

Production of Al-Ni-B₄C-Al₂O₃-Si₃N₄ Composite and Investigation of Mechanical Properties

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ABSTRACT: Intermetallic materials such as AlNi, is among advanced technology materials that have outstanding mechanical and physical properties for high temperature applications. Especially creep resistance, low density and high hardness properties stand out in such intermetallics. The microstructure, mechanical properties of (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) powders were investigated using specimens produced by tube furnace sintering at 600-700-800-900-1000-1100-1200°C temperature. A composite consisting of quinary additions, a metallic phase, Al and Ni have been prepared under Nitrogen shroud and then tube furnace sintered. XRD, SEM (Scanning Electron Microscope), were investigated to characterize the properties of the specimens. Experimental results carried out for composition (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) at 1200°C suggest that the best properties as 188,73HV and 6,22g/cm³ density were obtained at 1200°C

KEYWORDS: Sintering, Ceramic powders, high temperature, composite

I. INTRODUCTION

Aluminum matrix composites are using as advanced engineering materials for applications in automotive, aerospace, and other industries [1]. Ceramic particles such as Al₂O₃, Si₃N₄ are the most widely used materials for reinforcement of aluminium. Boron carbide (B₄C) could be an alternative to SiC and Al₂O₃ due to its high hardness. Boron carbide has attractive properties like high strength, low density (2.52 g/cm³), extremely high hardness, good wear resistance and good chemical stability [2]. There has been an increasing interest in composites containing low density [3-5]. Suggested applications for Al-B₄C composites include their use as structural neutron absorber, armor plate materials and as a substrate material for computer hard disks. [6-7].

The purpose of this article is to present the results of an experimental study of the effect of Alumina, Silicon Nitride, Boron Carbide addition on the microstructure and some properties of Ni-Al alloys. Hardness and comprehension behaviour of the as-powder metallurgy (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) alloys would be evaluated with a hope of developing an alloy suitable for industrial application.

II. MATERIALS AND METHODS

Starting powders employed in this study were as follows: the purity of 99.8% for Ni powders with a particle size lower than 40 µm, the purity of 99.95% for Al powders a particle size lower than 75 µm and the purity of 99.9% for Al₂O₃, B₄C and Si₃N₄ powders with a particle size lower than 150µm. The compositions of (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) powders specimens were prepared in 5g cylindrical compressed pre-form. They were mixed homogenously for 24 hours in a mixer following the weighing. The mixture was shaped by single axis cold hydraulic pressing using high strength steel die. A pressure of 300 Bar was used for the compacting all the powder mixtures. The cold pressed samples underwent for a sintering at 600, 700, 800, 900, 1000, 1100 and 1200°C for 2 hours in a traditional tube furnace using Nitrogen gas atmosphere. The specimens were cooled in the furnace after sintering and

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their micro hardness measurements were carried out using METTEST-HT (Vickers) micro hardness tester machine, respectively.

Shimadzu XRD-6000 X-Ray Diffraction analyzer was operated with Cu K alpha radiation at the scanning rate of 2 degree per minute. LEO 1430 VP model Scanning Electron Microscope fitted with Oxford EDX analyzer was used for microstructural and EDX compositional analysis.

The volumetric changes of (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) powders composites material after sintering were calculated by using (d=m/V) formula (Fig. 1). The volume of post-sintered samples was measured with Archimedes principle. All the percentages and ratios are given in weight percent unless stated otherwise. (5)

III. RESULTS AND DISCUSSION

Characterization of specimens

In the study, the samples prepared and shape were sintered at temperatures ranging from 600°C, 700°C, 800°C, 900°C, 1000°C, 1100°C and 1200°C in conventional furnace and made ready for physical, mechanical and metallographic analyses. Density-temperature change curve is shown in Figure 1. The composition of (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) highest sintered density was achieved at 1200°C as 6,22g/cm³.

