Bolesław Formanek[1], **Bożena Szczucka-Lasota**[3]
Politechnika Śląska, ul. Krasińskiego 8, 40-019 Katowice
Lucjan Pająk[2]
Uniwersytet Śląski, ul. Bankowa 12, 40-007 Katowice

STRUCTURE OF POWDERS FROM Ni-Al SYSTEM AND THESE MODIFIED BY CERAMIC PHASES

Microstructure, morphology and phase composition of powders from the Ni-Al system is characterised. Atomisation method of melted Ni-Al alloys was applied for the preparation of the Ni_3Al powders. Powders of NiAl and Ni_2Al_3-NiAl phases and these modified by ceramic phases were prepared in the process of self-propagation, high-temperature synthesis. The structure of NiAl-Al_2O_3 and NiAl-Al_2O_3-AlN composite powders was studied by light and scanning microscopy as well as by X-ray diffraction methods. The selected powders are destined for thermal spraying of coatings.

STRUKTURA PROSZKÓW Z UKŁADU Ni-Al ORAZ ICH MODYFIKACJA FAZAMI CERAMICZNYMI

Przedstawiono wyniki badań składu fazowego i morfologii wybranych proszków z układu Ni-Al. Mieszaniny proszków wyjściowych niklu i aluminium są substratami do wytwarzania materiałów kompozytowych z fazami międzymetalicznymi z wykorzystaniem procesów metalurgii proszków i odlewniczych (tab. 1). Proszki faz międzymetalicznych z układu NiAl wytwarzano metodą rozpylania lub samorozwijającej się syntezy wysokotemperaturowej SHS. Dyfraktogramy syntezowanych proszków, analizowane metodą Toraya, przedstawione na rysunkach 1-4 wykazują pełną zgodność z kartami ASTM. Charakterystyczną morfologię proszków NiAl 70-30 i NiAl 95-5, ujawnioną na mikroskopie skaningowym, przedstawiono na rysunkach 6 i 7. Skład chemiczny wybranych materiałów NiAl określony metodą EDX podano w tabeli 2. Dyfraktogram kompozytowego proszku zawierającego fazy: NiAl, tlenków aluminium i żelazo oraz azotek aluminium charakteryzuje proszek otrzymany w procesie SHS (rys. 5). Złożony skład fazowy proszku wskazuje na potrzebę dopasowania parametrów technologicznych procesu wytwarzania kompozytowych proszków o zadanym składzie fazowym. Wytwarzane proszki są przeznaczone dla procesu natryskiwania cieplnego powłok.

INTRODUCTION

Intermetallic NiAl alloys have potential high temperature structural materials because of their attractive properties such as low density, high melting temperature, high thermal conductivity, very good oxidation and hot corrosion resistance and good mechanical properties [1, 2]. Metallurgy of powders completes the founding methods of intermetallic phases production of nickel and aluminium. It constitutes a technological alternative for a production of materials of high dispersion of reinforcing phases. Examples of results for Ni-Al powders and Ni-Al composite materials produced by selected reaction synthesis process is presented in Table 1.

AIM AND SCOPE OF INVESTIGATIONS

The main aim of present studies was the verification of the technology procedures through the chemical and phase composition analysis of the powders of the phases from Ni-Al system and composite powders of these phases modified by ceramic phases. The preparation of X-ray standards were necessary for a quick phase analysis of synthesized, modified or composite powders with desired intermetallic phases.

For the realisation of the assumed goal of studies the following scope of investigations was chosen:
- powder preparation of intermetallic phases from the Ni-Al system as well as a preparation of composite powders,
- analysis of chemical and phase compositions of the synthesised powders,
- determination of the powders morphology.

MATERIAL AND EXPERIMENTAL PROCEDURE

Powders from Ni-Al system of definite chemical composition were prepared. The method of alloys atomisation and self-developing, high-temperature synthesis were applied for the preparation of these powders. The

[1]dr inż., [2] dr hab., [3] mgr inż.

