報告番号	甲 第 13160 号

主 論 文 の 要 旨

論文題目 **Development of Ni-Al intermetallic compounds with cellular structure by combustion synthesis reaction and space holder method**
(燃焼合成法とスペーサー法を利用したポーラス構造を持つ Ni-Al 金属間化合物の開発)

氏 名 舒 运茂

論 文 内 容 の 要 旨

In this research, manufacturing technology of fabricating porous Ni-Al intermetallic compounds is developed by combining space-holder method with combustion synthesis reaction. The fabricated porous Ni-Al intermetallic compounds possess controllable porous structure, good fluid permeability as well as high mechanical strength. As the matrix materials of porous metals, Ni-Al intermetallic compounds also exhibit higher corrosion resistance and higher thermal stability than those of traditional metals. Hence, it is indicating an extensive application prospect of porous Ni-Al intermetallic compounds. The motivation of this research derived from the reflections on the hot issues today such as energy problem and environmental problem. The applications of porous metals highly relate to the fields of catalytic filter (e.g. porous framework), thermal management (e.g. porous wick of Loop Heat Pipe) and electrochemistry (e.g. porous anode), which are tightly knitted with the energy and environmental issues. In recent years, the research on porous metals is expected to promote the developments of the above fields. For this research, there are three specific tasks: 1) Manufacture of the porous Ni-Al intermetallic compounds with hierarchical porous structure; 2) investigating the effects on porous structures of small pores derived from combustion synthesis reaction; 3) investigating the mechanical property and fluid permeability of the fabricated porous Ni-Al intermetallic compounds.

In chapter 1, the backup and purpose were mainly introduced. The fluid permeability which are significantly impacting the functional properties have become the hot topics, and also a number of manufacturing technologies such as sintering method, slurry method and investment cast method are reported. However, the space holder method has attracted intense attention recent years due to the highly controllable porous structure, simple procedure and low cost. Furthermore, the porous metals fabricated by the space holder method have not presented a satisfactory fluid permeability yet. In other word, there was still no manufacturing technology that could fabricate highly controllable porous structure with ideal fluid permeability. Therefore, the goal of this research is clear that developing a manufacturing technology of porous metals with both highly controllable porous structure and high fluid permeability. In this research, space-holder method was utilized due to the excellent porous structural controllability. On the basis of space-holder method, combustion synthesis reaction was brought for generating small pores between the large pores fabricated by space-holder method to achieve the high fluid permeability simultaneously.

In chapter 2, the combination of space-holder method and combustion synthesis reaction between Ni and Al was carried out, and porous Ni-Al intermetallic compounds with hierarchical porous structure were successfully fabricated. This hierarchical porous structure was composed of small-scale pores derived from combustion synthesis reaction (between Ni and Al) and large-scale pores derived from space holders (NaCl particles) method. Small-scale pores derived from combustion synthesis reaction in metallic cell walls could not be formed without adding NaCl (space holder). This is because the melt caused by high reaction temperature which is positively related to the adiabatic temperature of combustion synthesis reaction exists during the process. It is suggesting that the NaCl particles are used not only for generating the large-scale pores but also for absorbing heat from combustion synthesis reaction between Ni and Al to avoid melt during reaction, thereby forming small-scale pores in metallic walls. Hence, the necessity of combining space-holder method with combustion synthesis reaction for generating this hierarchical porous structure was also proved in this chapter.

In chapter 3, the effects of NaCl addition and Ni:Al molar ratio on porous structure were investigated, and then the strategy of controlling porous structure was acquired. The porous structure of large pores derived from NaCl is simple to control by adjusting the use of NaCl, and then controlling the porous structure of small pores derived from combustion synthesis reaction became the crucial subject in this research. As aforementioned in Chapter 2, NaCl not only affects the large pores derived from NaCl, but also affects the small pores derived from combustion synthesis reaction. The constituting phases and melting of intermediate product just after the reaction occurred are affected by NaCl and the molar ratio of Ni:Al in raw mixture. This is because shrinkage rates of average atomic volume from the mixture of nickel and aluminum to the intermediate Ni-Al intermetallic compounds vary with varying Al content and NaCl addition in raw mixture. As known, different shrinkage rates of metallic cell wall in intermediate Ni-Al intermetallic compounds results in different structures of small pores surrounded by metallic cell walls. In addition, size and porosity of small pores also increase with raising Al content due to the Kirkendall effect. In order to control the porosity and morphology of the pores in cell walls, it is necessary to select appropriate Al content in raw mixture and control the constituting phase just after the reaction occurs.

The mechanical property of porous Ni-Al intermetallic compounds was investigated in chapter 4. The results showed us a significant enhancement on mechanical property through combining space-holder method with combustion synthesis reaction. Comparing to porous Al, the mechanical strength of porous Ni-Al intermetallic compound is increased as well as the corrosion and oxidation resistance at high temperature. Comparing to multiple-phase matrix, the porous Ni-Al intermetallic compounds with single-phase matrix exhibited higher initial yield strength and longer plateau end strain. This is because multiple-phase structure influences the mechanical properties of materials by increasing total interface energy inside the materials, resulting in higher brittleness and lower strength of materials. It is suggesting that higher mechanical strength and stability for applications could be acquired when the matrix materials are single-phase substance. On the basis of the reliable strength, other improvements of porous Ni-Al intermetallic compounds on functional properties are considered to be more meaningful on applications as well.

In chapter 5, the fluid permeability was investigated. In terms of fluid permeability, the poor contact and poor connection between pores result in the low fluid permeability of porous metals fabricated by space holder method. In this research, we improved the contact and connection between pores generated by space holders, thereby improving the fluid permeability significantly. The small pores derived from Ni-Al combustion synthesis reaction were formed in the metallic cell walls, and then contributed to enhancing the contact and connection between the large pores generated by space holders. As a result, the fabricated porous Ni-Al intermetallic compounds possess approximately an order of magnitude higher fluid permeability than the porous metals fabricated by traditional onefold space holder method. And we also revealed that the fluid permeability increases with increasing the porosity of small pores in metallic cell walls.

Taken together, manufacturing technology of fabricating porous Ni-Al intermetallic compounds is developed through the combination of space-holder method and combustion synthesis reaction. This manufacturing technology shows us a possibility to fabricate porous metals which have controllable porous structure, higher fluid permeability and better mechanical properties. Comparing to traditional metallic materials, intermetallic compounds commonly exhibit higher corrosion resistance, higher thermal stability and higher mechanical strength. Moreover, porous metals with bi-scale pores (hierarchical porous structure) are showing a higher fluid permeability than that of porous metals with mono-scale pores. Through this manufacturing technology, the follow strategy of fabricating porous metals with higher permeability and strength was acquired: 1) In the term of matrix metal, intermetallic compounds are superior; 2) in the term of porous structure, hierarchical structure with bi-scale pores is preferred. Since the fabricated porous Ni-Al intermetallic compounds are expected to play decisive roles in a number of fields such as energy and environment, the study on specific applications is imperative to continue in the future.