

## EFFECT of COPPER PARTICLE SIZE on PROPERTIES of Cu-Al<sub>2</sub>O<sub>3</sub> COMPOSITES

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### Abstract

This study aims to investigate the effects of copper matrix's grain size (10 and 40 μm) and alumina (0.3 μm) reinforcement at ratios of wt. 5 and 7% on the properties of the composites. All samples were sintered at 925°C for 2h in a graphite powder. The relative densities of Cu (10 μm)-Al<sub>2</sub>O<sub>3</sub> samples decreased from 98.8 and 97 % for reinforcements amount of 5 and 7 wt%, respectively. SEM studies revealed that alumina particles were located homogenously between Cu grains. The presence of alumina and copper were confirmed by EDS and XRD analysis. Depending on the amount of alumina, the electrical conductivity of test samples ranged from 58.6 to 44.8 %IACS. There is a little change in the microhardness of test materials with increment in the amount of reinforcement.

### 1 Introduction

Copper has been extensively used because of its high heat and electrical conductivity. However, pure copper has not very well mechanical properties like tensile and yield strength [1,2]. A variety of Cu alloys has been developed for enhancing mechanical properties, but they exhibit a rather large increase of resistance in both electrical and heat conductivity and low time stability at elevated temperatures. Powder metallurgy can give a solution in dispersing particles in the prepared material appropriate characteristics [3]. Incorporating fine ceramic particles as oxides or carbides in copper provides high strength and hardness but causing only a relatively small loss in electrical conductivity. The effectiveness of dispersed particles in matrix strengthening and strength retention depends primarily on particle characteristics: size, distribution, spacing, thermodynamic stability, and low solubility and diffusivity of its constituent elements in the matrix. Among oxide phases, addition alumina to copper matrix is very common. This is because it is cheap with stable properties even up to high temperatures [1]. Copper matrix composites have a wide range of applications because of the combination of high mechanical strength and electrical/thermal conductivity [4]. In the copper-alumina system, the nano-scale Al<sub>2</sub>O<sub>3</sub> particulate dispersion can provide unique characteristics, such as high thermal and electrical conductivities, as well as high strength and excellent resistance to high temperature annealing [5]. Therefore, Cu-based metal matrix composites are being used in many industrial applications such as: contact supports, frictional break parts, electrode materials for lead wires, spot welding, international thermonuclear experimental reactor (ITER), high-heat flux components, e.g. connectors, diverters and first wall, and switch, electric touch top, integrated circuits lead frame [5-7]. The main requirement

for structure of these materials is a homogenous distribution and small size of oxide particles in copper matrix. Many manufacturing processes have been used for producing such composites. In general most metal matrix composites are produced by squeeze or stir casting, spray forming or by powder metallurgy techniques, high energy ball milling and self propagation high temperature synthesis (SHS)[5,8]. Among these methods, powder metallurgy has the advantages of homogeneous mixing of constituent materials which eventually gives good final mechanical properties to the composite with sufficient physical properties [9].

In the present study, the copper matrix was strengthened by adding  $\text{Al}_2\text{O}_3$  particles into the matrix via PM method. The effect of the two different size of starting copper powders and sub-micron sized  $\text{Al}_2\text{O}_3$  powder particles on the properties of the composites such as, matrix strengthening, structure, relative density and electrical conductivity was investigated.

## **2 Experimental Studies**

### *2.1 Test Materials*

In this study, commercial copper powders (purity of 99.9%) with 10 and 40  $\mu\text{m}$  particle size and commercial  $\text{Al}_2\text{O}_3$  powder (purity of 99%) in a particle size of 0.3  $\mu\text{m}$  were used as starting powders.

### *2.2 Preparation of Test Materials*

Copper-alumina composites including 5 and 7 wt.% alumina reinforcements for each copper powder were produced by firstly mixing starting powders followed by compaction in an uniaxial press with a pressure of 200 MPa. Then, this compacts were sintered at 925 °C for 2h in a graphite powder and finally, sintered samples were hot pressed with a pressure of 700 MPa as soon as sintering process finished.

