出國報告（出國類別：國際會議）

2017年第六屆材料科學與工程科技國際研討會

服務機關：國防大學理工學院動力系
姓名職稱：少校教師曾有志
派赴國家：韓國
出國期間：106/10/19-106/10/23
報告日期：106/10/21

摘要

2017 年「第六屆材料科學與工程科技國際研討會」(2017 6th International Conference on Material Science and Engineering Technology, ICMSET 2017)，於 106 年 10 月 19 日至 23 日在韓國首爾大學舉行，本人投稿該研討會論文乙篇，論文題目：**鋯對 6061 鋁合金微結構與機械性質之影響**，因榮獲刊登及大會議程邀請於 106 年 10 月 21 日下午 1530-1700 場次進行論文口頭發表，故於 10 月 19 日搭機前往與會。當日該場次會議中，計有來至台灣、馬來西亞、印尼、日本及大陸等 8 篇論文發表，期間發表人均詳細報告其研究成果，報告完後，台下與台上學者討論熱絡，彼此交流受益良多。

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壹、目的：

2017年「第六屆材料科學與工程科技國際研討會」(2017 6th International Conference on Material Science and Engineering Technology, ICMSET 2017)，由主辦單位 University of Maryland 於106年10月20日至22日假韓國首爾大學舉行，該研討會主要探討的主題為：材料行為(Materials behavior)與製程(Materials forming)等新興科技領域，其屬於探討現今材料先進製程技術與應用科技於系統工程應用之國際學術研討會，而本次參與發表之專家學者，計有來至韓國、日本、台灣、馬來西亞、俄羅斯、印尼、越南、加拿大及泰國等各國學者專家，合計發表論文達300餘篇。藉由參加本次國際研討會的互相討論，除了平日鑽研研究與查閱期刊論文所得知識，更能開闊自身眼界，瞭解國際研究趨勢與脈動，因而增進研究動力與方向。此外，本會議所投稿之論文均經由國際相關領域之學者、專家審查，因此一旦獲得大會收錄刊登，亦將大幅增加本院的能見度及學術地位。

貳、過程：

會議議程

Session X, October 21, 2017, Room C: 15:30 – 17:00

Chair: Prof. Dong Nyung Lee

本人發表之論文名稱：

Effects of Zr on the microstructure and mechanical properties of 6061 alloys

作者：

Yu-Chih Tzeng(曾有志)

(Chung Cheng Institute of Technology, National Defense University, ROC)

本次赴韓國首爾大學參加國際研討會，舉辦地點為韓國首爾大學，機票方面則委託旅行社代訂來回機票，住宿則依大會建議住宿於首爾大學附近之飯店住宿四晚，下榻飯店離研討會舉辦會場首爾大學僅有 15 分鐘車程，且首爾大學附近交通便利，故可搭乘捷運或公車即可到達研討會議地點。本國際研討會舉行時間為 106 年 10 月 20 日至 22 日，故由旅行社代訂 10 月 19 日上午 07 時 30 分搭乘中華航空班機赴韓國仁川機場，抵達韓國仁川機場時已逾當地時間 12 時 15 分(台灣時間 11 時 15 分)，辦好出關手續，即自行搭乘仁川機場捷運約 90 分鐘抵達首爾大學捷運車站，步行 10 分鐘後抵達下榻飯店，此時已逾韓國當地時間 16 時，由於會議註冊報到時間為 20 日上午 9 時，而發表之場次為 21 日下午 14 時，故 19 日當天晚上在飯店稍作休息及準備。10 月 20 日當日早上 08 時 30 到達會場首爾大學並順利完成報到手續後，即參加研討會開幕會議與大會專題講演，大會專題講演則邀請美國華盛頓大學 Prof. Ramesh K. Agarwal 教授與美國馬里蘭大學 Prof. Sreeramamurthy Ankem 教授針對現階段國際最先進材料發展趨勢與未來發展進行報告，由本專題講演亦收取最新科研析知，收穫良多。