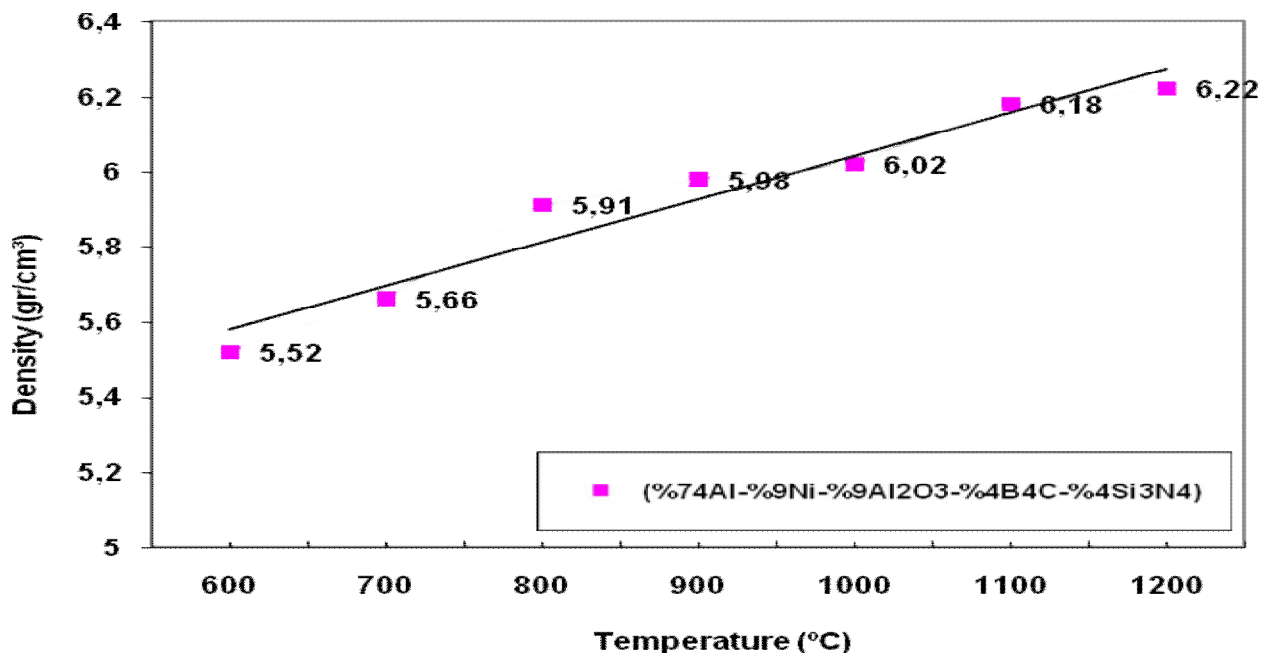


Fig. 1 The density change with respect to sintering temperature

The micro hardness-temperature change diagram is shown in figure 2. The micro hardness values of the composite samples produced using conventional sintering technique within the temperature range 600°C, 700°C, 800°C, 900°C, 1000°C, 1100°C and 1200°C. According to this, the highest micro hardness value in the composite samples of (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) produced using powder metallurgy method was observed to be 188.73HV at 1200°C.