### *2.3 Characterization*

Microstructures of as sintered composite samples were investigated by using SEM microscope. The present phases in the test materials as well as possible other phases formed during sintering, e.g. copper-oxide were determined via XRD analyses technique. Confirmation of XRD analyses and matrix-reinforcement interface examinations were conducted by EDS. The relative density, microhardness and electrical conductivity of the composites were measured by Archimed's Principle, Vickers Indentation and DC electrical conductivity measurement equipment, respectively.

## **3 Results and Discussions**

### *3.1 Microstructure*

Figure 1 shows SEM-BES images of sintered test materials. As it can be seen in Figure 1, the distribution of the reinforcement agent is homogenous and it is located around the copper grains for both composites which have different copper particle sizes. Grey regions indicate copper matrix, while black areas around the copper matrix reflect reinforcement agent,  $\text{Al}_2\text{O}_3$ . From the Figure 1, the difference of morphology between for both composites are being emanated from initial morphology of the copper powders as well as pressure of hot pressing.

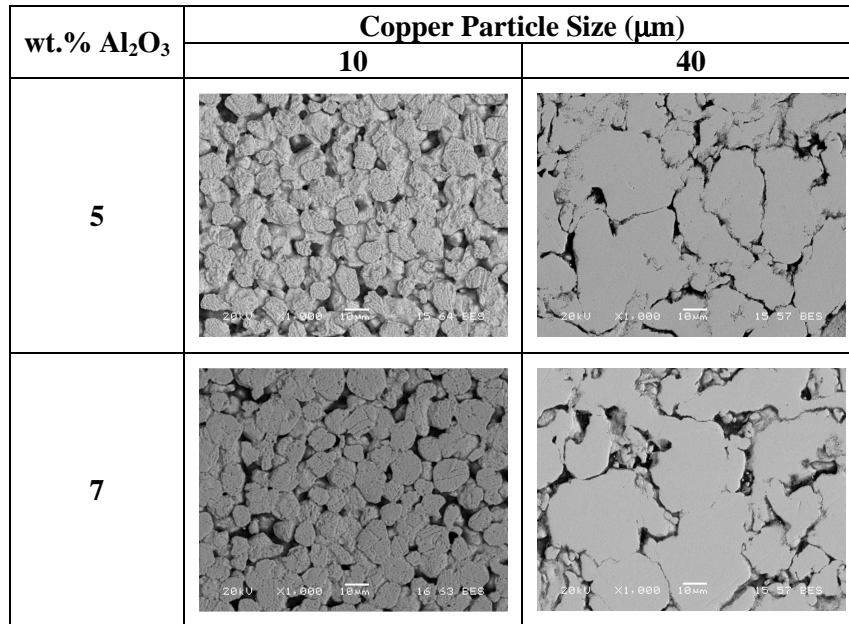


Figure 1. SEM images of composite samples sintered at 925 °C for 2h.