10 月 21 日則針對各材料領域，安排各研討議程進行研討，本人研討議程為當日下午 1530 開始，本人為第一順位，會議一開始，由會議主持人(Session Chair) Prof. Alan Lin 主持議程並由發表人逐一開始報告，本會議共發表 8 篇論文，分別由菲律賓、印尼、印度、大陸和日本等國之專家學者與流發表，發表人均詳細報告其研究成果，報告完後，會議主持人亦提供時間供在場與會各國專家學者進行提問，由於所研究之領域具相關性，因此台上議題報告專家與台下學者討論熱絡，導致會議主持人為控管時間而打斷討論，也因而會議延遲至下午才結束。本人發表之論文第 1 順位，本人論文發表完後，會議主持人及台下學者均提出適當的見解及寶貴的研究建議，因此對於本次參加國際研討會，使自身眼界更開闊及瞭解國際材料科學研究的趨勢與動向，因此對於未來研究與方向將產生更大的動力。

10 月 22 日則依大會安排至首爾大學校內各相關先進材料實驗室進行參訪與參觀，由本日之行程也深刻體會首爾大學除研究設備先進與教學環境優良外，學術風氣亦非常鼎盛，同學間相互研討實驗數據與結果，令人印象深刻，該校亦發表已多篇研究成果至國際著名期刊，顯見其學術地位不凡；另大會亦安排時程至校園進行參觀，由校園導覽中

亦對其校園環境教學設施、設備留下深刻印象。

本人在本次國際研討會議所發表之論文為 Effects of Zr on the microstructure and mechanical properties of 6061 alloys，論文內容報告摘要如下：本研究探討微量鋯對 6061 鋁合金之微結構與機械性質之影響。結果顯示，添加微量鋯除可細化 6061 鋁合金之晶粒結構，並可有效提升合金 T6 時效熱處理後的硬度與機械性質，且合金經 250℃ 熱暴露試驗後，未添加鋯之 6061 鋁合金，因非平衡合金中非平衡之 Mg_2Si 強化相在熱暴露的過程中會成長粗化成平衡 β-Mg_2Si 相，導致合金的機械強度大幅的下降，而含鋯之 6061 鋁合金則可在 250℃熱暴露過程中析出大量的奈米級 Al_3Zr 相，且此 Al_3Zr 相與基地成整合關係，且可有效阻礙差排的移動與晶界的遷移，進而抑制晶粒在熱暴露過程中所產生的粗化，致使含鋯之 6061 鋁合金在 250℃熱暴露後之機械性質較不含鋯之合金為高，顯示添加鋯可有效提升 6061 鋁合金之機械性質與熱穩定性。