TABLE 1. **Characteristics of intermetallic NiAl phases formed by reactive processes**
TABELA 1. **Charakterystyka faz NiAl otrzymanych za pomocą reaktywnych metod**

No.	Chemical composition Ni-at% Al	Process	Conditions	Phase composition	Ref.
		SRS	Flaky Ni powder + Al powder		[3]
1	25Al		✓ 0,9 kms^{-1} impact	Ni_3Al, Ni, NiAl,	
2	25Al		✓ 1,37 kms^{-1} impact	NiAl, Ni_2Al_3, Ni_3Al	
3	25Al		✓ 1,60 kms^{-1} impact	NiAl	
4	25Al	SHS	GD - 54%	Ni, Ni_3Al, Al rich NiAl	[4]
5	25Al		GD - 72%	Ni_3Al, Al rich NiAl	
6	25Al		GD - 80%	Ni_3Al	
7	25Al	RI	*T* - 1073 K, *P* - 41 MPa	Ni_3Al	[5]
8	molten Al	PC	55% D Ni perform 50 MPa	NiAl,Ni_3Al	[6]
9	molten Al		66% D Ni perform *T* - 8073 K	Ni_3Al	
10	40Al	HPRS	*T* - 973 K, *P* - 1 GPa	NiAl, Ni_3Al, Ni_2Al_3,	[7]
11	50Al	HPRS	*T* - 1173 K, *P* - 3 GPa	NiAl-Ni_3Al, Ni_2Al_3	
12	50Al + 15÷30 TiB_2		*T* - 1173 K, *P* - 3 GPa	TiB_2 + Ni_3Al + NiAl	
13		RHP	*T* - 1630 K, *P* - 20 GPa	TiB_2 + NiAl+ Ni_3Al Ni_2B, Al_2B, NiT_2,	
14	49Al+15 NiAl+15TiB_2	RS	T - 973, vacuum	NiAl, TiB_2	[8]

SRS shock-inducted reaction synthesis
SHS self-propagating high temperature synthesis
RI reaction infiltration
PC pressure casting
HPRS high-pressure reaction sintering
RHP reaction hot pressing
RS reaction synthesis

studies on Ni_5Al, Ni_3Al, NiAl, Ni_3Al_2-NiAl, NiAl-Al_2O_3, NiAl-Al_2O_3-AlN were performed. The microstructure of etched powder samples was determined by Reichert MF-2 light microscope whereas powders morphology on Hitachi 4200 scanning microscope. The phase composition of powders was analysed from X-ray diffraction patterns taken on Philips diffractometer equipped with copper tube and graphite monochromator on a diffracted beam. The chemical composition of powders was determined by means of the EDX method using the voyager system and the equipment of a scanning microscope.

RESULTS

Toraya procedure [9] of whole powder pattern fitting (WPPF) was applied for testing of the quality of the experimental patterns. Good agreement between experimental and calculated patterns was obtained (Figs 1-4). Moreover Toraya procedure enabled the finding of the second NiAl phase beside Ni_2AL_3 one (Fig. 4).

The complex powder prepared by SHS method is of complex composition and contain NiAl, $NiAL_3$, Al_2O_3, Ni_2Al_3, AlN, FeO phases (Fig. 5). The presents of FeO phase is the results of the high energy mill preparation conditions.

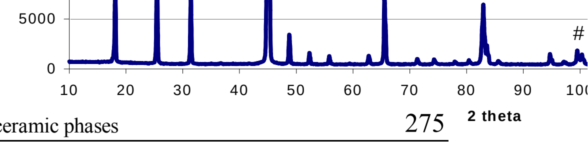
The chemical composition estimated by EDX method and morphology of powders is presented is given in Table 2 and in Figures 6 and 7 respectively.