### 3.2 XRD Analyses

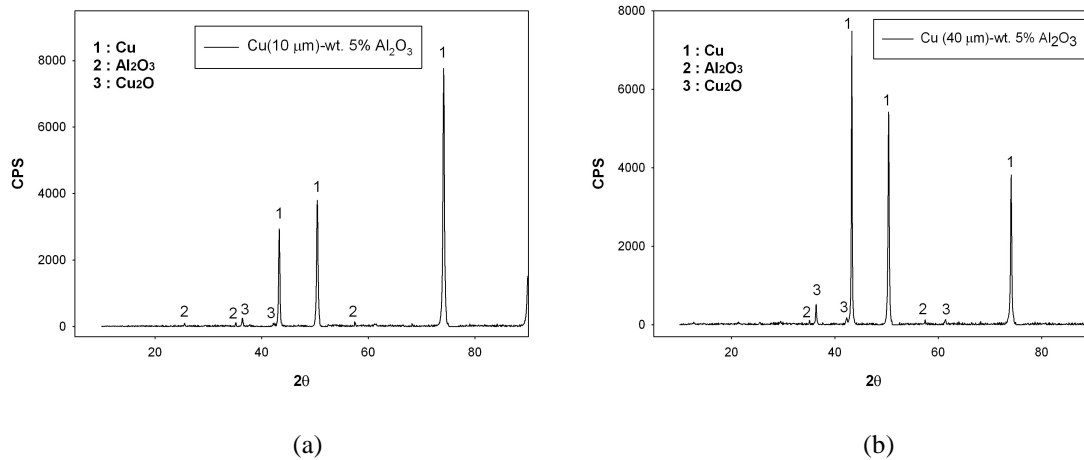
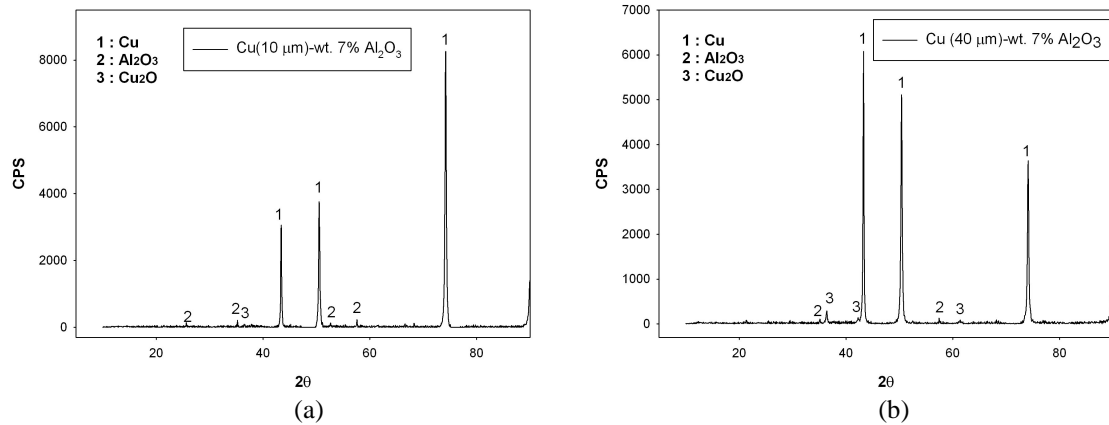


Figure 2. XRD patterns of the test samples: a) Cu (10 μm)-wt.% 5Al<sub>2</sub>O<sub>3</sub> b) Cu (40 μm)-wt.% 5Al<sub>2</sub>O<sub>3</sub>

The presence of phases which confirmed by XRD analyses are given in Figure 2 and 3 for both composites which having different copper particle sizes and ceramic based reinforcement agent. From Figure 2, increment in copper particle size resulted in a little more Cu<sub>2</sub>O phase and Al<sub>2</sub>O<sub>3</sub> peaks are visible in both composites. Similar results have been observed for both composites reinforced with wt. 7% alumina (Fig. 3). Depending on copper particle size alumina, an increment in copper-oxide content was determined, whereas a decreasing in copper-oxide content was found with increasing of the amount of reinforcement. Probably, the reason for this results is originated from different matrix morphology.