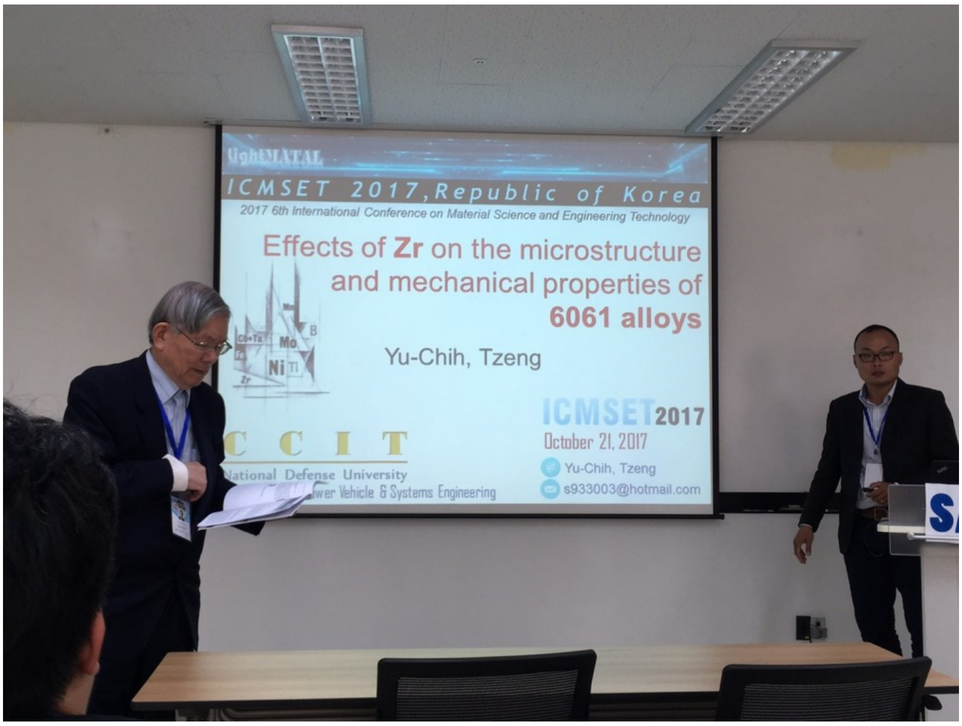
參、心得報告：

本次赴韓國首爾大學參加材料工程國際研討會，不僅可在材料科學學術領域方面，擴張自己研究知識，而在國際觀上，對韓國當地人民的生活習慣及社會工程與科技發展也有新的認識與觀感。在學術領域上藉由本次國際研討會，可以看到各國材料領域之專家學者對於自身所專研之學術研究，除具有一套自身的特殊見解及介紹最新的材料分析技術與學理知識，並也充分表達未來材料工程領域的應用範圍與趨勢，例如:日本學者提出如何利用冷加工方式，來強化現行最新的高熵合金(High-Entropy Alloys)之機械性質，高熵合金(High-Entropy Alloys)是一嶄新的合金設計理念，以多元主成份取代傳統上使用單一主成份的合金設計觀念，由已往研究中發現高熵合金在晶體結構及各種物理或化學性質上，和傳統合金有極大的差異。因此，甚有所感體會到，一篇 EI 或 SCI 研究論文，是經由多少科研人員的研究努力所產生的結果，背後須投注很大的研究心力，雖目前只是研究開發階段尚未真正應用與工程科技，但藉由本研討會可吸收國際新知，了解最新材料科技動態。另外，在國際觀上，因本次研討會在韓國首爾大學舉行，其校園環境優美，校內除課堂教室硬體設備先進外，科研單位之研究室更是使用最優良的檢測設備與儀器，因此才深刻體會為何首爾大學成為世界排名知名的學校。另首爾交通相當便利，因此在研討會期間利用搭乘該地區的各式捷運系統前往會場，沿途景觀可以充分感受到韓國首爾的繁榮與進步，另韓國民族性使然，道路上所看見之車輛，大多為韓國自身製造之車輛品牌，日常生活用品上也大多為韓國自製的品牌，顯見韓國民族性非常愛國，對國家自身製造之商品非常支持。最後，參加國際研討會是一項很有意義的學術活動，也非常感謝科技部研究經費補助，國防大學校院部各級長官的協助，使得此次研討會能順利成行。

肆、參考資料：

圖片為研討會內外場、大會出席證明及會議報告等

研討會海報合影



研討會口頭發表報告

與會議主持人合影

與各國專家學者會後合影

建議事項：

擔任教職或學術研究工作科研人員如能多利用時間與機會多加參加國際學術研討會，除可增進學術交流心得了解最新科學新知，亦可開闊自身之國際觀，利用參加國際學術研討會，使各國除能暸解我們的學術研究成果外，並能在會場上認識各國學者專家，以利拓展自身的學術人脈。學術研究無分國家，參加研討會，會議中藉由各國的學者專家們的互相研討，彼此激勵出火花，對於學術而言也是一項寶貴收穫，因此，在經費有限的情況下，期許能鼓勵擔任教職工作或研究學者們能多利用機會至各國參加自申領域重要之國際研討會，以暸解目前國際學術研究方法與科技，增進台灣與自身學校單位國際之能見度，以提升自身研究學能。最後，感謝科技部研究經費與出國費用的補助，及國防大學校院部各級長官的支持與協助，使得此國際研討會能順利成行。

陸、會議資料：

Effects of Zr on the microstructure and mechanical properties of 6061 alloys

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Keywords: 6061 alloys, Zirconium, Microstructure, Mechanical properties

Abstract. This study discusses how the addition of trace amounts of Zr (0.15 wt%) affect the microstructure and change the mechanical properties of 6061 alloys. The results show that adding a trace amount of Zr can refine the grains thereby enhancing the alloy's hardness and mechanical properties after aging heat treatment. After thermal exposure at 250ºC, alloys without Zr displayed a reduction of mechanical properties because the metastable Mg_2Si strengthening phase grew into the coarse β-Mg_2Si equilibrium phase during the thermal exposure, while the alloys with Zr displayed a plentiful precipitation of the Al_3Zr phase, which effectively hindered the movement of dislocations and thus improved their mechanical properties.