TABLE 2. **The chemical composition of NiAl powders**
TABELA 2. **Skład chemiczny proszku kompozytowego NiAl**

	Al (wt. %)	Ni (wt. %)
NiAl 70/30*	27.52	69.74
NiAl 95/5	4.64	95.36
* Oxygen - 2.74		

CONCLUSION

Powders of phases from the Ni-Al system have a different morphology depending on their preparation method. A verification of a phase composition of powders from X-ray diffraction patterns indicates that the technological parameters of the powder preparation were correctly chosen. Preparation of composite powders of Ni-Al phases with a definite volume fraction of ceramic phases is connected with obeying of a proper procedure and technological parameters. The selected powders of definite chemical and phase compo-



sitions are destined for spraying of bond coatings or of coatings with intermetallic phases of nickel and higher concentration of aluminium.

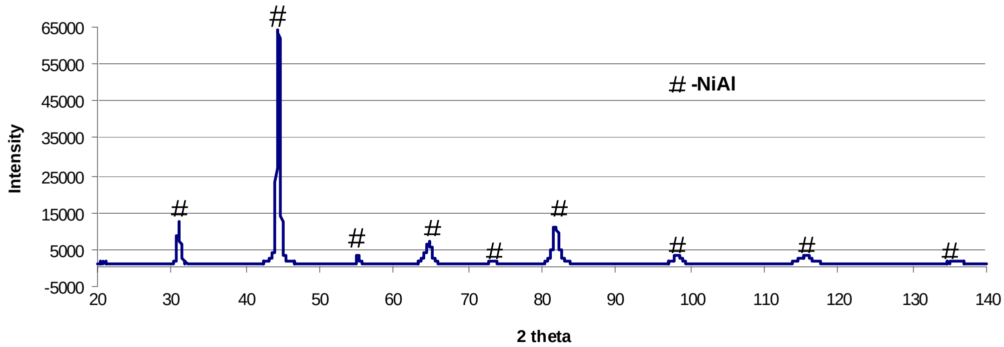


Fig. 1. X-ray diffraction pattern of NiAl 95-5 powder

Rys. 1. Rentgenogram proszku NiAl 95-5

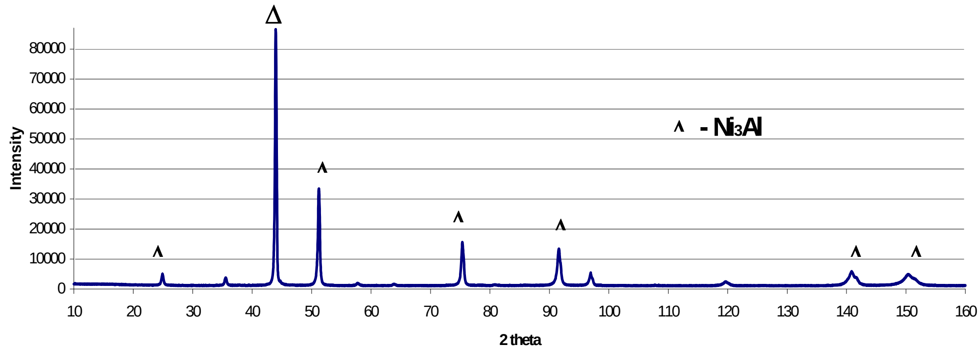


Fig. 2. X-ray diffraction pattern of Ni_3Al powders

Rys. 2. Rentgenogram proszku Ni_3Al

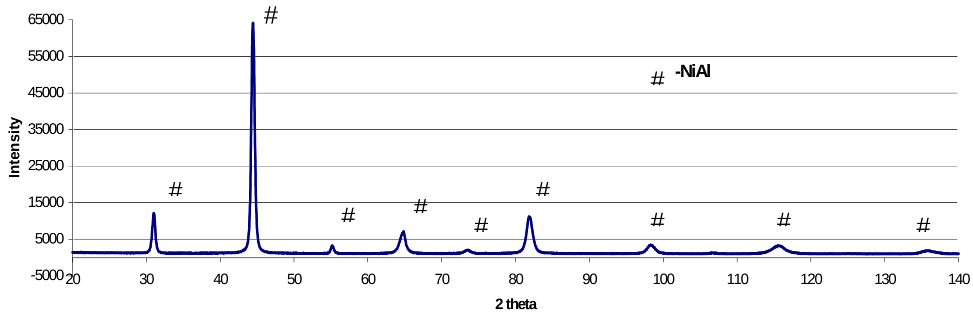