**Figure 3.** XRD patterns of the test samples: a) Cu (10 μm)-wt.% 7Al<sub>2</sub>O<sub>3</sub> b) Cu (40 μm)-wt.% 7Al<sub>2</sub>O<sub>3</sub>

### 3.3 SEM-EDS Analyses

The verification of SEM images and XRD analyses results were confirmed by SEM-dot EDS analyses (Figs 4,5). As it can be seen from Figure 4 and 5, grey regions are copper (in Fig. 4: # mark 2 for Cu with 10 μm particle size, # mark 1 for Cu with 40 μm particle size; in Fig. 5: #mark 2 for Cu with 10 μm particle size, # mark 1 for Cu with 40 μm particle size) and dark regions are Al<sub>2</sub>O<sub>3</sub> (in Fig. 4: # mark 5 for Cu with 10 μm particle size, # mark 3 for Cu with 40 μm particle size; in Fig. 5: #mark 1 for Cu with 10 μm particle size, # mark 2 for Cu with 40 μm particle size). A little amount of Cu<sub>2</sub>O which was determined by XRD was also detected and probably, this copper-oxide phase was taken place between copper grains like reinforcement agent because of there is no oxygen element was detected on copper grains except copper-alumina interfaces.

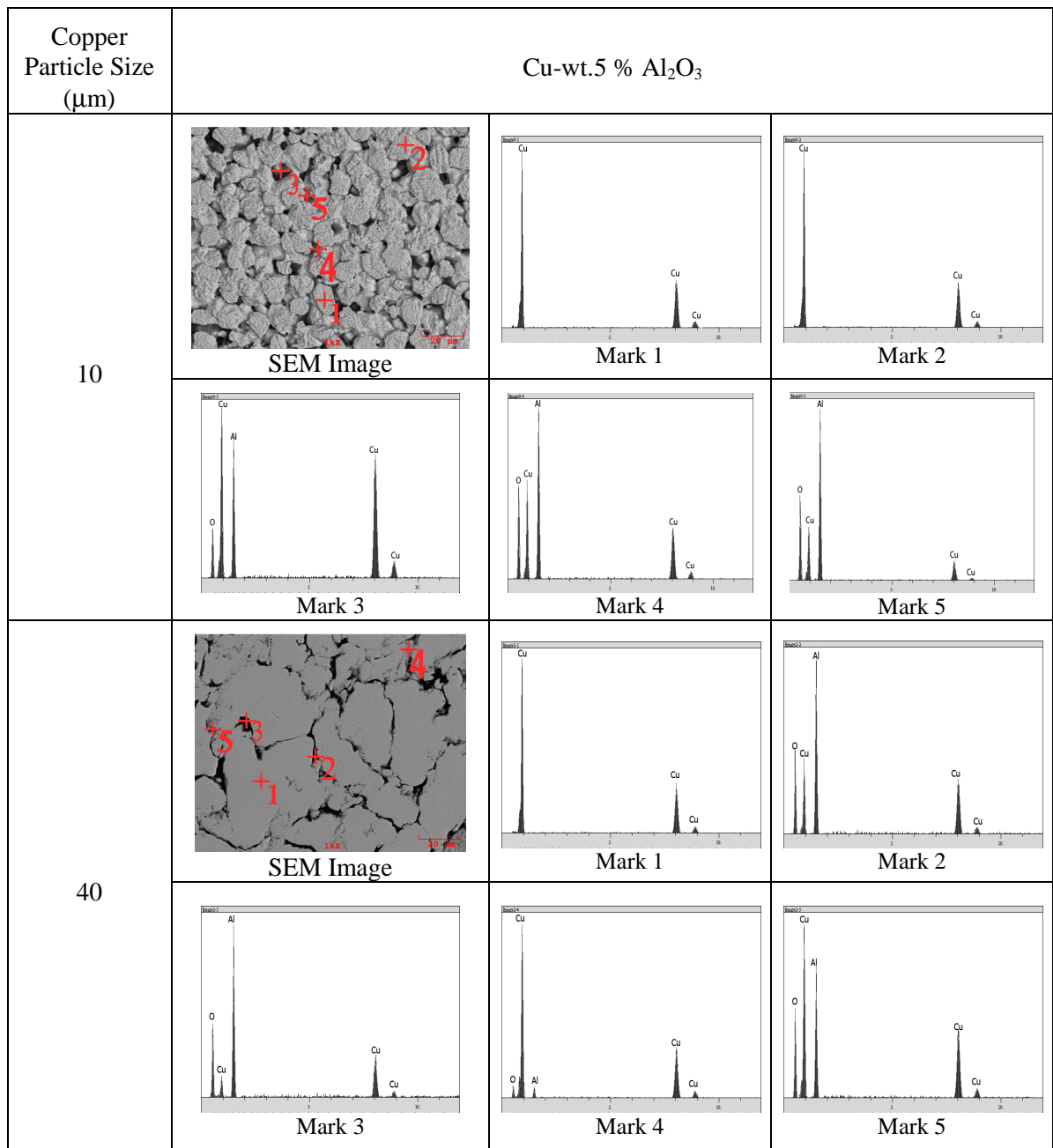


Figure 4. SEM images and EDS spectrums of Cu-wt. 5% Al<sub>2</sub>O<sub>3</sub> samples.