1.Introduction

6061(6xxx series) alloys, 6061 Al alloy which is one of Al–Mg–Si system alloys, have been broadly applied for the production of medium-strength materials for structural design and construction [1]. The 6061 alloy could become the preferred material for vehicle panels and other parts in the lightweight automobile and aerospace industries, because it has medial strength and good corrosion resistance, fatigue strength, and weldability [2]. However, the application of 6061 alloys is currently limited because their properties such as strength, formability, and heat resistance performance are inferior to those of steel alloys. Developments in the automobile and aerospace industries have resulted in a high demand for aluminum alloys that are resistant to heat (over 230ºC) [3,4]. The problem is that the metastable Mg_2Si phase precipitates from the aluminum matrix of the 6061 alloy after heat treatment, converting to the Mg_2Si equilibrium phase very rapidly at working temperatures of over 210ºC [5]. This change results in rapid deterioration of the alloy's mechanical properties making the traditional 6061 alloys unsuitable for structural components for the next-generation vehicles and aerospace technologies. Consequently, efforts are being made for the development of new aluminum alloys with better strength and better heat resistance. It has been reported that the addition Zr can effectively improve the recrystallization temperature, strength, fracture toughness, and stress corrosion resistance of Al–Zn–Mg and

Al–Zn–Mg–Cu alloys [6,7]. However, studies on how Zr affects the microstructure and mechanical properties of 6061 alloys, especially the 6000 series aluminum alloys are scarce.

The 6061 alloys are currently used as structural materials in the vehicle and aerospace industries. However, the traditional 6061 alloys do not possess the required strength and heat resistance of the materials needed for the production of high-end vehicles and aerospace technologies. This current work thus studies the effects of Zr on the microstructure and the mechanical properties of 6061 alloys. The thermal stability is expected to improve after extended thermal exposure as confirmed by examining the change in the alloy's heat resistance performance.

2. Experimental Procedures

Pure aluminum ingots (99.8%) were melted in an electrical resistance furnace at 750ºC. The alloying elements included pure Si, pure Mg, Al–75Mn (wt.%), and a master alloy of Al–60Ti (wt.%) and Al–10Zr (wt.%), which were added in sequence. After adequate agitation and 30 minutes of degasification with pure Ar gas, the melt was poured into a preheated (300 ºC) metallic cylinder mold with dimensions of Ø120 m × 200 mm. The compositions of the alloy ingots was measured by optical emission spectroscopy (OES) (results are listed in Table 1).

Table 1. Chemical compositions of the experimental alloys (wt%).

Alloy	Si	Mg	Fe	Mn	Ti	Zn	Zr	Al
A	0.45	0.82	0.11	0.15	0.03	0.01	-	Bal.
B	0.55	0.80	0.10	0.15	0.03	0.04	0.15	Bal.

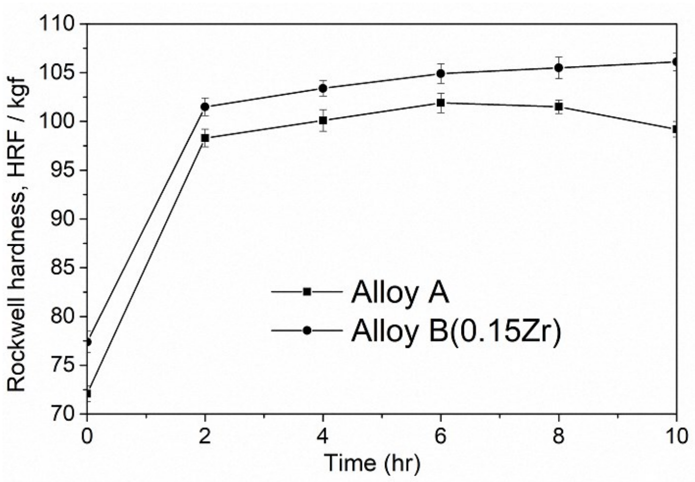
*N.D.:Non-detectable；Bal: balance.

