水平 CVD 單晶成長之不穩定熱流實驗與數值模擬研究（Ⅲ）（子計畫一）
Experimental and Numerical Study of Unstable Flow and Heat Transfer in Horizontal CVD Growth of Single Crystal（Ⅲ）

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一、中文摘要

本子計畫本年度研究共含有兩部分。第一部分以數值模擬探討底部均勻加熱的傾斜扁平管中浮力阻礙之空氣混合對流時空結構。第二部分則以實驗量測與觀測探討扁平管中底部加熱板傾斜而上板水平之空氣混合對流時空結構。實驗結果顯示傾斜管中的 Opposing Buoyancy 會明顯破壞 Mixed，Transverse and Longitudinal Rolls，使其變的極不規律。但底部加熱板向上傾斜則有明顯的穩定流場效果，傾斜角增加，穩定效果越高。

關鍵詞：薄膜單晶、浮力、渦流結構

Abstract

A combined numerical and experimental study was carried out in this project to investigate the effects of opposing buoyancy and the bottom plate inclination on the temporal and spatial vortex structures in a bottom heated flat duct inclined slightly from the horizontal. The results obtained from this study clearly reveal that the mixed, transverse and longitudinal vortex rolls are substantially destablized and destroyed by the opposing buoyancy. The resulting vortex flow is rather irregular . But the tapering of the flat duct by the bottom plate inclination stablizes the flow.

Keywords ： Thin Film Single Crystal, Buoyancy, Vortex Flow

二、計畫緣由與目的：

薄膜單晶為各類 IC 晶片常用的 component 之一，其純度對於晶片長期使用的可靠性，有很大的影響。如何在成長薄膜單晶的製程中(有 Horizontal 及 Vertical CVD 兩種)，改變熱流條件，避免不穩定對流的出現，對於減少薄膜單晶的 Defects 甚為重要。本三年期計畫的主要目的即在先探討水平 CVD 薄膜單晶製程中，由很大浮力所驅動之不穩定混合對流現象及渦流結構，進而探討將管道或加熱面傾斜所造成的浮力改變對浮力驅動流之時空結構的影響，以便找出穩定流場之方法。

三、結果與討論

經由詳細的數值模擬與實驗量測、觀測，我們發現當矩形管傾斜使 Opposing Buoyancy 增加時，渦流的時空結構慢慢被破壞，但當 Transverse Rolls 仍然存在時，其 Convection Speed 及 Oscillation Frequency 有一些受傾斜角的影響。而在 Vortex Flow 之結構已變形的情況，則 Oscillation Frequency 會變小或根本沒有 Frequency Peak 存在。除外，在增加傾斜角時，Longitudinal Rolls 也逐漸變亂。部份的結果簡要的列於表一。而當底部加熱板向上傾斜時，流體速度之增加，會明顯的減

弱渦流強度及穩定流場，部份結果如圖一所示。

四、計畫成果自評

本年度的計畫成果對於傾斜扁平管中三種主要的 Vortex Flow Structures 如何受到 Opposing Buoyancies 之影響，其轉變的時空過程已有詳細了解。另外，我們亦發現底板傾斜對穩定流場有極佳之效果。此對於 Horizorntal CVD Growth of Single Crystal 所面對的流力問題提供了重要的參考資料，進而可能設計出去除這些 Vortex Flow 的反應爐。