Fig. 3. X-ray diffraction pattern of NiAl powders

Rys. 3. Rentgenogram proszku NiAl

Fig. 4. X-ray diffraction pattern of Ni_2Al_3 powders

Rys. 4. Rentgenogram proszku Ni_2Al_3

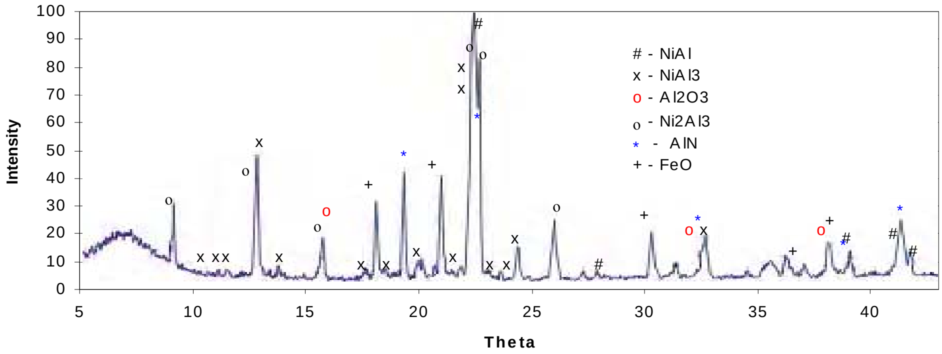


Fig. 5. X-ray diffraction pattern of composite powder

Rys. 5. Rentgenogram proszku kompozytowego

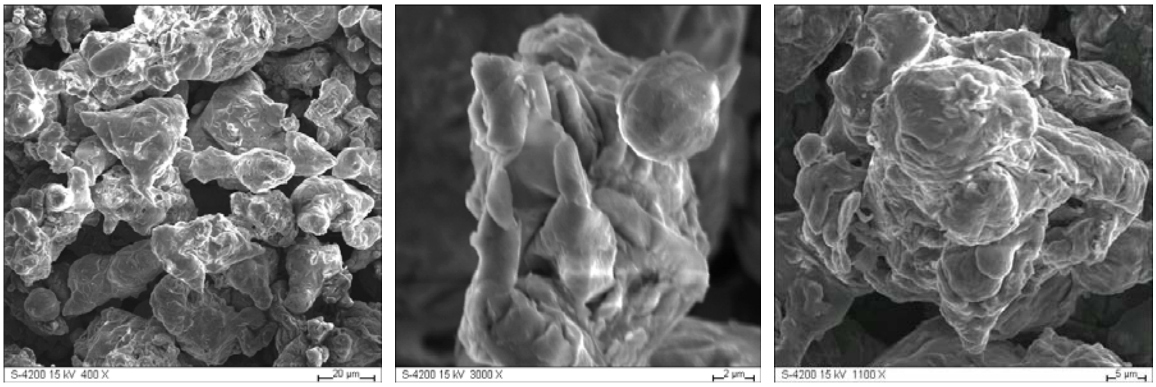


Fig. 6. Morphology of NiAl 70/30 powder

Rys. 6. Morfologia proszku NiAl 70/30

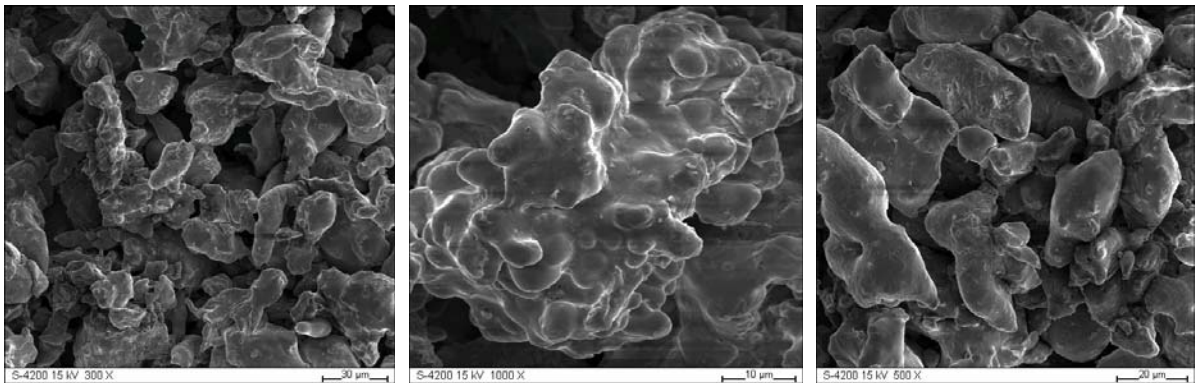


Fig. 7. Morphology of NiAl 95/5 powder

Rys. 7. Morfologia proszku NiAl 95/5

The presented results are a part of investigations financed by KBN (Committee of Scientific Research) in the ordered project no PBZ/KBN-041/T08/12-11.

REFERENCES

[1] Deevi S.C., Sikka V.K., Nickiel and iron aluminides: an overview on properties, processing and applications, Intermetallics 1996, 4, 357-375.

[2] Deevi S.C., Sikka V.K., Liu C.T., Processing, properties and applications of nickiel and iron aluminides, Prog. Mater. Sci. 1997, 42, 177-192.

[3] Song I., Thadhani N.N., Met. Trans. 1992, 23A, 41-48.

[4] Lebrat J.-P., Varma A., Miller A.E., Met. Trans. A 1992, 23A, 69-76.

[5] Nakae H., Fujii H., Nakajima K., Goto A., Mater. Sci. Eng. 1997, A223, 21-28.