Two different alloys were used for comparison: alloy A, containing no Zr; and alloy B, containing 0.15 wt.% Zr. After homogenization treatment of the cast ingots at 530ºC for 4 hours, they were extruded at 450ºC to form long sticks with a dimension of Ø15 mm, after which they were processed into specimens with dimensions of 20 mm × 13 mm × 13 mm. The alloys were then subjected to a T6 heat treatment. The process started with a solution heat treatment at 530ºC for 2 hours, followed by quenching to the ambient temperature in water and then an 10 hours artificial aging treatment at 170 ºC. Thermal exposure started with the T6 heat treatment, after which the specimens were stored at the ambient temperature for 5 hours before they were subjected to a 100-hour thermal exposure in an air furnace at 250ºC. The mechanical properties of the specimens were tested at the ambient temperature to evaluate the thermal stability of the alloys. A spherical aberration corrected field emission transmission electron microscope (Cs Corrected Field Emission TEM, JEM-ARM200 FTH) were used to observe the microstructure of the alloys, while an energy dispersive spectroscope (EDS) was used for the second phase composition analysis.

3. Results and Discussion

3.1 Effects on the microstructure and mechanical properties during aging

The curve for the age hardening of alloy B(0.15 Zr) with Zr is similar to that of alloy A without Zr (Fig. 1). In the 0–4 hour stage, the hardness of both alloys rapidly improved. The alloy hardness reached a peak after 4 hours of aging. After the hardness of alloy A, which did not contain Zr, reached its peak, it gradually declined with the aging time. However, the hardness of alloy B, which contained Zr, stayed at around 100 HRB. The reason for this result



is that the addition of Zr allowed the refined Al_3Zr phases to precipitate, mainly along the grain boundaries which effectively hindered the movement of the grain boundaries and dislocations, thus significantly improving the alloy hardness.

Figure 1. Changes in the Rockwell hardness of alloys A and B (Zr-containing) with time during artificial aging at 170°C.

Figure. 2 displays the transmission electron microscopy (TEM) micrographs of alloys A and B(0.15Zr) after 10 hours of aging. We can observe that the strengthening β′-Mg_2Si phases are evenly distributed throughout both the alloy matrix, but additional fine Al_3Zr phases can be found in alloy B(0.15Zr).

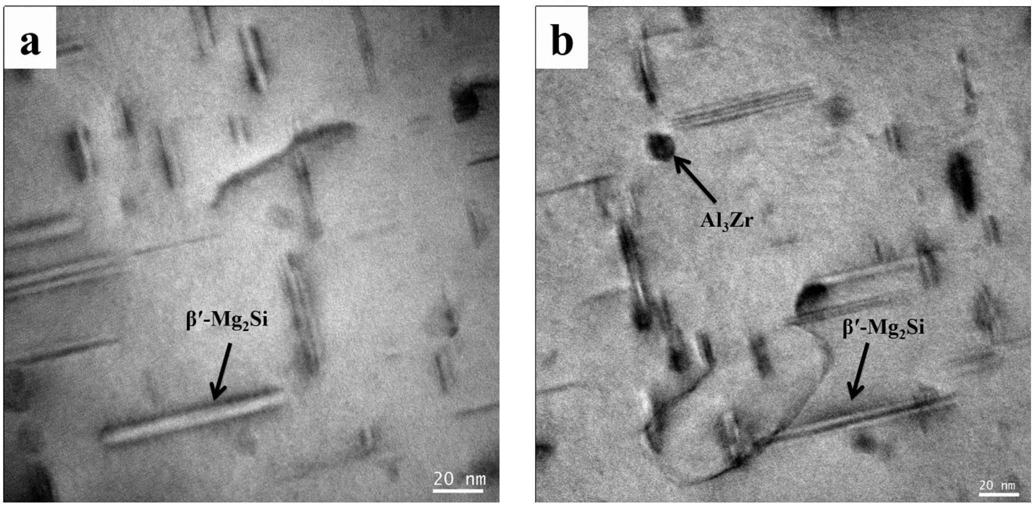
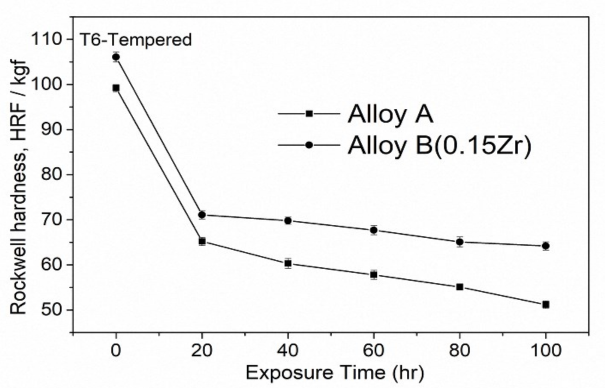


Figure 2. TEM micrographs of the microstructure observed in the T6 heat treated 6061 alloy: (a) alloy A and, (b) alloy B (Zr-containing).

