Brazing of *Gamma TiAl* with Ag-based Filler Metal

Z.K. Sallom[1], ***O.M. Akselsen*[1]***, C. van der Eijk[1], C. Li[2], and J. Zhang[3]

[1] SINTEF Materials and Chemistry, Trondheim, Norway
[2] Chalmers Technical University, Gothenburg, Sweden
[3] Central Iron and Steel Research Institute, Beijing, China

* Corresponding author: Odd.M.Akselsen@sintef.no
Phone: +47 9305 9450, fax: +47 7359 2931

EUROMAT 2005, Prague, The Czech Republic, September 5-8, 2005

Outline

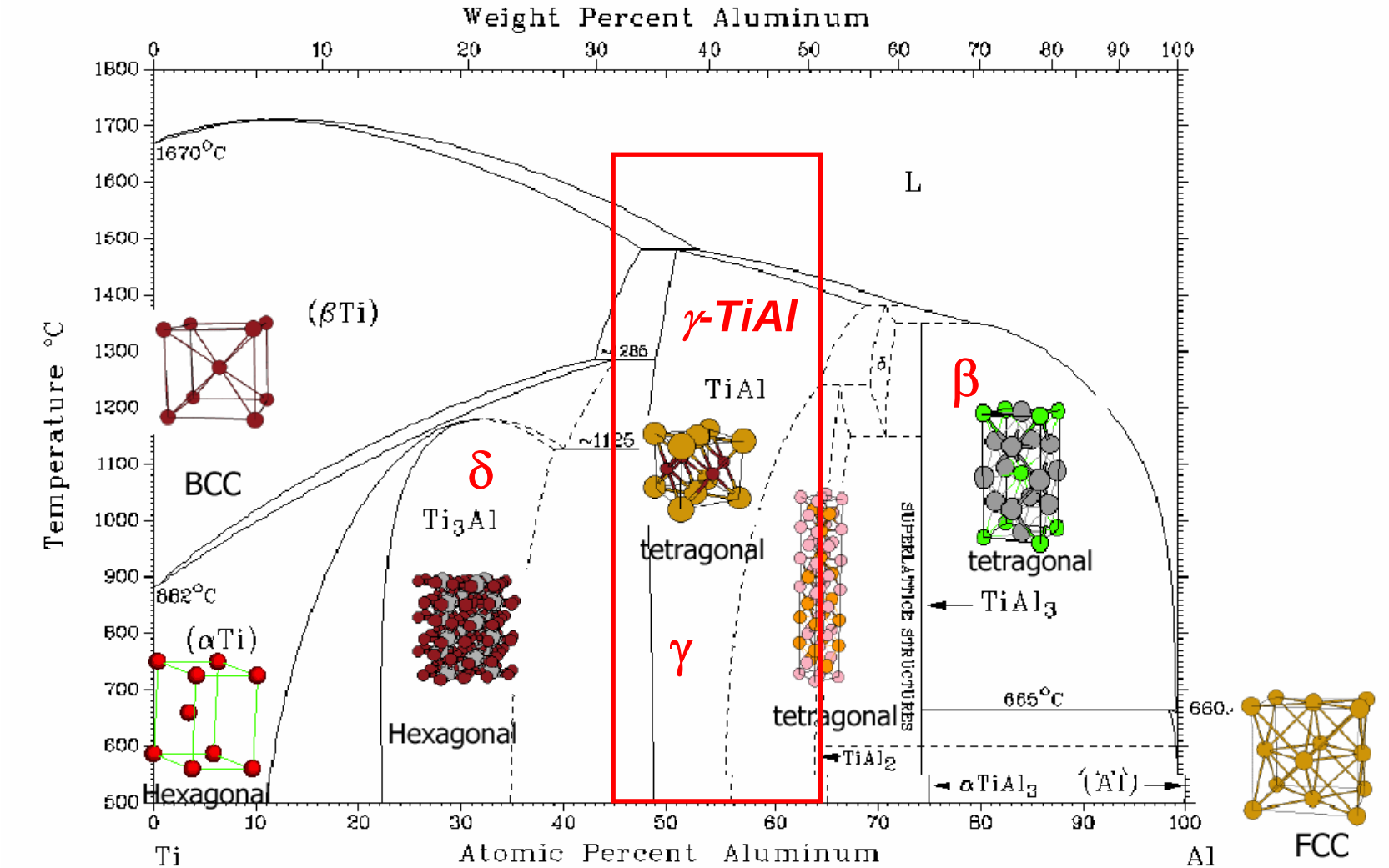
- Background
- Materials and Experimental Details
- Results and Discussion
- Conclusions
- Ackowledgements

Background

Background

- Superalloys are currently used in gas turbine blades (examples are Rene alloys 80 and 100). These are heavy, and may not be optimal for this application. If lighter alloys could be used, the energy economy would be much improved.
- Here, the intermetallic alloy γ-TiAl is a candidate to replace Ni alloys in structural applications in the temperature range from 400 to 800°C. Other TiAl alloys do not attract similar attention anymore. Properties of γ-TiAl: strong, low density, lightweight, high resistance to oxidation and hydrogen absorption, excellent creep properties, wear and temperature resistance.
- Present limitations: Aluminides have generally proved difficult to process, have limited heat treatability, and generally low ductility at room temperature.
- The application of light-weight materials requires availability of suitable joining technologies.
- Therefore, an attempt was made to conduct microwave brazing with reductive atmosphere since it is rapid and cheap.

The Ti-Al binary phase diagram



In some literature $TiAl_2$ and $TiAl_3$ may appear with β high temperature and α low temperature phases.

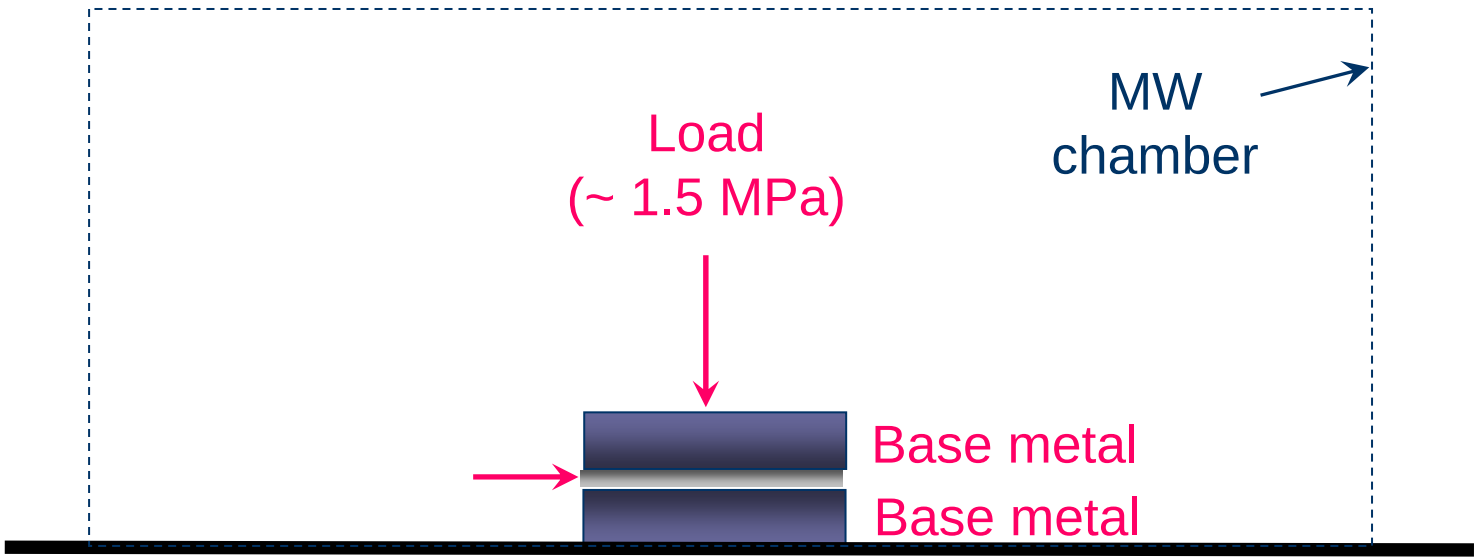
Materials and Experimental Details

Materials and Experimental Details

- Materials:
  - γ-TiAl (made by CISRI, Beijing, China)
- Brazing alloys (Degussa, Germany):
  - *CB4*: 70.5Ag-26.5Cu-3Ti, T_M=790-805°C
  - *CB2*: 96Ag-4Ti, T_M=970°C
- Discs of 5x5 mm were cut from TiAl rectangular bars
- These were mounted in a die with filler metal between
- Brazing was done by microwave heating with 1MPa load
  - *CB4*: 875-925°C for 5,10, 15, and 20 min
  - *CB2*: 1000-1050°C for 5, 10, 15 and 20 min
- Optical microscopy
- X-ray diffraction
- FEG-SEM analysis