[6] Suganuma K., Mater. Letts. 1993, 6, 22-25.

[7] Bhaumik S.K., Divakar C., Rangaraj L., Singh A.K., Mater. Sci. Eng. 1998, A257 (2), 341-348.

[8] Alman D., Stoloff N.S., Int. J. Powd. Metall. 1991, 27, 1, 21-49.

[9] Toraya H., J. Appl. Cryst. 1986, 19, 440-447.

[10] Chaoo H., Nash P., Dollar M., Mechanical properties of NiAl- -AlN-Al_2O_3 Composites, Mater. Scand. Eng. 1997, 239-240, 464-471.

[11] Lin Z.G., Guo J.T., Mechanical alloying of the NiAl(M) system, Mater. Scan. Eng. 1995, 192-193, 577-582.
[12] Rybicki G.C., Smiałek J.I., Oxid. Metals 1989, 34, 275.
[13] Grahle P., Arzt E., Microstructural development in dispersion strengthened NiAl produced by mechanical alloying and secondary recrystalization, Acta Mater. 1997, 5, 1, 201-211.
[14] Chaoo H., Nash P., Dollar M., Processing and fabrication of Advanced material v. TMS, Warrantable 1996, 361.
[15] Chen T., Hampilzian J.M., Thadhani N.N., Synthesis and characterization of mechanically alloyed and shock consolidated nanocrystalisation NiAl intermetallic, Acta Mater. 1999, 47, 8, 2567-2579.
[16] Than W.H., Toughening alumina with nickel aluminide inclusions, J. Eng. Cesam 2000, 500, 20, 895-899.

Recenzent
Stefan Szczepanik