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Study of the Microstructure of Synthesed Laminates

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Abstract

$Ti-Al_3Ti$ metal - intermetallic laminates synthesized by thermal explosion, reaction sintering with and without pressure, explosion welding with further heat treatment for powder mixtures and foils were studied using a microstructural analysis.
The structure and composition of the samples were studied by X-ray diffraction, X-ray microanalysis, and metallography. The best microstructural parameters were obtained by explosion welding of a multilayer package of titanium and aluminum plates, then by sintering this package in a muffle furnace with selection of time-temperature parameters. **The conducted studies can be used to obtain laminates with a desired thickness of titanium and intermetallic layers.**

INTRODUCTION

A new promising class of structural and multifunctional materials is metal - intermetallic laminates (MIL). Such materials have many **useful properties and characteristics, such as high temperature strength, high oxidation stability, high creep resistance and others,** which make them attractive for use in many fields of engineering and also for ballistic applications.
The studies show **the possibility of obtaining titanium - titanium aluminide laminates by the interaction of titanium with aluminum.** An important role in the study and obtaining of such materials is assigned to the study of diffusion processes between titanium and aluminum layers, and the formation of intermetallic layers and their microstructure.

EXPERIMENTAL

Foils of Ti (VT1-0) and Al (8011) 0.3 and 0.15 mm in thickness,
the plates of titanium (0.5 and 0.6 mm) and aluminum (1 mm) of the same grades,
the powders of titanium (PTS), aluminum (ASD-4) were used in the experiments.

The thermal explosion mode

A stoichiometric powder mixture of Ti and Al and Ti foil (0.3 mm)s was used to synthesize titanium trialuminide Al_3Ti (37.2 wt.% Ti + 62.8 wt.% Al).
The powder mixture was pressed into tablets (20 mm and a porosity of 10-15%).
To determine the temperature, a 200 μm tungsten-rhenium thermocouple was used.

The reaction sintering

Ti and Al plates and a PM-12M muffle furnace were used. The ratio of the number of Ti and Al plates was selected based on the layers of the intermetallide Al_3Ti and pure titanium formed during sintering.
The package was sintered at a temperature of 700 and 900°C for 2, 4 and 6 hours.

The reaction pressing (reaction sintering under pressure)

Ti and Al plates were used, and temperature, pressure, and time of the process varied.

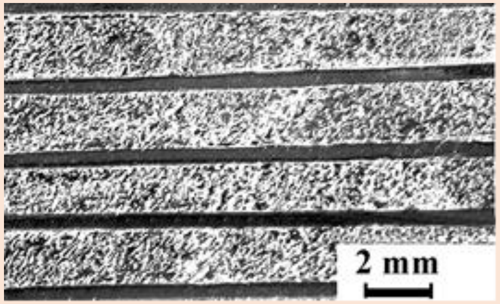
Explosion welding

The packages of 11 and 13 alternating titanium (0.5 and 0.6 mm) and aluminum (1 mm) plates with the size of 50x100 mm, the package of 21 titanium (0.6 mm) and aluminum (1 mm) plates with the size of 120x300 mm were obtained by explosion welding. The samples obtained by explosion welding were subjected to reaction sintering in a muffle furnace at temperatures of 700 and 900°C for 2, 4, 6 and 8 hours.

The synthesized samples were studied by X-ray diffraction (XRD), X-ray microanalysis (CAMECA), and metallography (Axiovert 200M).

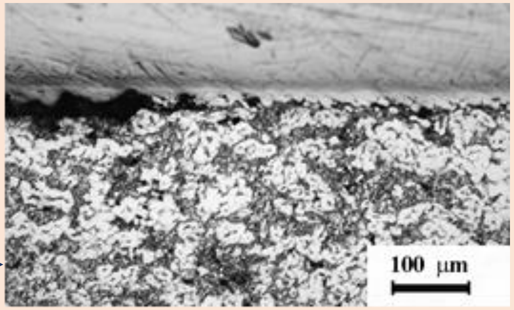
RESULTS

Investigation of the interaction of titanium foil and a powder mixture in thermal explosion mode



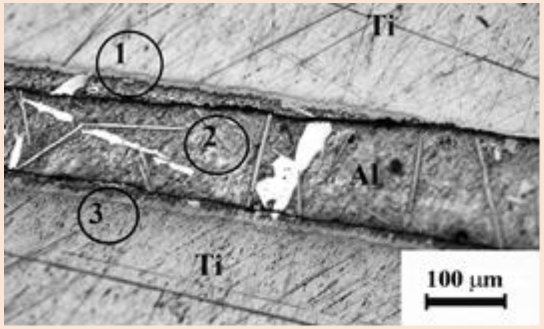
The structure of the laminate synthesized from Ti foil and stoichiometric powder mixture Al_3Ti (37.2 wt.% Ti + 62.8 wt.% Al).