Materials and Experimental Details

Brazing set up

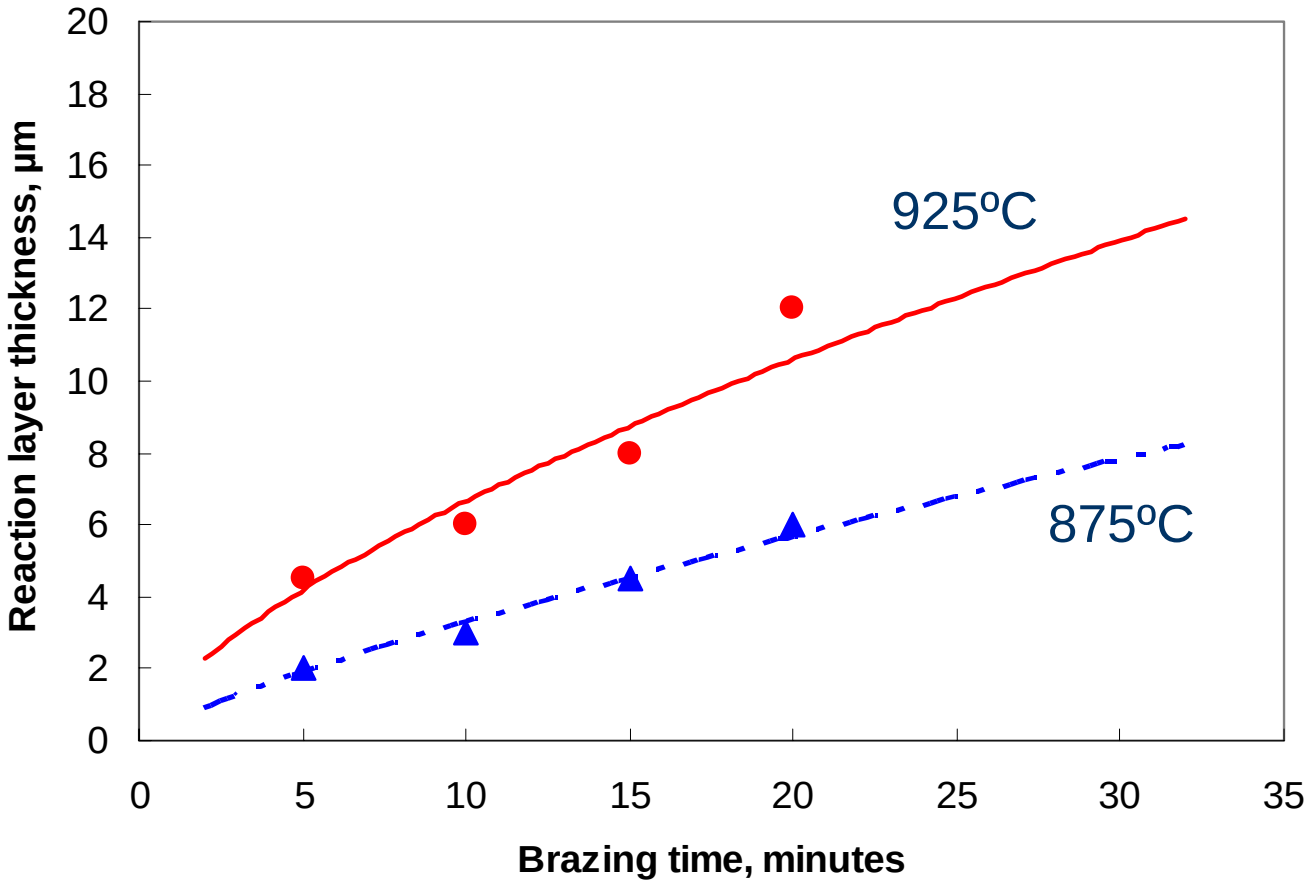


Microwave assisted brazing with uniaxial pressing

Results and Discussion

Results and Discussion

Reaction layer growth



Example: CB4 brazing alloy

Results and Discussion
Reaction layer growth

Reaction layer thickness, X:

$X\ (\mu m) = k\ t^{n}$

k is a constant

t is the time

n is the parabolic growth rate constant

Results and Discussion

Reaction layer growth

T = 925 °C:

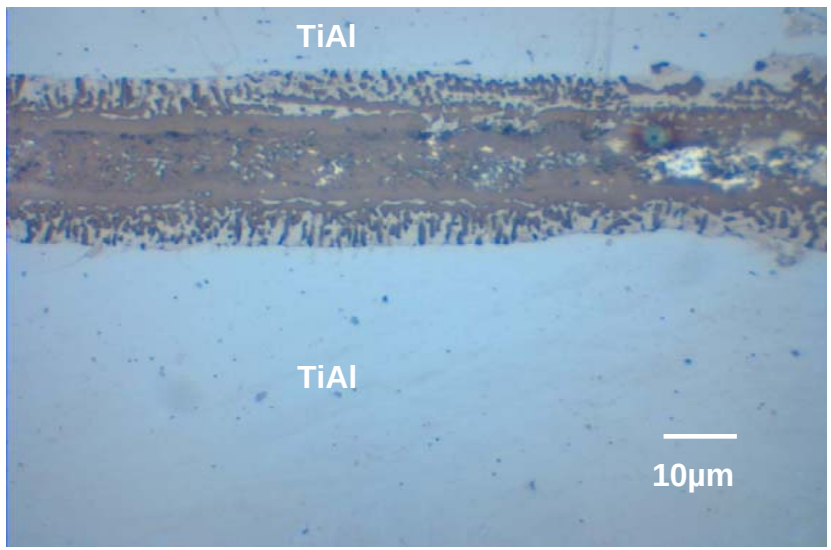
$X = 1.43\ t^{0.67}$ $R^2 = 0.9251$

T = 875 °C:

$X = 0.54\ t^{0.79}$ $R^2 = 0.9799$

Results and Discussion
Optical microscopy

Example - TiAl to TiAl:

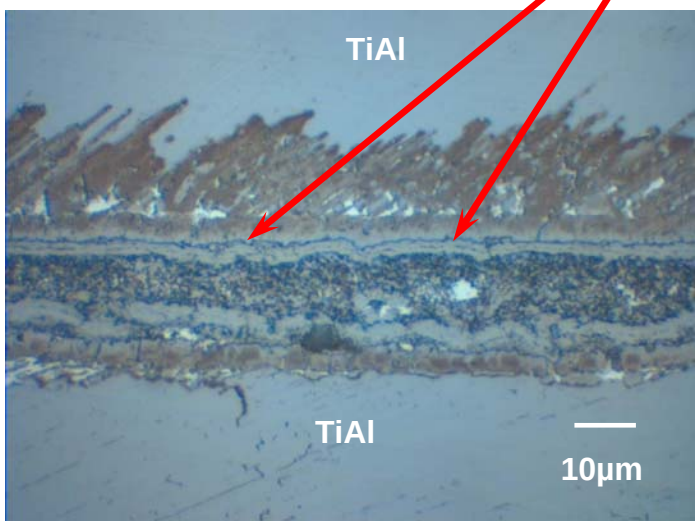


CB4: 925ºC/5min

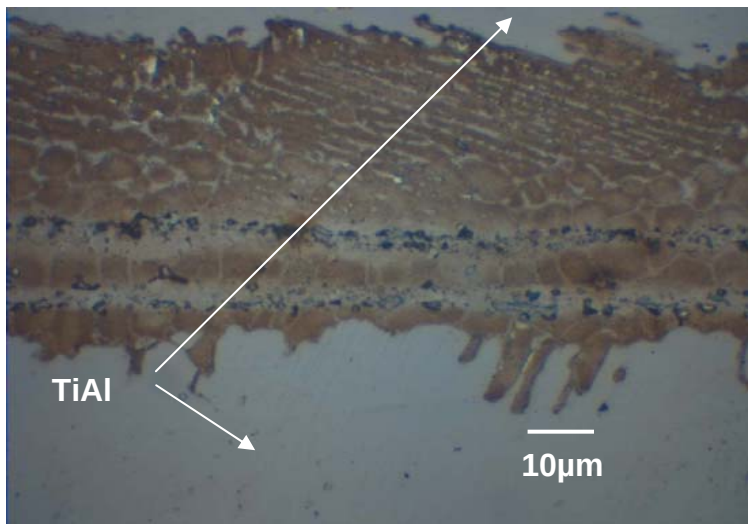
Results and Discussion
Optical microscopy