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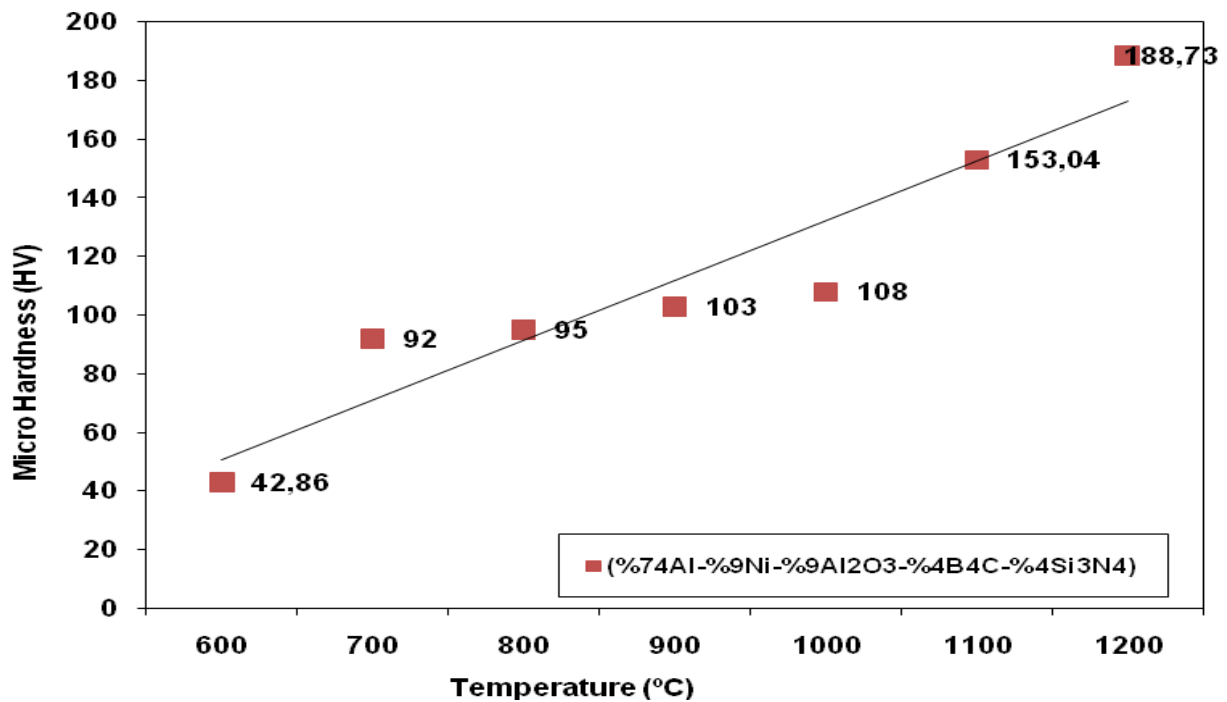


Fig. 2 The micro hardness tests results from sintered specimens treated at different temperatures

Metallographic Analysis

The SEM analysis result of the metal matrix composite specimen obtained (74Al-9Ni-9Al₂O₃-4B₄C-4Si₃N₄) powders sintered at 1200 °C magnification 1kX is shown in Figure 3. grain growth is observed and a homogeneous structure and grain boundaries can be seen that the pores very smaller and different shapes. (74Al-9Ni-9Al₂O₃-4B₄C-4Si₃N₄) powders sintered at 1200 °C is shown In Figure 4, 1200 °C magnification 3kX to become apparent degree of grain boundaries and Sintering is not better understood at (74Al-9Ni-9Al₂O₃-4B₄C-4Si₃N₄) composition at 1200 °C temperature. This density, and hardness values are confirmed.

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Fig. 3 SEM view of (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) composite 1200°C 1kX