3.2 Thermal exposure test

Figure. 3 shows a mechanical properties graph of alloys A and B (0.15 Zr) after T6 thermal exposure at 250ºC. We can see from the figure that during thermal exposure, both alloys decreased in hardness, with the hardness of alloy B(0.15 Zr) being markedly higher than that of alloy A. This result indicates that alloy B (0.15 Zr) had better heat resistance. The TEM microstructure graph of T6-heat-treated alloys A and B (0.15 Zr) after 50 hours of thermal exposure at 250ºC reveals that the β′-Mg_2Si phase strengthened and coarsened into the stick-shaped β-Mg_2Si phase, which was not integrated to the alloy matrix, resulting in a loss of the strengthening effects on the alloy (as shown in fig. 4). This effect is the main reason for softening of the alloy at high temperature. However, there was a substantial change in the morphology of the refined Al_3Zr phase which did effectively enhance the alloy's heat resistance. In Al_3Zr the movement of dislocations is affected by growth and coarsening of the grains at the grain boundaries. With the application of Zener formula [8], $P_z = 3f\gamma GB/2r$ (r and f are the radius ratio and volume ratio of the dispersoids; γGB is the grain-boundary energy), it can be found that when the precipitates are more refined, the force that drags the grain boundary is larger, thereby hindering the movement of the grain boundaries and enhancing the alloy's hardness. Therefore, adding Zr can significantly improve the thermal stability of the alloy.

a



b

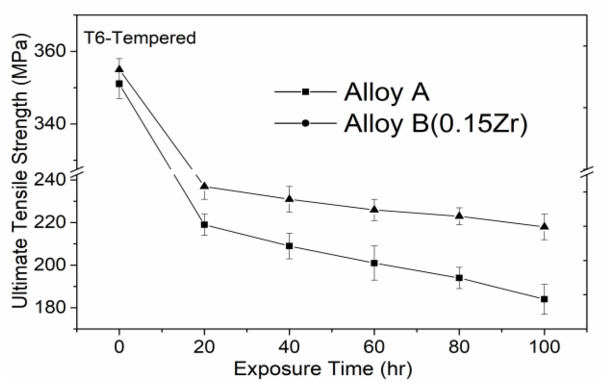


Figure 3. (a)Hardness and (b) ulitimate tensile strength of the T6 heat treated alloys A and B (Zr-containing) after thermal exposure at 250ºC for various times.

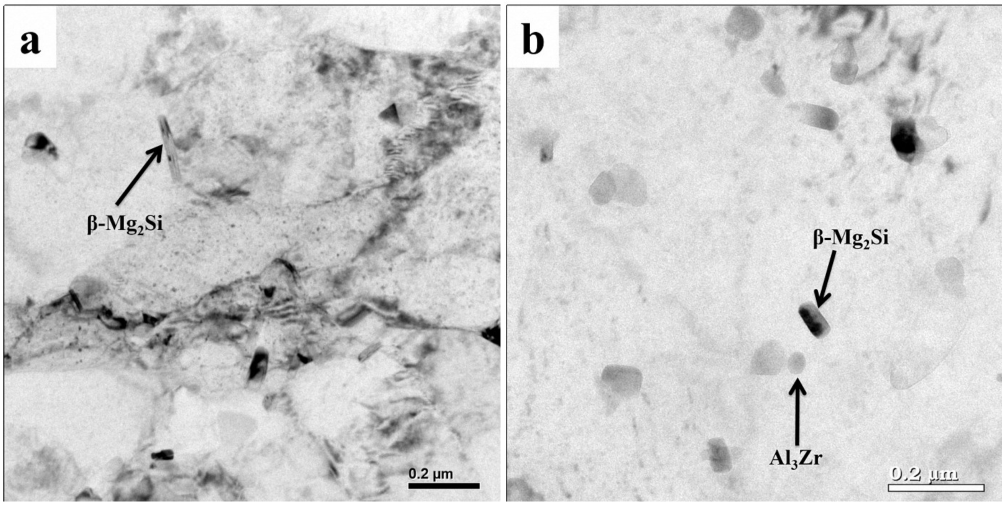


Figure 4. TEM micrographs for the T6 heat treated 6061 alloy after thermal exposure at 250ºC for 50 h: (a) alloy A and, (b) alloy B (Zr-containing).