Examples – TiAl to TiAl:

Interface cracking



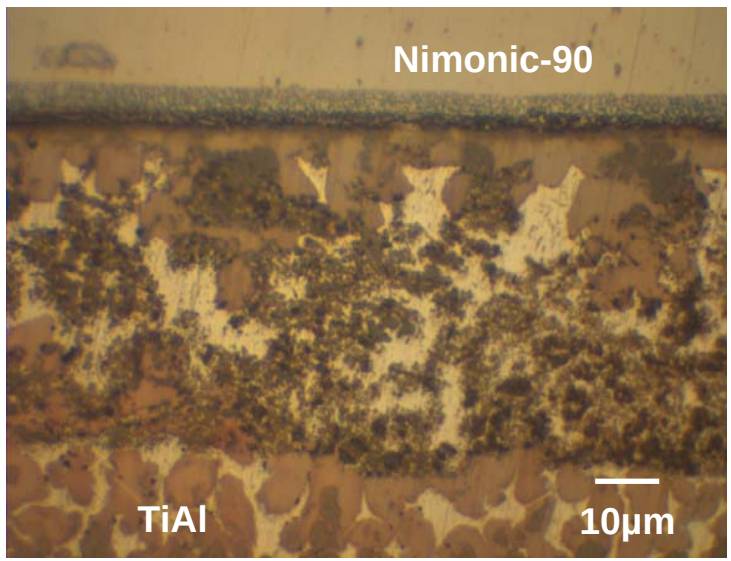
CB2: 1000ºC/5min



CB2: 1050ºC/5min

Results and Discussion
Optical microscopy

Example -TiAl to Nimonic 90:



CB4: 925ºC/5min

Results and Discussion
X-ray diffraction

- TiAl-TiAl joints:
  Numerous phases may form, depending on the brazing alloy used.
  - CB2: Mainly TiAl, but with $TiAl_2$ and TiO
    With the use of NH_4 containing atmosphere, TiO was found
    With H_2+NH_4 oxides were not found, Ti_3Al, possibly $TiAl_2$, and Ag_3Al were found in addition to TiAl
  - CB4: Here, TiAl, $TiAl_2$ and $CuAl_2O_4$ may have formed

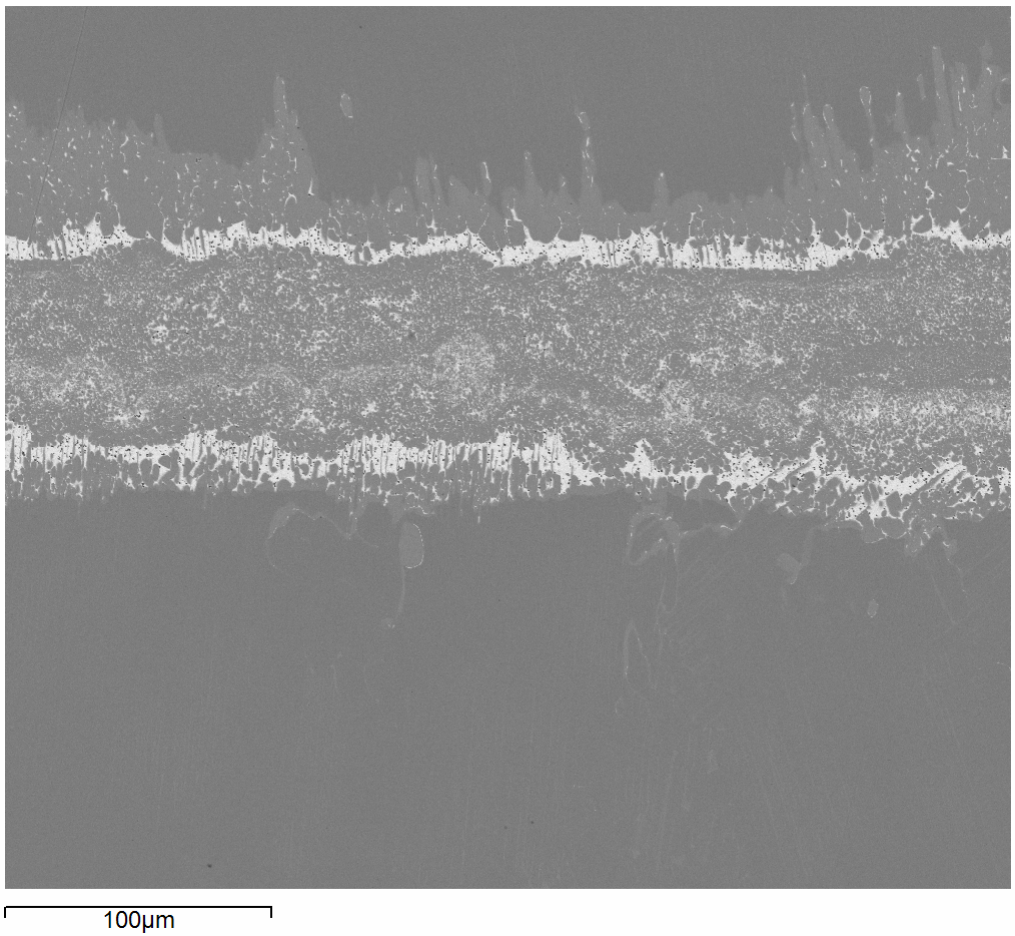
- TiAl-H13 joints
  - CB2: Ti_3Al and Ag_3Al, together with TiAl

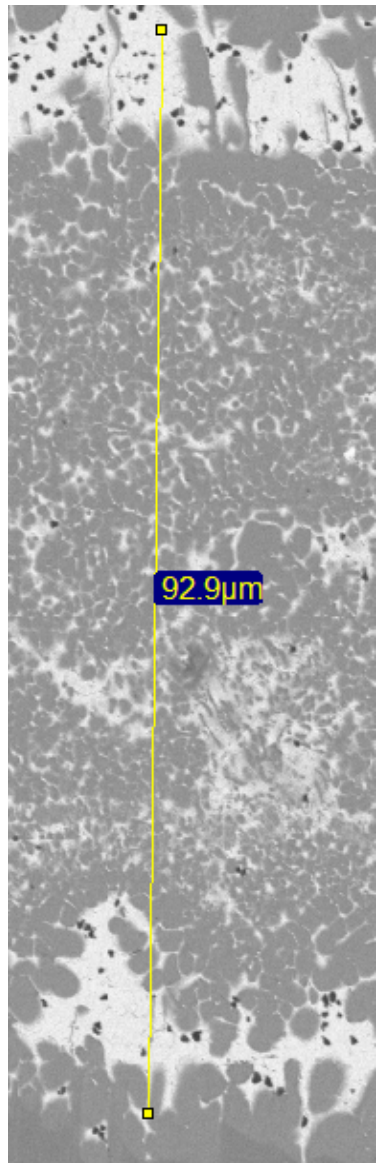
Results and Discussion
FEG-SEM examination

