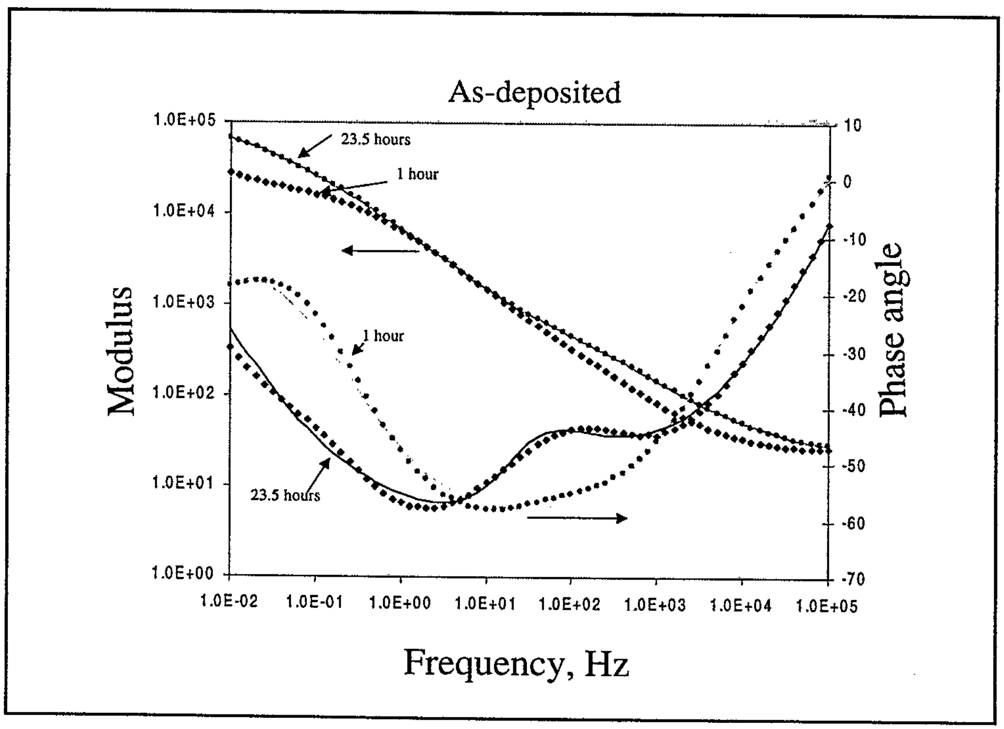

reheated zone
reheated zone
Acc.V Spot Magn Det WD Exp
2 00 kV 5 0 100x SE 7 7 0
500 µm

