ABSTRACT

Atomic diffusion is a fundamental process that dictates material science and engineering. Direct visualization of atomic diffusion process in *in situ* ultrahigh vacuum TEM could comprehend the fundamental information about interface dynamics, phase transitions, and different nanostructure growth/migration phenomenon. This thesis is comprised of the *in situ* TEM observations of the electronmigration and electrical properties of nanocrystal-modified Ag NWs, the formation of In_2O_3 hollow nanoparticles/ZnO heterostructure, and the complete replacement of ZnO nanowires by indium.

In situ TEM analyses reveal that electromigration in the twinned Ag NW could be inhibited at the boundaries of twin and stacking fault in the first study. The rate and activation energy of indium atoms diffusing into ZnO nanowires are measured in the second study. The third study demonstrates the replacement processes strongly depend and dominated by the interface dynamics between indium and ZnO. The processes are explained based on thermodynamic evaluation and growth kinetics.

These results present the potential possibilities to increase the lifetime of nanodevices by the nanocrystal-modified Ag NWs, and to completely replace metal-oxide semiconductor with metal nanowire without oxidation and form crystalline metal nanowire with precise epitaxial metal-semiconductor atomic interface. Formation of

such single crystalline metal nanowire without oxidation by diffusion to the metal oxide is unique and it is crucial in nanodevice performances, rather challenging in manufacturing perspective in 1D nanodevices.

摘要

原子擴散是一個基本的現象並廣泛的應用在材料科學以及工程上。在臨場觀察超高真空穿透式電子顯微鏡上直接觀察原子擴散，能夠幫助了解各種基本的異質介面變化、相變化，以及各種不同的奈米結構的成長或遷移的現象。本論文主要以臨場觀察電子顯微鏡技術觀察有奈米微結構的銀奈米線之電遷移現及其電性量測，氧化銦中空奈米顆粒與氧化鋅異質結構的生成，以及氧化鋅奈米線被金屬銦完全取代置換的現象。

在第一組臨場觀察電子顯微術的研究中，觀察到了電遷移會受到雙晶界以及疊差的阻擋；第二組研究中則是得到了銦於氧化鋅奈米線中的擴散速率以及生成氧化銦中空奈米顆粒與氧化鋅奈米線的異質結構；第三組實驗中則是觀察到了取代置換現象與銦和氧化鋅間異質介面的關係。這些現象可由熱力學以及動力學的觀點來解釋。

這些結果顯示了利用具有奈米晶粒的銀奈米線以延長奈米元件壽命的可能，以及利用置換反應製造具有良好磊晶關係的金屬與金屬氧化物異質結構。利用置換反應製造金屬奈米線亦可利用來生產奈米元件。