TiAl

CB2

TiAl

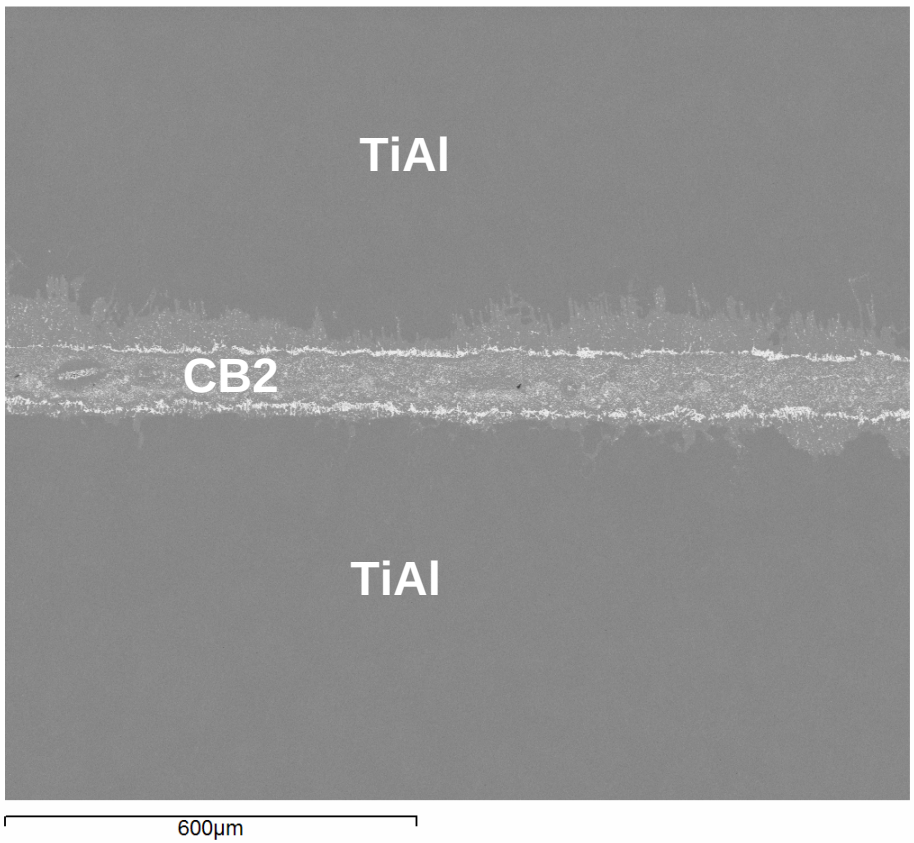




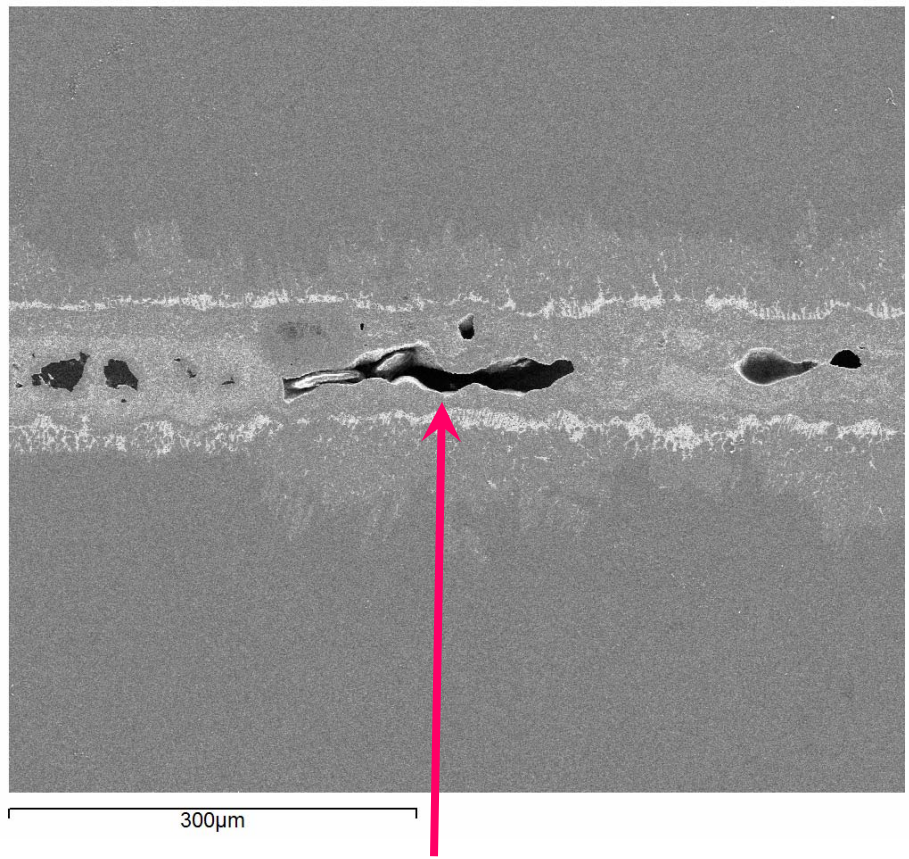
Brazing zone ca. 100µm

Diffusion into the TiAl: ca. 50 µm. CB2 alloy.

