

A NEW FAMILY OF NICKEL POWDER FOR ELECTRICAL ENGINEERING APPLICATIONS

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Very fine nickel powders starting from NiAl intermetallic compound by removing of aluminium from the lattice of NiAl intermetallics using a chemical processing were prepared. Powders with particle sizes up to 1 micron with high specific surface area were obtained. These powders can be used for applications in which a paste or smooth fine coating is needed, for example, in multilayer capacitors. Also, nickel coated graphite particles are employed for electromagnetic shielding. Very fine nickel powders with high surface area can be sintered together to make controlled porous structures for metal filters and electrode applications (batteries, fuel cells).

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1. Introduction

New materials that can be tailored for individual applications are in a constant demand. As the range of uses for powder metallurgy, hard metals and electronic materials expands, customer requirements are causing materials companies to come up with new products that have the required properties. Several methods can be used to obtain very fine nickel powders. Chemical routes are the most indicated and usually, the carbonyl process is applied at industry level due to its versatility in the obtaining of some fine nickel powders with spherical, cubic and filamentary shapes. Nickel can bring a number of benefits to these and other industries. It can improve the mechanical and fatigue properties of alloy steels, enhances conductivity and magnetic properties of electronic materials, improves the interface activities in the electrode processes and allows high rates of charge-discharge in batteries.

The nickel powders with high specific surface area are the goal of our researches. In the experiments, nonstoichiometric Ni 35 at% Al 65 at% intermetallic compound materials were prepared and subject to chemical processing.

2. Experiments

The experiments were performed in order to obtain the aluminium rich NiAl intermetallic compound. In this connection, the elemental Ni and Al powders were mixed together. The grain sizes of the starting used powders were: situated in the range 45 -100 μm for the aluminium powder and $< 10 \mu\text{m}$ for the Ni powder. The wet homogenization was adopted by using 1 ml – 2% polyvinilic alcohol solution for 100 g of mixtures. The uni-axial pressing at 100 – 200 MPa was done to obtain samples with a cylindrical shape having 10 mm in diameter. NiAl intermetallic

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synthesis was conducted in argon atmosphere at 650 °C for 15 minutes. At this temperature, the aluminium powders are in a melt state and, due to their good wetting property enter into the porous structure of the compact sample and, by self propagation high temperature synthesis, react with the solid Ni particles to form NiAl intermetallic compound. [1] During the synthesis reaction of the NiAl aluminide, a high quantity of reaction heat is released, which is used for the total transformation of the reactants (Ni and Al mixture) in reaction products (NiAl intermetallic compound). A schematic presentation of the SHS process can be seen in Fig. 1 [2].

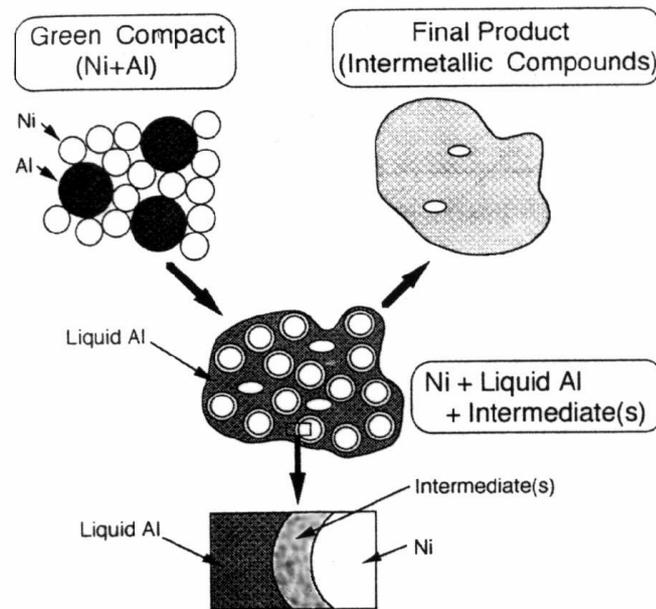


Fig. 1. A schematic presentation of the SHS process.

The resulted NiAl samples were, thereafter, mechanically milled using a mortar in order to get NiAl powder. The obtained powder was chemically processed in 25 % sodium hydroxide solution. After leaching, the remaining powder was dried in vacuum and then annealed in hydrogen [3].

The physico-mechanical and microstructural characterizations were performed in all the technological steps. The microscopical investigation and the identification of the phases in the material were made on samples, which were prepared for metallographical investigations by electrochemical etching (50 % methanol – 50 % HCl solution).

3. Results and discussion

From the macroscopic point of view, all the samples change dramatically their shapes because the synthesis of the NiAl intermetallic phase takes place by the appearance of a very high level of the liquid phase. At the synthesis temperature, the entire quantity of Al powder is melted and although it is quickly absorbed in the porous structure of the material, the quantity of the liquid phase, which appears in the system is too large and produces a significant deformation of the samples.

In the first stage, the identification of the resulted phase was performed by X-ray diffraction. A NiAl phase was observed (Fig. 2).

The microstructural aspect of the processed material (Fig. 3) support the results obtained by X-ray diffraction. The EDAX – analysis evidences two types of NiAl compositions. This aspect

consists in NiAl grains of stoichiometric compositions having at the grain boundaries a nonstoichiometric NiAl intermetallic compound, rich in aluminium.