The contact zone between titanium foil and the powder mixture (b).



X-ray diffraction patterns contain Al_3Ti peaks; peaks belonging to titanium oxide are infrequent.

Investigation of the interaction of titanium and aluminum foils in thermal explosion mode



Contact zone between titanium and aluminum foils after thermal explosion.

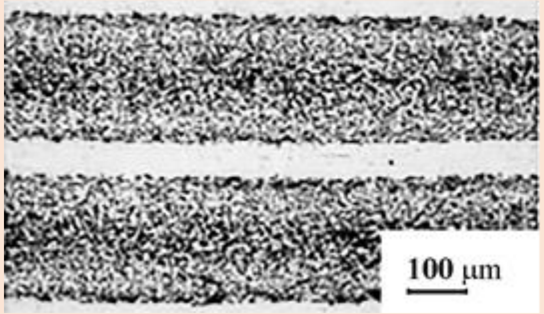
Zone 1 is the boundary between Al and Ti foils. Microanalysis showed Ti content in the range of 78 to 86 wt %. This ratio is close to the $AlTi_3$ phase.

Zone 2 is the zone of Al foil. The Ti content reduced to 2 to 3 wt% at certain points in the middle of Al foil. But points containing 100% aluminum were not found. The light inclusions inside the Al foil contain Ti, the weight of which is close to that in the Al_3Ti phase.

Zone 3 is the zone of Ti foil. Pure Ti was not found at a distance of 0.15 mm from the boundary with Al foil. The Ti content increases with the distance from the boundary with Al.

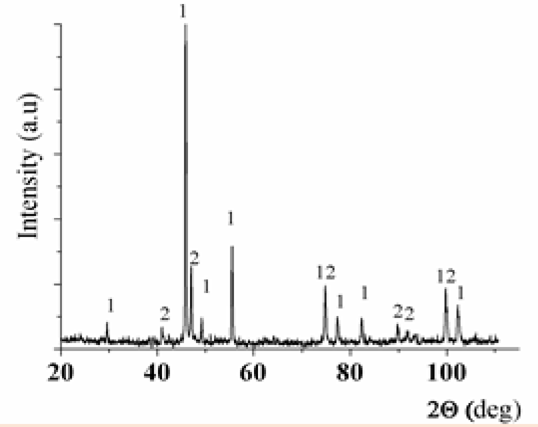
RESULTS

Investigation of the interaction of titanium and aluminum plates in the reaction sintering mode



After sintering at T = 900°C for 6 hours. microstructure

and X-ray diffraction pattern of a laminate (1-$TiAl_3$; 2-Ti)



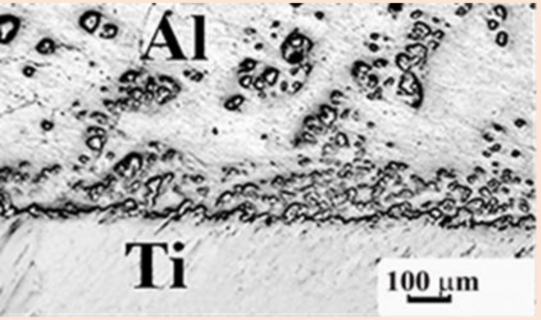
The sintering of the samples at T = 700°C initiates diffusion processes that form layers between titanium and aluminum plates, which provides a relatively strong bond between the plates. Depending on the sintering time, aluminum may not be completely consumed.

At the boundary between the Ti interlayer and the two-phase area, a diffusion region providing a strong bond between the layers is observed. Two phases are identified in the X-ray spectrum of the sample: Ti and Al_3Ti.

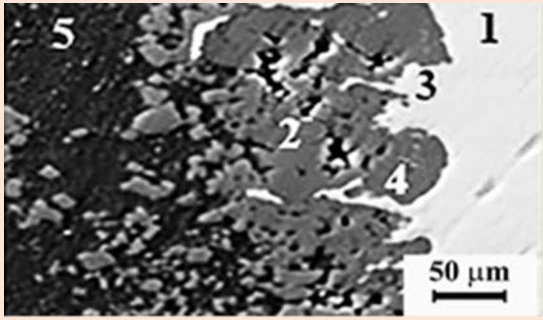
The two-phase area consists of the Al_3Ti phase and pores. In some places between the layers there are gaps, the occurrence of which can be associated with a high sintering temperature.