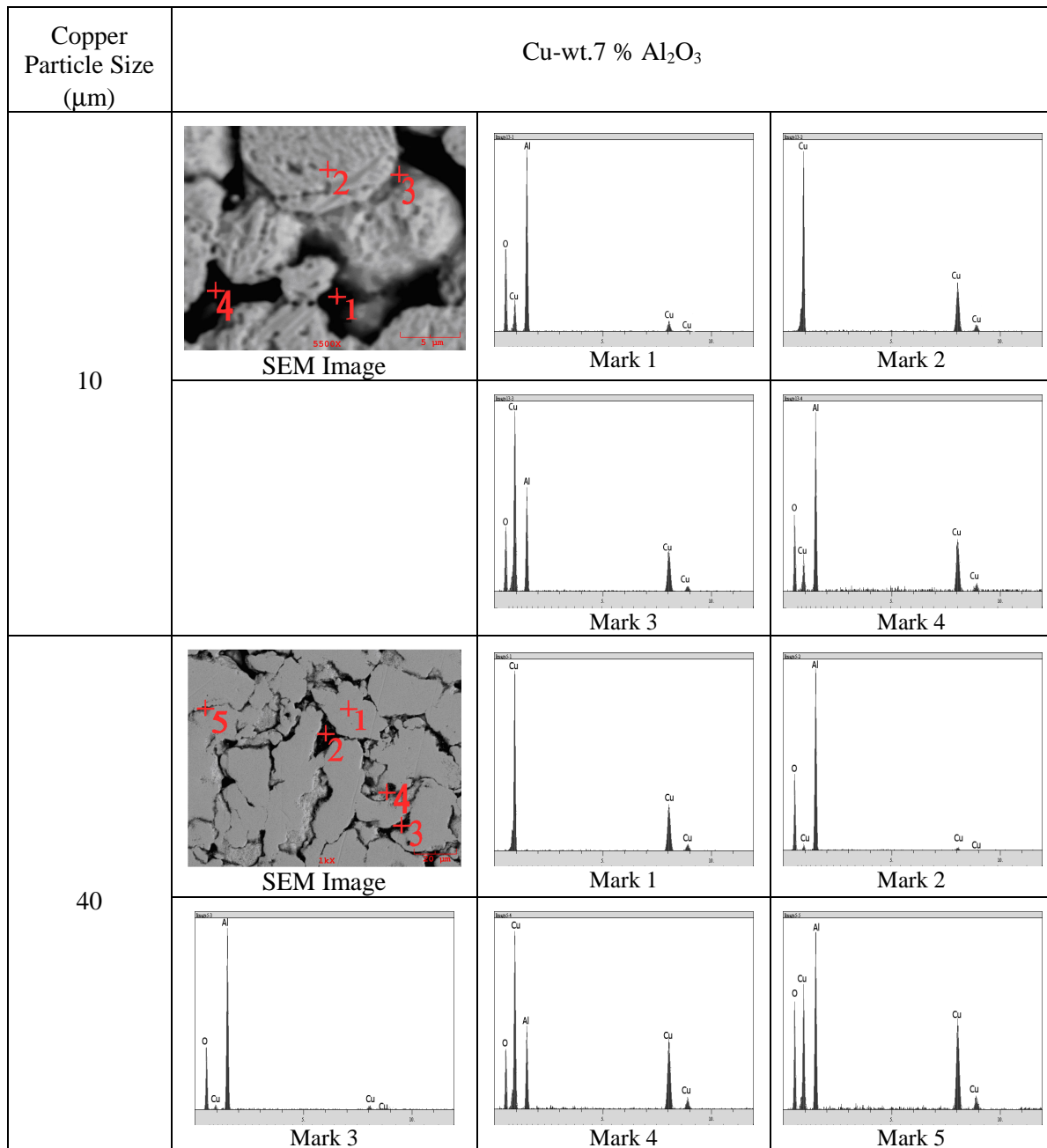


Figure 5. SEM images and EDS spectrums of Cu-wt. 7% Al<sub>2</sub>O<sub>3</sub> samples.

### 3.4 Relative Density, Microhardness and Electrical Conductivity

Table 1 shows the relative density, hardness and electrical conductivity of composites samples . In general, it is possible to claim that physical properties of composite test materials except electrical conductivity increases with increasing of copper particles. It was observed that Cu (40 µm)-wt. 5% composite provided optimum physical properties combination.

Wt.% Al <sub>2</sub> O <sub>3</sub>	Copper Particle Size (μm)					
	10			40		
	Relative Density (%)	Microhardness (HVN)	Electrical Conductivity (% IACS)	Relative Density (%)	Microhardness (HVN)	Electrical Conductivity (% IACS)
5	98.47	132.8	59.91	98.78	156	58.62
7	98.42	139	50.86	97.04	159.4	44.83

**Table 1.** The variation of relative density, microhardness and electrical conductivity of composites as a function of copper particle size and amount of reinforcement agent.

#### 4. Conclusions

The following results can be derived from present study,

- It was found that ceramic based reinforcement agent were homogeneously distributed around the copper grains for both composites with 10 and 40 μm copper particle size.