Results and Discussion
FEG-SEM examination



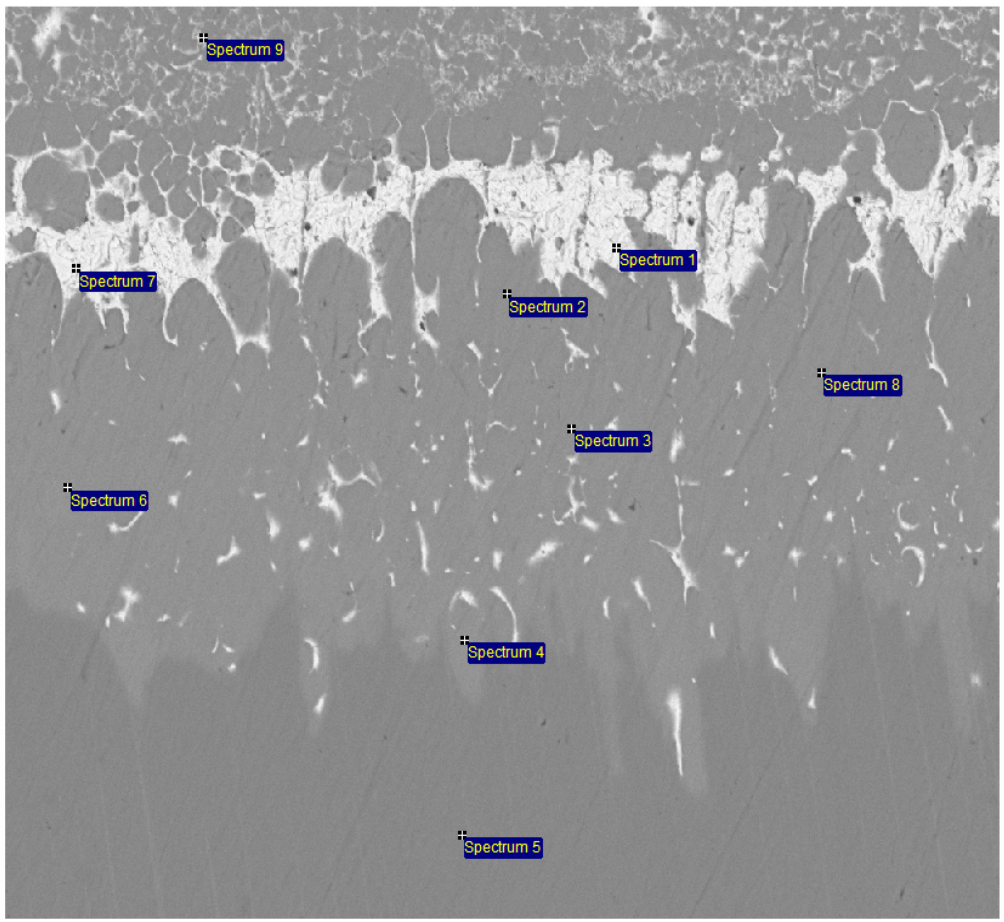
No porosity



Shrinkage porosity, 1000°C/5 min

Results and Discussion

FEG-SEM examination

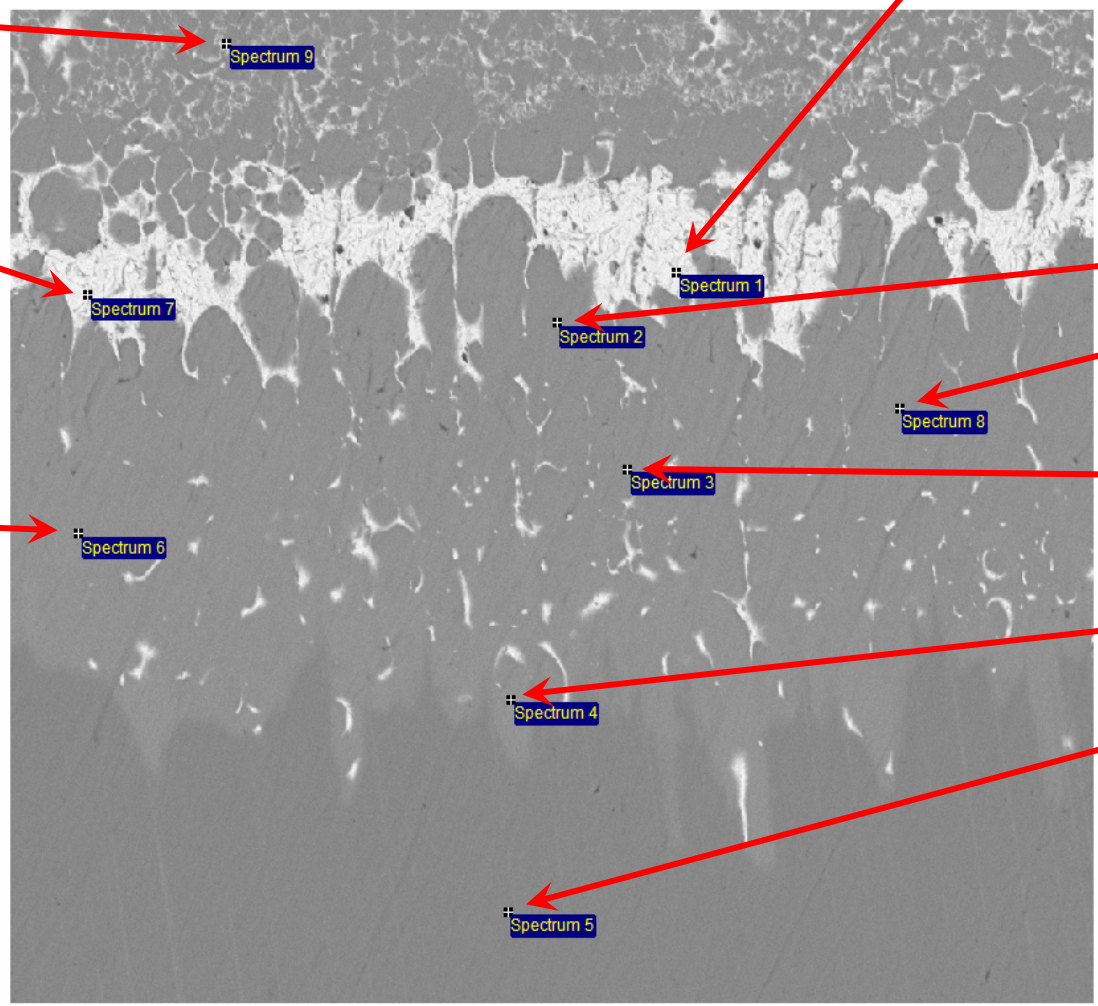


Spectrum, at %	Al	Ti	Ag
Spectrum 1	12.55		87.45
Spectrum 2	47.12	49.49	3.39
Spectrum 3	48.45	48.46	3.09
Spectrum 4	36.93	58.49	4.58
Spectrum 5	50.51	49.49	
Spectrum 6	37.36	62.64	
Spectrum 7	10.07		89.93
Spectrum 8	44.61	52.43	2.96
Spectrum 9	33.05	63.60	3.35

CB2, 1000°C/5 min

Results and Discussion

FEG-SEM examination



γ-Ti(Al,Ag)

β-Ag_3Al

Two phase region γ-TiAl + δ-Ti_3Al ?

β-Ag_3Al

γ-Ti(Al,Ag)

γ-Ti(Al,Ag)

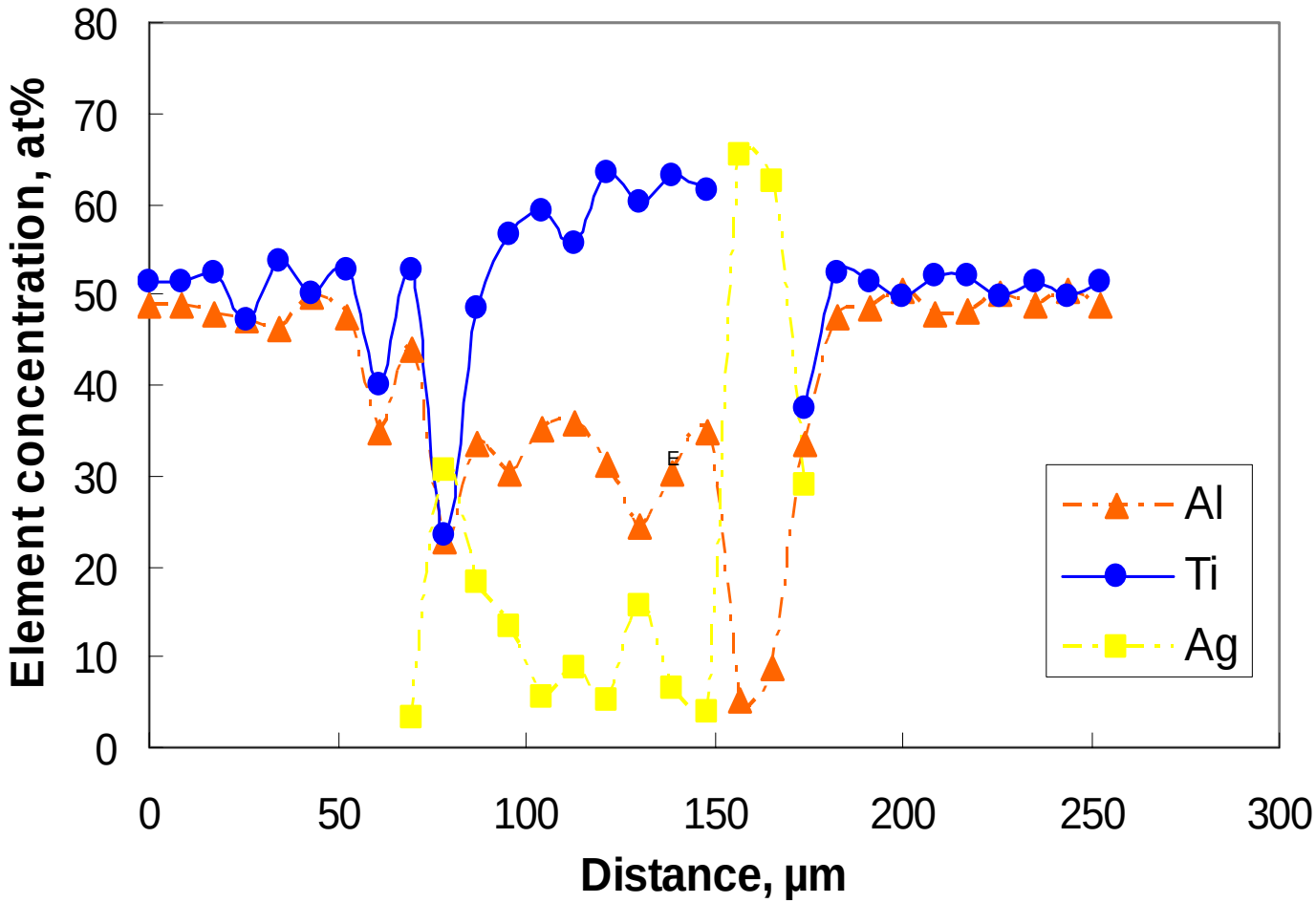
γ-Ti(Al,Ag)

γ-Ti(Al,Ag)