RESULTS

Investigation of the interaction of titanium and aluminum plates after explosion welding and sintering

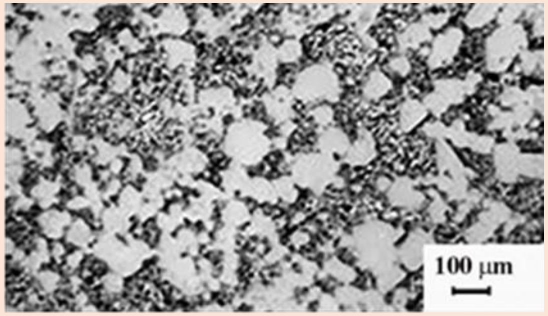


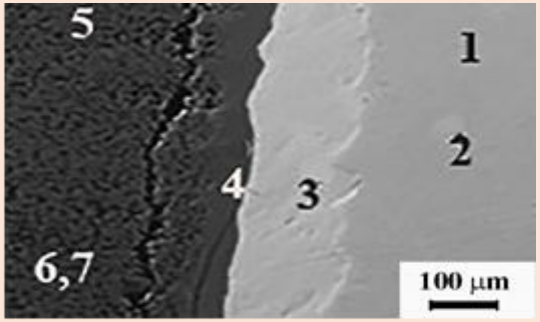
Microstructure of Ti-Al laminate after explosion welding.



Microstructure of the contact area of the laminated composite after sintering at T = 700ºC and 2- hour holding time.

The intermetallic layer formed by the diffusion interaction of Ti with liquid Al is not homogeneous. The numbers indicate the areas in which the chemical composition was determined.
The points 1, 3 are pure titanium,
points 2, 4 are Al_3Ti,
point 5 is Al.
The round particles inside the Al foil are Al_3Ti intermetallide grains surrounded by solidified Al(Ti) melt.





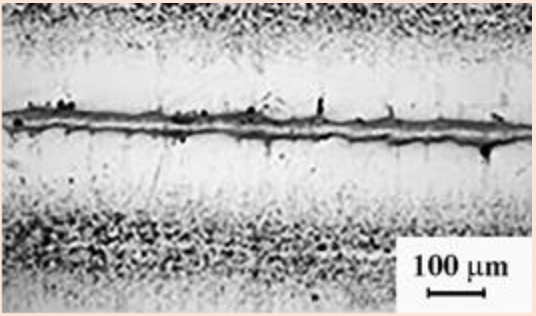
Microstructure of the laminated composite after sintering at T = 700ºC and 4-hour holding time.

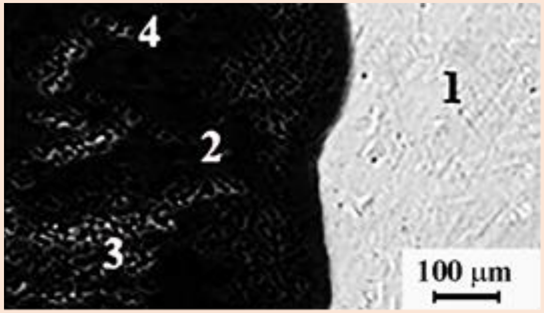
Microstructural studies showed that an increase in the holding time to 4 hours led to the formation of a homogeneous layer of the Al_3Ti intermetallide at the interface with Ti and the occurrence of a two-phase structure in aluminum. The microanalysis determined the content (at%) of the following elements:

1. Al – 0, Ti – 100.0;
2. Al – 0, Ti – 100.0;
3. Al – 0, Ti – 100.0;
4. Al – 75.040, Ti – 25.364;
5. Al – 75.719, Ti – 24.281;
6. Al – 91.580, Ti – 8.420;
7. Al – 92.144; Ti – 7.856.