- XRD results revealed that the dominant phases in both composites are Cu and Al<sub>2</sub>O<sub>3</sub> in addition to small amount of copper-oxide.
- SEM-EDS analyses confirmed the results of SEM and XRD.
- It was observed that optimum conditions were obtained for Cu (40 μm)-wt. 5% composite.

#### References

- Fathy, A., Shehata, F., Abdelhameed, M., Elmahdy, M., *Materials and Design*, 36, pp. 100–107, (2012).
- Ritasalo, R., Liua, X.W., Söderberg, O., Keski-Honkola, A., Pitkänen, V., Hannula, S-P., *Procedia Engineering*, 10, pp. 124-129, (2011).
- Hrizdos, P., Besterci, M., Kulu, P., *High Temp. Mater. Proc.*, 30, pp. 573-577, (2011).
- Bozic, D., Stasic, J., Dimcic, B., Vilotijevic, M., Rajkovic, V., *Bull. Mater. Sci.*, 34, 2, 217-226, (2011).
- Shehata, F., Fathy, A., Abdelhameed, M., Moustafa, S.F., *Materials and Design*, 30, pp. 2756–2762, (2009).
- Ying, D. Y., Zhang, D. L., *Materials Science and Engineering A*, 286, pp. 152-156, (2000).
- Liu, A., Ding, H., Zhou, G., Zhang, G. Y., *Advanced Materials Research*, 311-313, pp. 26-31, (2011).
- Nasiri, H., Vahdети Khaki, J., Zeberjad, S. M., *Journal of Alloys and Compounds*, 509, 17, pp. 5305-5308, (2011).
- Hussain, Z., Keang, K. H., *Jurnal Teknologi Universiti-Teknologi Malaysia*, 43, pp. 1-10, (2005).