γ-TiAl base metal

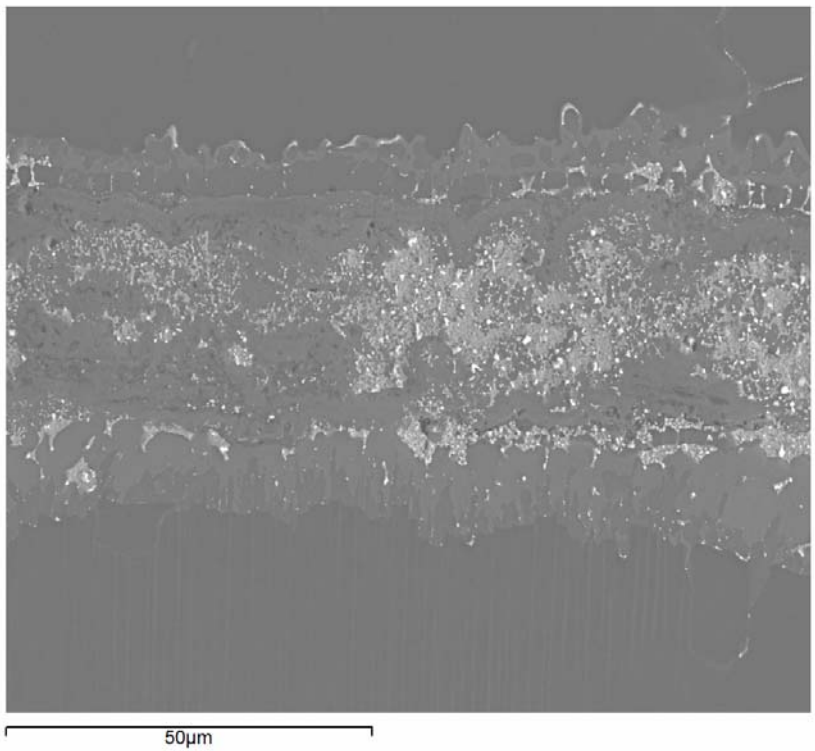
Results and Discussion

FEG-SEM examination

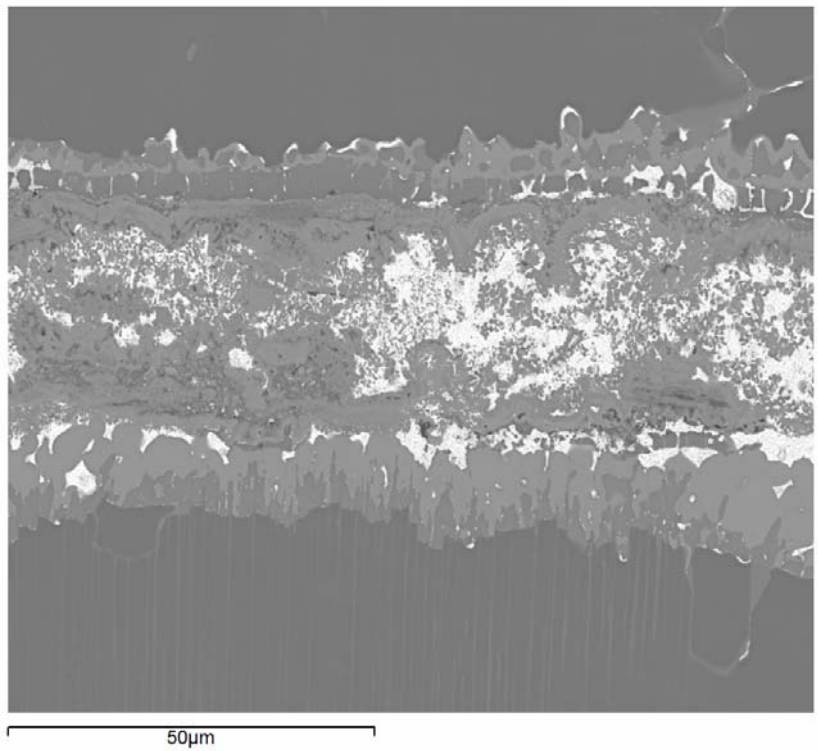


TiAl - TiAl linescan, CB2, 1000°C/5 min

Results and Discussion
FEG-SEM examination



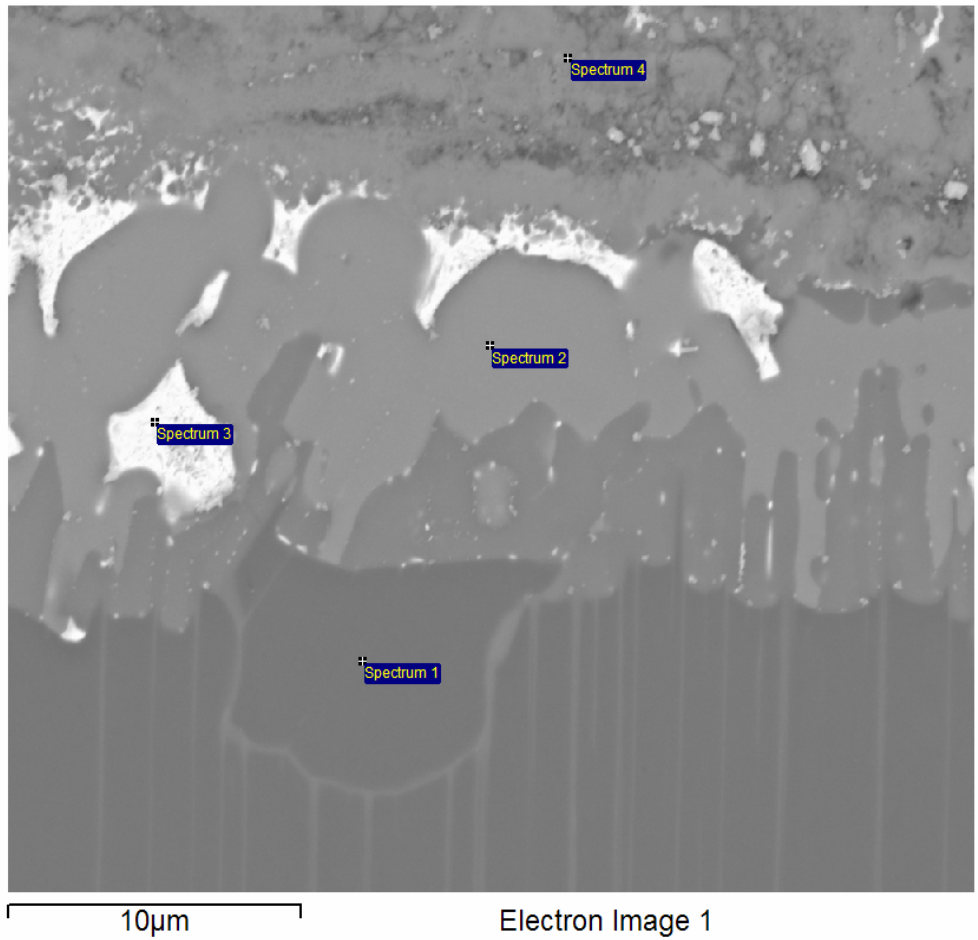
SE



BSE

CB4 alloy, 925°C/5 min

Results and Discussion
FEG-SEM examination



Position	Al	Ti	V	Cr	Cu	Ag
Spect. 1	47.09	49.54	2.52	0.85		
Spect. 2	35.18	31.93	1.83	1.20	28.13	1.73
Spect. 3	7.55	3.73			4.77	83.95
Spect. 4	24.74	52.32			22.37	0.58