3.3 Fracture morphology

Figure 5 shows the fracture surfaces of tensile specimens of the alloy A and B (0.15Zr) in the T6 state. The fracture surfaces of the two specimens contained a distribution of dimples. The dimples in alloy A, shown in Figure 5(a), were more coarser with noticeable cleavage planes. A finer dimple distribution was displayed on fracture surface of alloy B(0.15Zr) (Figure 5(b)). Since cleavage represents brittle fracture and dimples ductile fracture, the fracture surface of alloy A, with poorer ductility, showed a mixed rupture mechanism of brittle and ductile fracture. Alloy B (0.15Zr) with better ductility than alloy A, exhibited more ductile fractures.

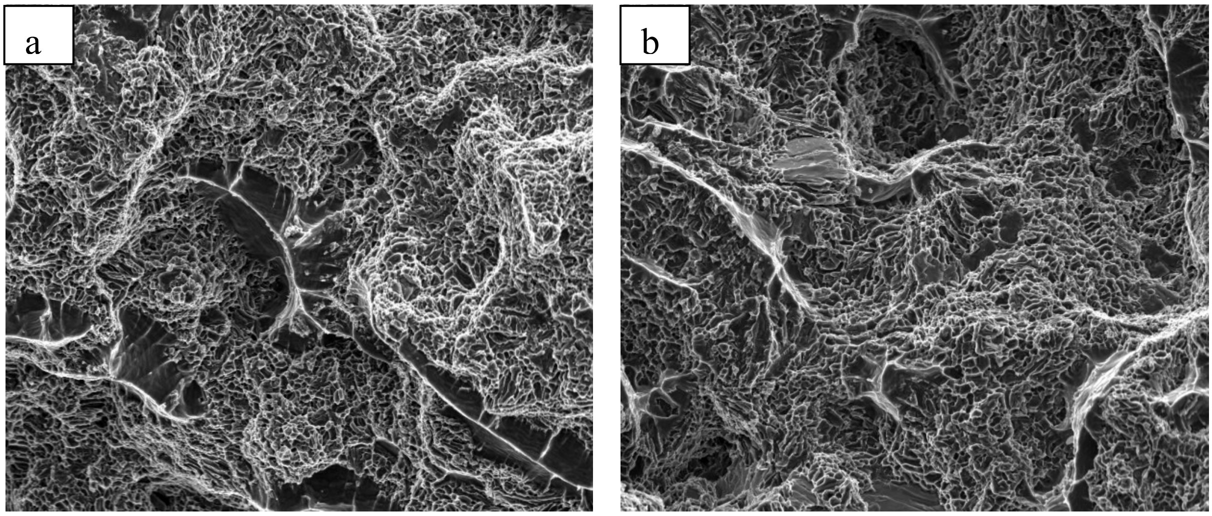


Figure 5. SEM fractographs of the T6–treated tensile specimens: (A) alloy A, and (B) alloy B (Zr-containing).

4. Conclusions

This study explored the effects of adding trace amounts of Zr on the microstructure, mechanical properties, and thermal stability of 6061 alloy. Based on the results obtained and their analysis, the significant findings were drawn:

1. The addition of Zr allowed the formation of a precipitate Al_3Zr phase during aging heat treatment, which enhanced the mechanical properties of the alloy.

2. Thermal exposure resulted in a strengthening of the metastable Mg_2Si phase and the β-Mg_2Si equilibrium phase, which led to a dramatic decline in the alloy's mechanical properties.

3. The addition of a trace amount of Zr led to precipitation of the Al_3Zr phase during thermal exposure, thus hindering the growth of the grains and the movement of the dislocations, which effectively enhanced the thermal stability of the 6061 alloy.

References

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