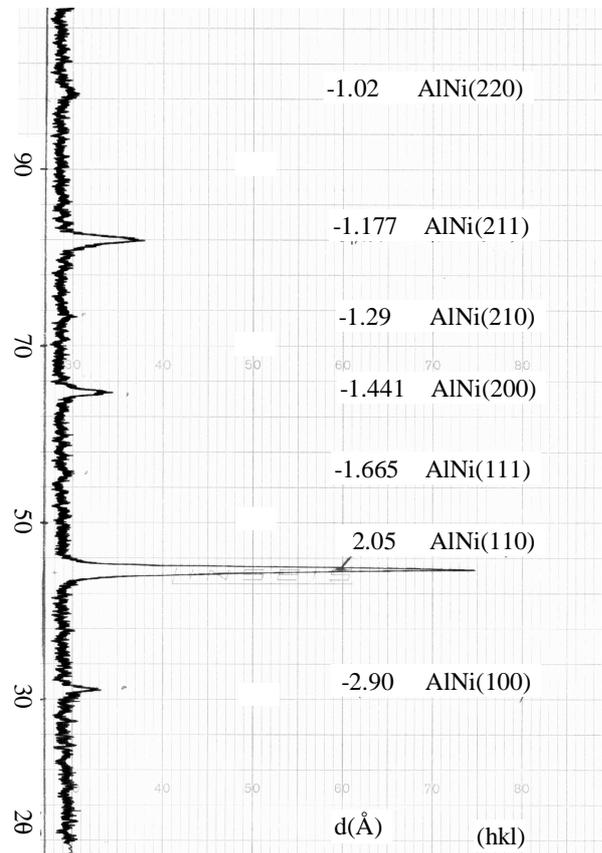


Fig. 2. X-ray diffraction of the NiAl material pattern.

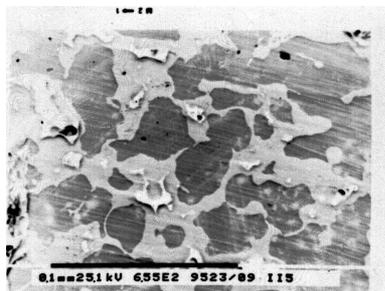


Fig. 3. NiAl material – (x 655) microstructural feature.

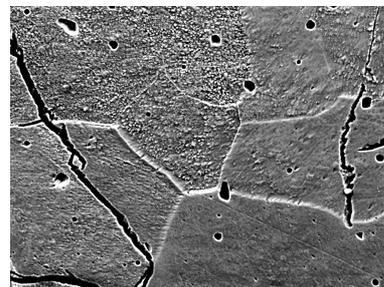


Fig. 4. NiAl powder – (x 500) microstructural feature.

After the mortar and pestle milling of the NiAl samples, the powder microstructure (Fig. 4) shows a further facility for subsequent milling in order to obtain very fine NiAl particles. This is possible, because the NiAl intermetallic compound is very brittle and the SHS processed materials have a high quantity of pores. Two factors act in pore formation. The first, is an extrinsic technological factor generated by the pressing force applied to form green compacts, and by the adsorbed gases at the powder surface; the second is an intrinsic factor generated by the changes of the molar volume from the reactants to the reaction products [4].

The value of the NiAl powder obtained by the pycnometer method (5.854 g/cm^3) is very close to that was reported in other scientific papers [1,2].

After chemical extraction of aluminum from the crystalline lattice of NiAl it was found by X-ray diffraction that the CsCl structure of NiAl intermetallic compound with the lattice parameter of $a_0 = 2.86 \text{ \AA}$ is retained.

As a result of the experiments, the new obtained Ni powder also maintains the pycnometric density value, which is closer to the intermetallic NiAl powder (5.66 g/cm^3) than the Ni carbonyl powder value (7.9 g/cm^3).

The specific surface area values using BET method show that the chemically processed Ni powders have a very high specific surface area ($> 60 \text{ m}^2/\text{g}$), which recommend them for electrical applications, especially for electrode applications. For Ni carbonyl powder the specific surface area was found $0.68 \text{ m}^2/\text{g}$.

The evaluation of the chemisorbtion characteristics by using hydrogen selective adsorbtion method shows that the modified Ni powder exhibits high power of hydrogen adsorption ($600 \mu\text{gH}_2/\text{g}$), which recommend them as catalysts in hydrogen addition reaction.

Table 1 compares the experimental values of Ni carbonyl and those of modified Ni powder.

Table 1. The experimental values of some physical characteristics for modified Ni chemical processed and Ni carbonyl.

Physical characteristic	Ni Carbonyl	Modified Ni
Pycnometric density (g/cm^3)	7.9	5.66
Specific surface area (m^2/g)	0.68	> 50
Crystalline lattice	cfc	cvc
Lattice parameter a_0 (\AA)	3.516	2.86

4. Conclusions

The new family of modified Ni powders obtained by chemical processing enhances the surface/interface properties due to their high specific surface area. The obtained values for these characteristics recommend them in electrical (batteries, fuel cells) and catalyst applications. Taking into account the low density of the new modified Ni powders, the weight of some devices (batteries, anodes) could be decreased. This advantage can be exploited in portable apparatuses.

References

- [1] R. L. Orban, A thermodynamic aproach of some aluminides and aluminide matrix composite by SHS, RoPM'96 Proceedings, p 143-146, Cluj Napoca, Romania, 1996.
- [2] S. Miura, T. Ohashi, Y. Mishima, Amount of liquid phase during reaction synthesis of nickel aluminides, Intermetallics **5** (1997) 45-59 Elsevier Science Limited, 1996.
- [3] C. C. Koch, J. D. Whittenberger, Review of mechanical milling/alloying of intermetallics, Intermetallics **4** (1996) 339-355 Elsevier Science Limited, 1996.
- [4] R. L. Orban, SHS Processing of advanced materials. An overview, RoPM 96 Proceedings, p. 67-80, Cluj Napoca, Romania 1996.