五、參考文獻：

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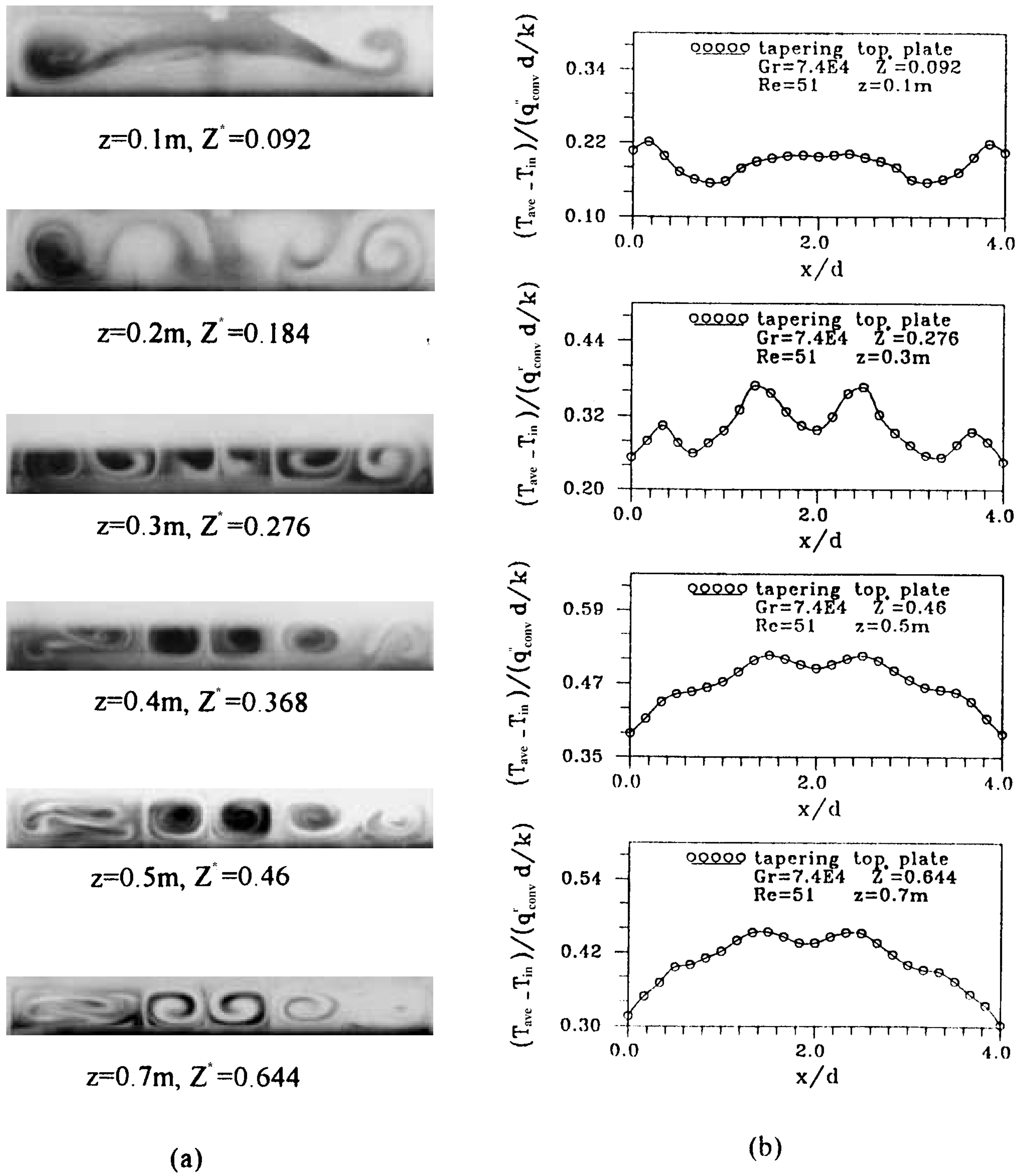
六、圖表：

表一 Summary of some major flow characteristics for Ra=5000 and Re=10 in aiding and opposing mixed convection.

Φ	Flow Condition	Frequency of Transverse Wave	Velocity of Transverse Wave	Wavelength of * Transverse Wave
0°	periodic	f_1=0.512	1.27	2.9
5°	periodic	f_1=0.467	1.16	2.7
7.5°	periodic	f_1=0.24	0.95	2.6
10°	periodic	f_1=0.217	-	-
12.5°	0<z<2.57	0<z<2.57		
	quasi-periodic	f_1=0.111		
	2.57<z<15	f_1=0.033	-	-
	chaotic			
15°	chaotic		-	-
20°	chaotic		-	-
-2.5°	periodic	$f_1$0.52	1.86	3.0
-5°	periodic	f_1=0.55	1.30	2.9
-7.5°	0<z<2.57	0<z<2.57		
	periodic	f_1=0.55		
	2.57<z<15	2.57<z<15	-	-
	quasi-periodic	f_1=0.55		
		f_2=0.027		
-12.5°	0<z<2.57	0z2.57		
	periodic	f_1=0.573		
	2.57<z<15	2.57<z<15	-	-
	quasi-periodic	f_1=0.573		
		f_2=0.088		
-15°	chaotic	-	-	-
-20°	chaotic	-	-	-

* average wavelength of regular transverse rolls at x=6



圖一 Comparison the results for Re=51 and $Gr=7.4\times10^4$ at selected cross sections for (a) the instantaneous flow photos and (b) the time-averaged spanwise temperature distributions for tapering duct.