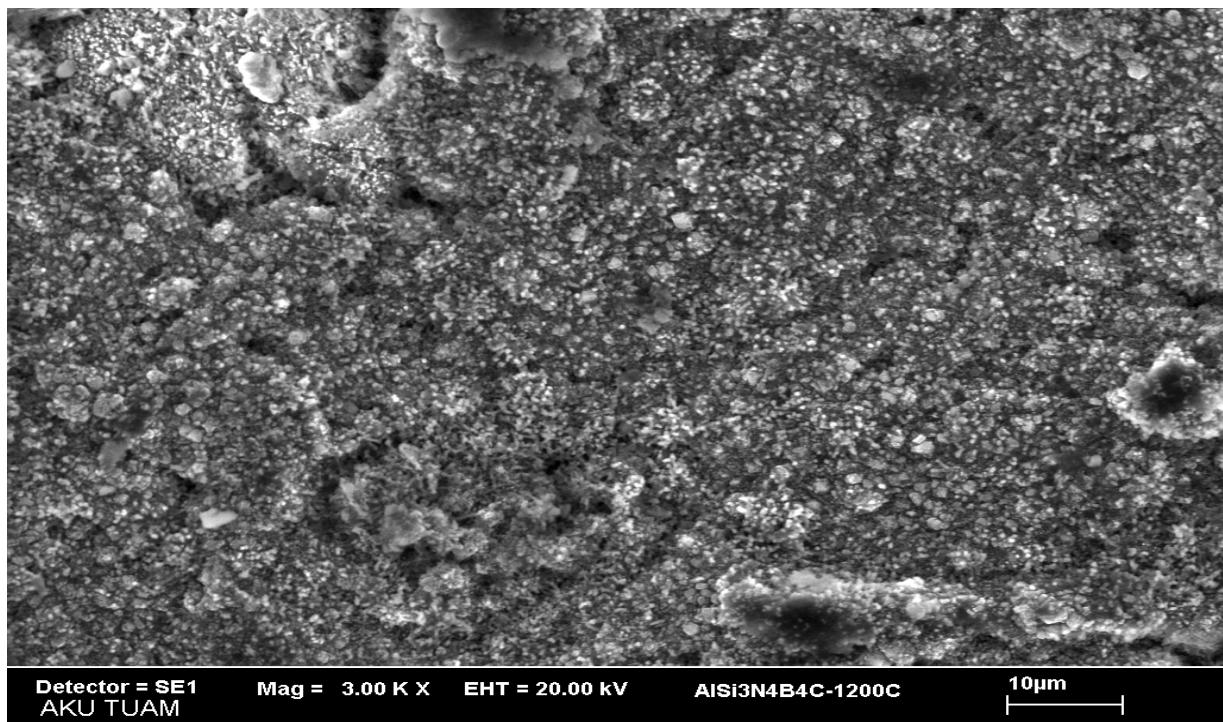


Fig. 4 SEM view of (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) composite 1200°C 3kX

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XRD Analysis

In Figure 7, Al, Al₂O₃, B₄C, Ni, NiAl and Si₃N₄ peaks can be seen in the XRD analysis (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) at 600°C and (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) composite sintered in tube furnace at 1200°C