Results and Discussion

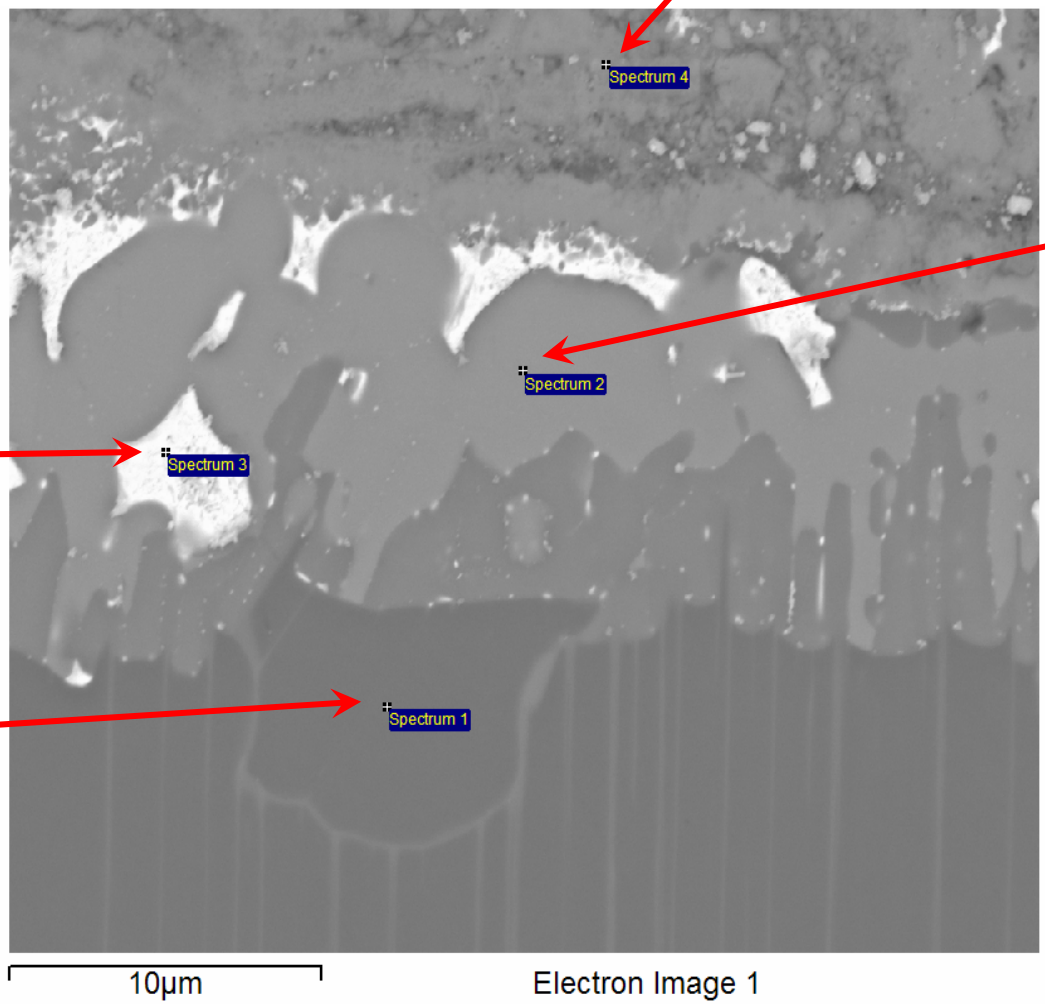
FEG-SEM examination

Ti(Al,Cu) phase ?

Ternary Cu-Ti-Al phase ?