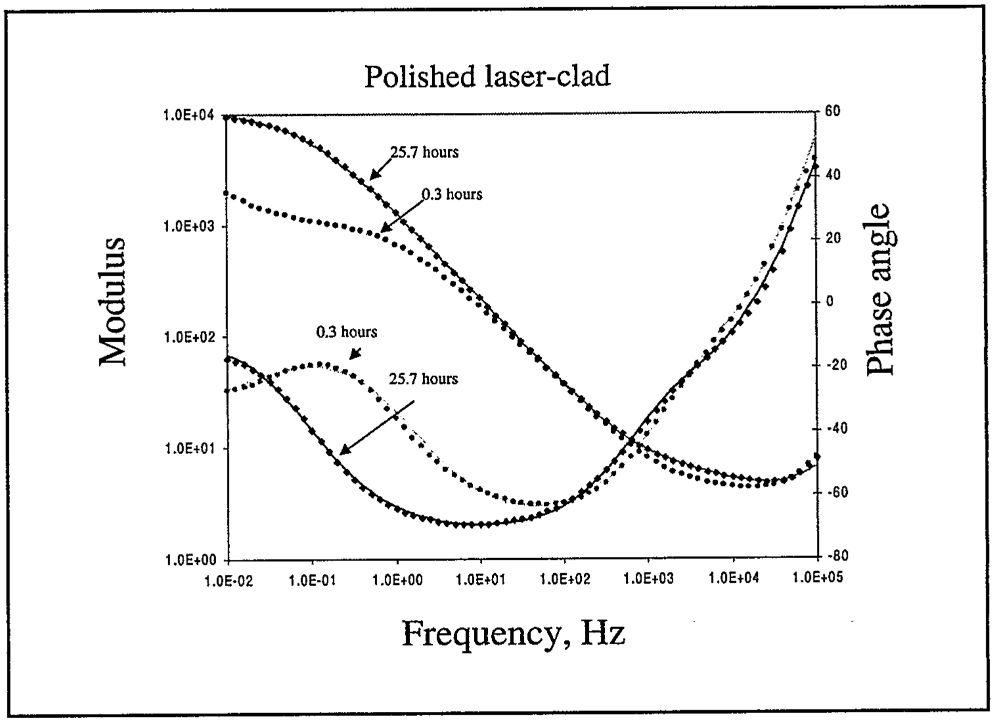

As-deposited, polished
As-deposited, un-polished
Gleeble
Base alloy

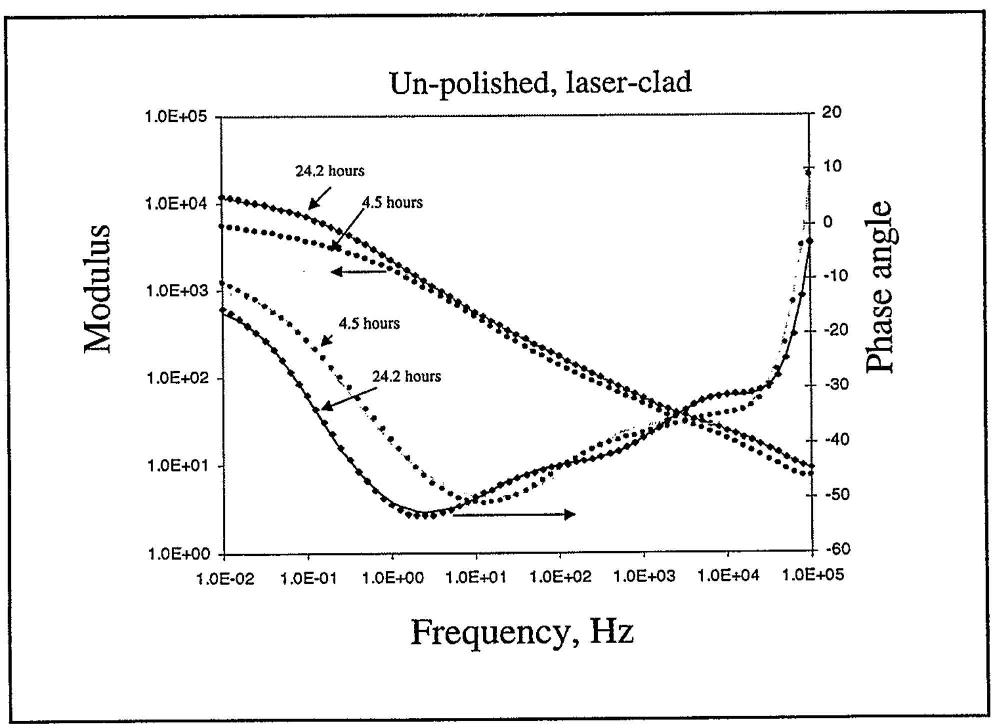

1/(Rp-area), (kohm-cm2)-1
As-deposited
Gleeble
base
unpolished
polished
Immersion time, hours
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50


Base alloy
Modulus
Phase angle
27.8 hours
5 hours
Modulus
5 hours
27.8 hours
Phase angle
Frequency, Hz
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
60
40
20
0
-20
-40
-60
-80
1.0E-02
1.0E-01
1.0E+00
1.0E+01
1.0E+02
1.0E+03
1.0E+04
1.0E+05


Gleeble
24.6 hours
9.2 hours
9.2 hours
24.6 hours
Modulus
Phase angle
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
1.0E-02 1.0E-01 1.0E+00 1.0E+01 1.0E+02 1.0E+03 1.0E+04 1.0E+05
Frequency, Hz


As-deposited
23.5 hours
1 hour
1 hour
23.5 hours
Modulus
Phase angle
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
10
0
-10
-20
-30
-40
-50
-60
-70
1.0E-02 1.0E-01 1.0E+00 1.0E+01 1.0E+02 1.0E+03 1.0E+04 1.0E+05
Frequency, Hz


Polished laser-clad
Modulus
Phase angle
Frequency, Hz
25.7 hours
0.3 hours
0.3 hours
25.7 hours
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
60
40
20
0
-20
-40
-60
-80
1.0E-02
1.0E-01
1.0E+00
1.0E+01
1.0E+02
1.0E+03
1.0E+04
1.0E+05


Un-polished, laser-clad
Modulus
Phase angle
Frequency, Hz
24.2 hours
4.5 hours
4.5 hours
24.2 hours
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
20
10
0
-10
-20
-30
-40
-50
-60
1.0E-02
1.0E-01
1.0E+00
1.0E+01
1.0E+02
1.0E+03
1.0E+04
1.0E+05

EIS curve fitting

- the value of the capacitance of the film was about 10 μF/cm2 for all of the runs below the dotted line

- this value corresponds to a thickness of 0.6 nm of ordered aluminum oxide which is fairly consistent with the thickness measured by Schussler and Exner (9 nm by Auger analysis)

- the Warburg element was consistently higher for the runs below the dotted line; this indicates that the mass transfer resistance increased during passivation

- these results are consistent with the development of a thin layer of aluminum oxide as the reason for the passivation

Conclusions

- Reheated zone passivates more slowly than as-deposited zone in neutral saline.

- Laser-clad surface passivates faster than base alloy.

- Martensitic region of reheated zone seems to be preferentially attacked.

- Passivation is consistent with the development of a thin layer of aluminum oxide that restricts mass transfer.

- The welding oxide behaved as a passivation film.