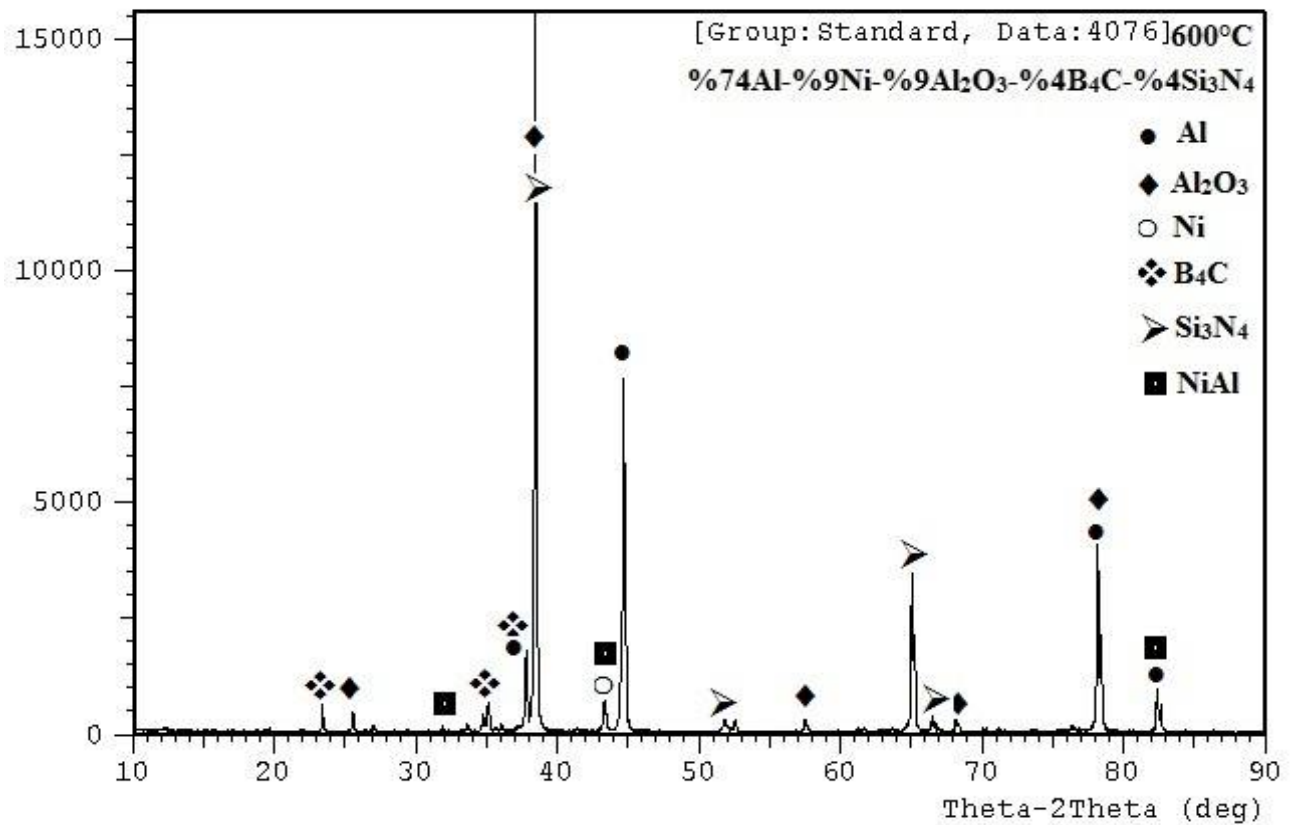


Fig. 5 The XRD analysis (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) composite Sintered in tube furnace at 600°C

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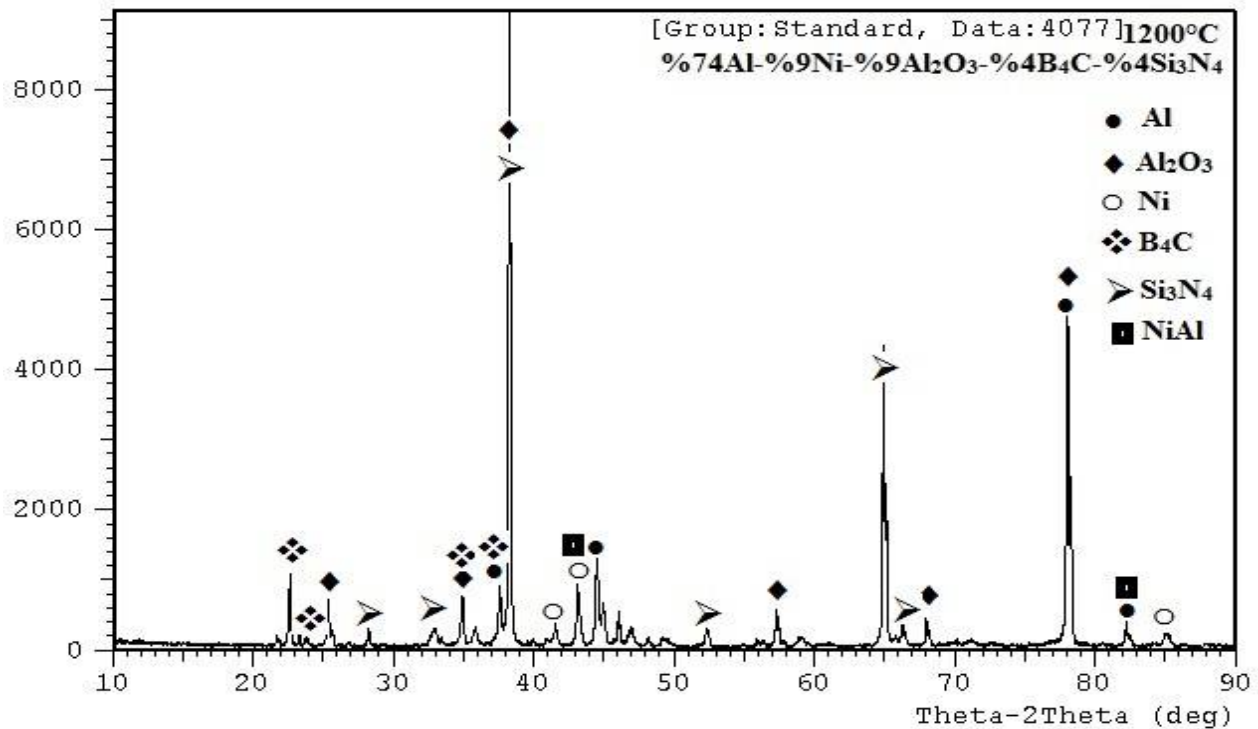