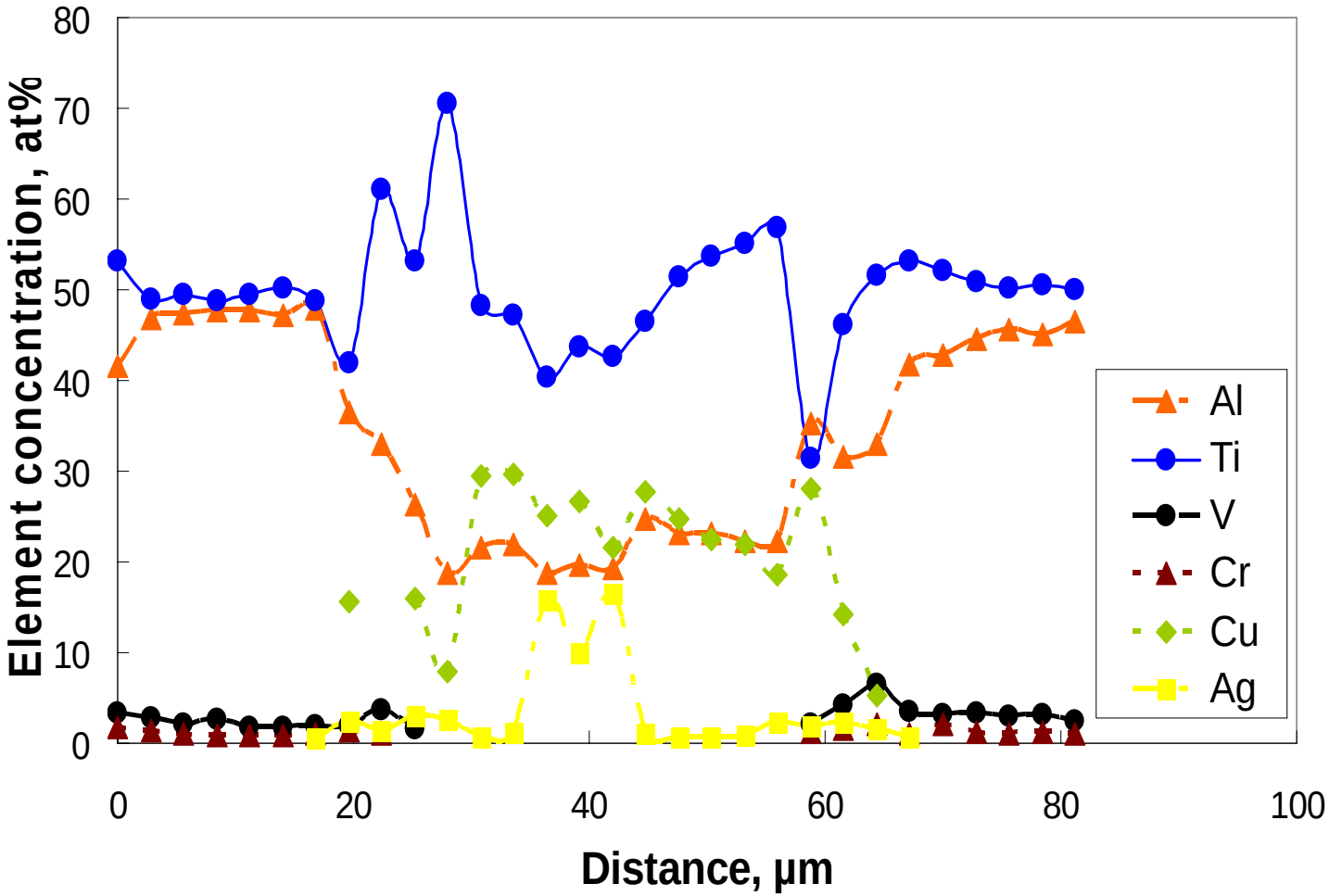
β-Ag_3Al with Ti and Cu

γ-TiAl, with Cr and V base metal



Results and Discussion

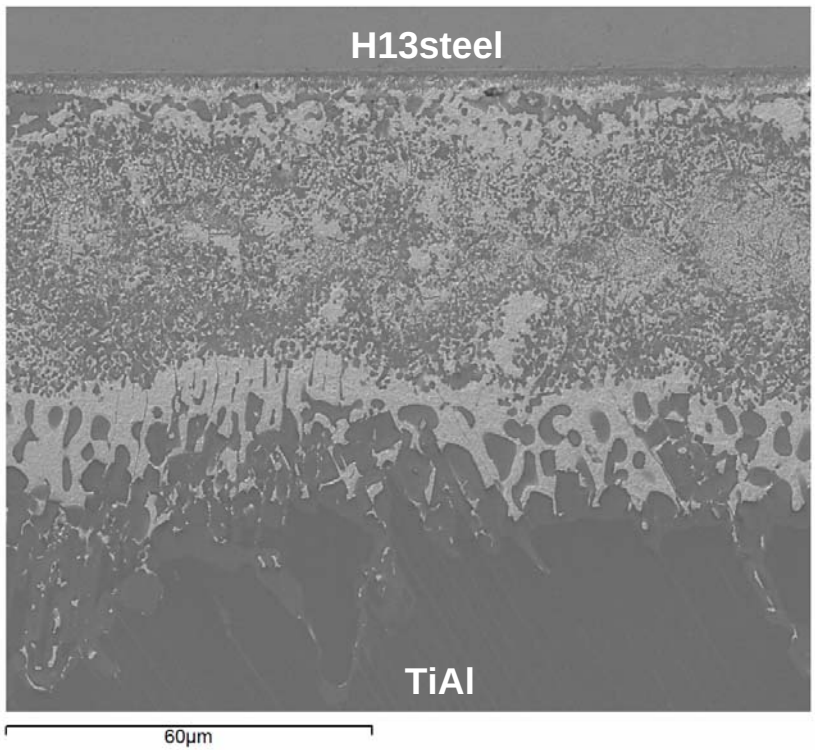
FEG-SEM examination

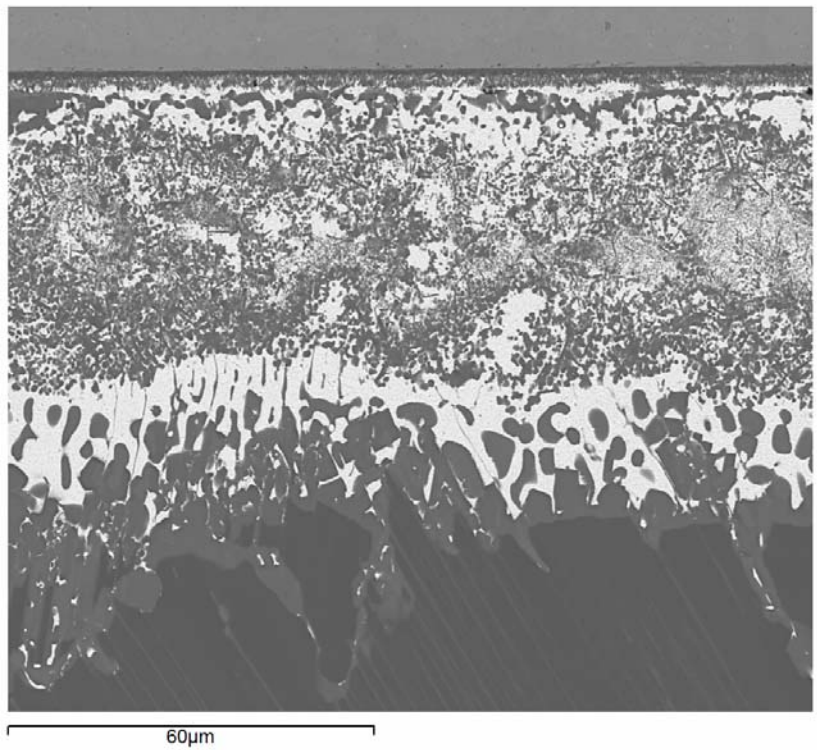


TiAl - TiAl linescan, CB4, 925°C/5 min

Results and Discussion
FEG-SEM examination

Example TiAl to H13 steel with CB2 alloy:



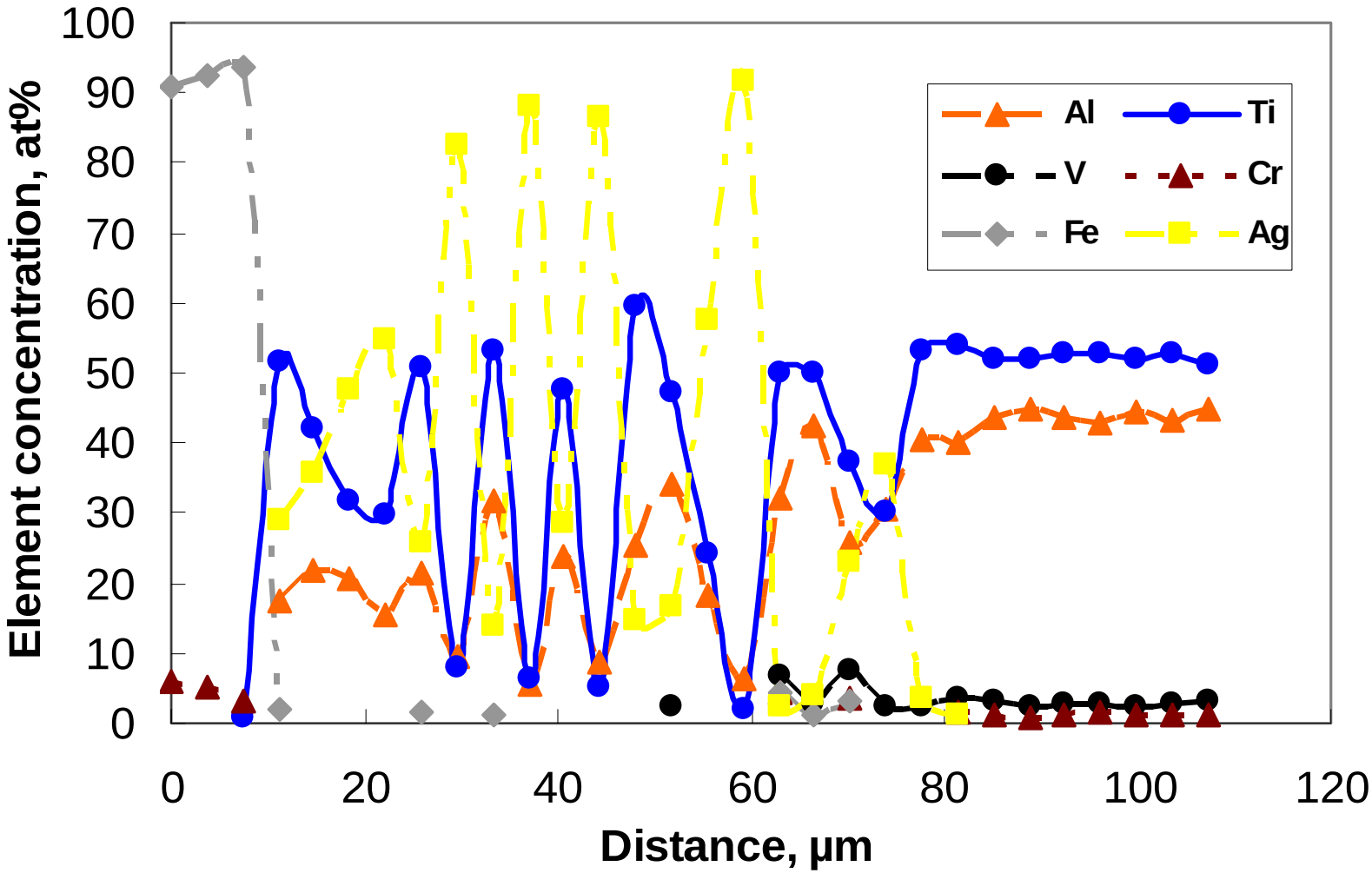


SE BSE

Crack free joint (but cracking took place)

Results and Discussion

FEG-SEM examination



TiAl - H13 steel linescan, CB2, 1000°C/5 min

Conclusions

Conclusions

- Brazing in an Ar+H_2 atmosphere does not give full protection against oxidation. Certain modifications are required.
  Use of H_2 and ammonia gives less oxides.

- Reaction layers are formed, which means that sound metallurgical bonds are obtained. The layer width was between 2 and 12 μm, depending on the brazing parameters.

- Brazing of NiTi is fully possible with Ag based alloys due to their content of an active species (Ti).

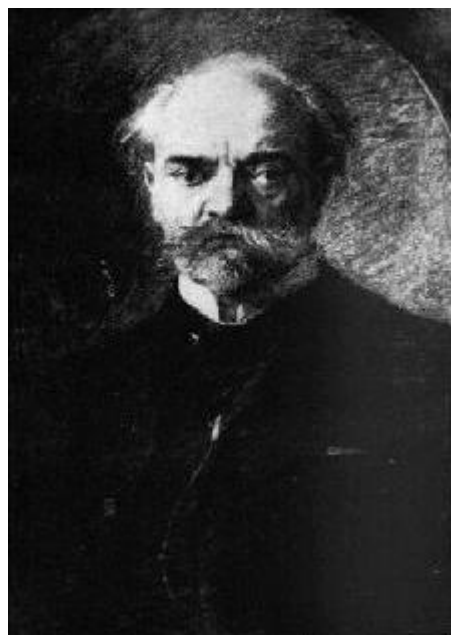
- Further work in phase identification is necessary.

Ackowledgements

The authors wish to thank Central Iron and Steel Research Institute (CISRI) in Beijing, China, for provision of TiAl.

Thanks also to Mr Kjell R. Kvam, NTNU, Trondheim, Norway for performing the X-ray diffraction analyses.

Bedrich Smetana (Litomysl,Prague, 1824-1884)



Antonin Dvorak (Bohemia, 1841-1904)