RESULTS

Investigation of the interaction of titanium and aluminum plates after explosion welding and sintering





The microanalysis determined the content of the following elements (at%):

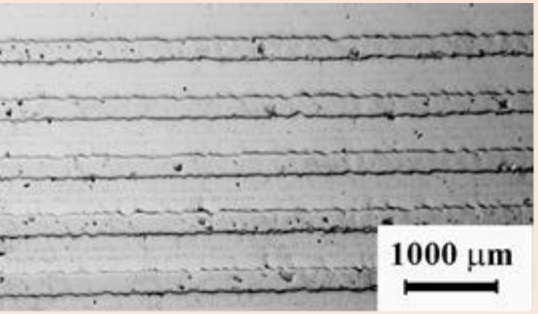
1. Al – 0, Ti – 100.0;
2. Al – 74.573, Ti – 25.427;
3. Al – 67.573, Ti – 32.427;
4. Al – 74.412, Ti – 25.585.

The fragments of the microstructure of a laminate after sintering at T = 700°C for 6 hours. Ti layers (narrow layer) and wide layers of Al_3Ti intermetallide can be seen. Dark narrow areas, which are two-phase regions consisting of Al_3Ti and solidified Al(Ti) melt are visible in all intermetallic interlayers in the central part. These areas are characterized by greater porosity.

A homogeneous laminated sample consisting, according to the data of X-ray spectral and X-ray diffraction analyzes, of alternating layers of Ti and intermetallic Al_3Ti was obtained increasing the holding time to 8 hours.

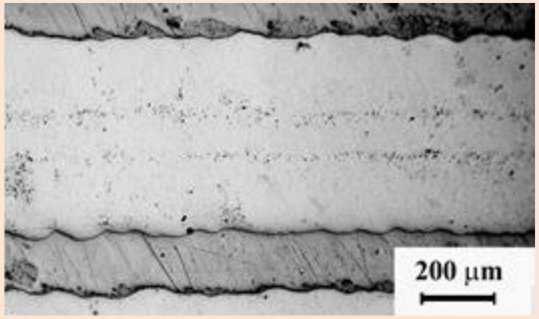
RESULTS

Investigation of the interaction of laminates after reaction sintering under pressure



The microstructure of the sample,

and the contact zone between the layers at a higher magnification.



The microhardness measurement of some layers showed the following:

Dark narrow layer: ~ 141 kg/mm^2;

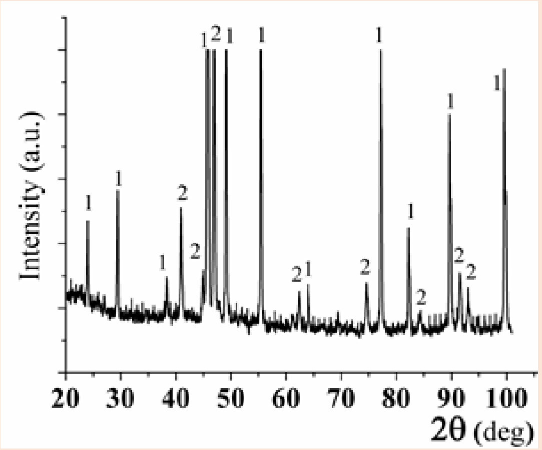
wide light layer: ~ 752 kg/mm^2.

Table values: titanium: 140 - 200 kg/mm^2,

TiAl: 180 - 280 kg/mm^2,

Al_3Ti: 595 - 620 kg/mm^2.

Based on these data, it can be concluded that the dark narrow layer is titanium, and the light wide layer is Al_3Ti intermetallide.



The data of X-ray diffraction analysis (Fig. 10) show that the laminate consists of two phases: titanium and Al3Ti, which is in good agreement with the microhardness measurements.

Based on the experimental results obtained, it was shown that it is possible to obtain a laminate based on titanium aluminide Al_3Ti and Ti by reactive sintering under pressure.

CONCLUSION

In the experiments the desired laminated microstructure was obtained by all four methods. At the same time, the disadvantages inherent in each of these methods were found.

After synthesis in the thermal explosion mode, the intermetallic layers of the samples have high porosity and low strength. There are also problems of mechanical and physico-chemical compatibility of dissimilar materials at the interface between the layers, which leads to the absence of a strong bond between the titanium foil and the synthesized intermetallide.

After reaction sintering, an intermetallic layer has high porosity and low strength, while a region of increased porosity is formed in the middle of the intermetallic layer.

The reaction pressing method partially solves the problem of high porosity in the intermetallic layer, but nevertheless, there are the pores that are unevenly located in the layer, which requires additional improvement of the synthesis modes for metal - intermetallic laminates.

After combined processing by explosion welding and sintering, a central layer of increased porosity is also formed, which reduces the strength characteristics of the composite.

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