Fig. 6 The XRD analysis (%74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄) composite Sintered in tube furnace at 1200°C

(%74Al-%9Al₂O₃-%4B₄C-%4Si₃N₄) powders were plated %9Ni and then sintered in a conventional furnace within the temperature range 600°C, 700°C, 800°C, 900°C, 1000°C, 1100°C and 1200°C. After sintering, a considerable drop in the mechanical properties of specimens. It was concluded that %74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄ particles were occurred by Al, Al₂O₃, B₄C, Ni, NiAl and Si₃N₄ phases at 1200°C and Hardness test results suggest that %74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄ composite sintered at 1200°C shows Vickers micro hardness values respectively.

IV. CONCLUSION

The following results were concluded from the experimental findings

- The highest density in composite made from %74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄ powders sintered at different temperatures was obtained as 1200°C The highest density sample was found as 6, 22gr/cm³ at 1200°C.
- The highest microhardness in %74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄ composite samples fabricated using powder metallurgy method was found as 188,73HV at 1200°C.
- It was also found out for composition %74Al-%9Ni-%9Al₂O₃-%4B₄C-%4Si₃N₄ at 1200°C suggest that the best properties.

REFERENCES

- [1] R Mazahery A. and Ostadshabani M., Investigation on mechanical properties of nano-Al₂O₃-reinforced aluminum matrix composites, Journal of Composite Materials 45(24) 2579–2586.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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- [2] Mohanty, R.M., Balasubramanian, K., Seshadri, S.K., Boron carbide-reinforced aluminium 1100 matrix composites: fabrication and properties, *Materials science and engineering*, 498(2008), p 42-52.
- [3] Seah, K.H.W., Hemanth, J., Sharma, S.C., Mechanical properties of aluminium/quartz particulate composites cast using metallic and non metallic chills, *Materials and design*, 24(2003), p 87-93
- [4] Belger, M.A., Rohatgi, P.K, Gupta, N., Aluminium composite casting incorporating used and virgin foundry sand as particle reinforcements, solidification processing of metal matrix composites-Rohatgi honorary symposium, TMS Annual Meeting (2006), p 95-104
- [5] Sulaiman, S., Sayuti, M., Samin, R., Mechanical properties of the as cast quartz particulate reinforced LM6 alloy matrix composites, *Journal of materials processing technology*, 201(2008), p 731-735
- [6] Chapman, T.R., Niesz, D.E., Fox, R.T., Fawcett, T., Wear-resistant aluminium-boron-carbide cermets for automotive brake applications, *Wear*, 236(1999), p81-87.
- [7] Blumenthal, W.R., Gray, G.T., Claytor, T.N. Response of aluminium-infiltrated boron carbide cermets to shock wave loading, *Journal of material science*, 29/17(1994), p4567-4576.