靜電力對原子力顯微鏡在表面高度量測的影響

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摘要

本論文主要是探討靜電力對頻率調制原子力顯微鏡表面高度量測時所造成的誤差。藉由我們所提出的數值計算，成功地解釋樣品與探針間的靜電力作用。第一章先介紹已被廣泛應用在表面量測的重要工具—原子力顯微鏡，再介紹先前文獻對靜電力造成頻率調制原子力顯微鏡量測誤差之研究。第二章內容是介紹實驗上所使用的儀器與實驗進行時所需的真空度需求，還有說明儀器的操作原理，以及實驗量測時所需的操作技巧與操作順序。第三章說明掃描探針顯微鏡—掃描穿遂顯微鏡與原子力顯微鏡的物理原理。文章內容還包含我們對掃瞄探針與樣品間的靜電力作用的探討，並提出一個數值計算來對樣品與探針間的靜電力作分析。第四章說明利用離子佈植方法在ｎ型半導體矽(100)面上佈植特定區塊的硼離子，使樣品表面同時具有ｎ型與ｐ型的區塊。使用矽探針和鍍上PtIr5的探針掃瞄此樣品，描述當有靜電力作用時在高度量測上所出現的變化，由量測的實驗結果與第三章的數值計算作相互對應，歸結探針與樣品間的作用力。第五章說明利用熱氧化方式在半導體矽(111)面上製造單層的氧化層，表面上部分單層氧化層藉由加熱樣品將所形成的氧化矽氣體脫附掉而露出下層的矽，因此在樣品表面上會有不同的區塊—矽與氧化層。量測此不同的矽與氧化層區塊所造成的影像高度變化，且將此結果與我們在第三章所做的數值計算作比對分析。第六章是將第四章與第五章所做的實驗作回顧與總結，說明當樣品表面同時存在不同材料時，利用頻率調制原子力顯微鏡量測

表面高度時，會受靜電力作用而造成高度量測誤差，誤差的原因與外加在探針的偏壓、探針半徑和探針的導電狀態息息相關。本論文中由靜電力與凡得瓦爾力的關係式來分析探針結構與樣品間的作用力所推導出的計算可以與本論文實驗結果相吻合。

Effect of Electrostatic Forces on the Topographic Height Measurement in Frequency Modulated Atomic Force Microscopy

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Abstract

The objective of this thesis mainly focuses on the discussion of deviation in topographic height measurement measured by the frequency-modulated atomic force microscopy as the electrostatic force is applied or not applied. The effect of electrostatic force between the sample and the tip is explained in an effective manner, based on the simulated calculations. In Chapter 1, it introduces atomic force microscopy as a widely used tool in surface measurement and how electrostatic force effects the deviation in measurement using the frequency-modulated atomic force microscopy during the research. Chapter 2 focuses on the types of instruments used in order to complete the experiments. In addition, the operating principles, techniques, and procedures are organized and elucidated in an orderly fashion. Chapter 3 discusses about the scanning probe microscopy, the physical principle of scanning tunneling microscopy and atomic force microscopy. Furthermore, the chapter discussed in detail the effect of electrostatic force between the scanning probe and the sample. The analysis of such argument is administered based on the simulated calculations. Chapter 4 describes the use of ion-implantation method on n-type semiconductor Si(100) plane for implanting typical boron ions, resulting the p-type and n-type regions on the sample surface

simultaneously. Using Si-tips and PtIr5 coated tips to examine the sample of the p-n region, it illustrates the height variations in the measurement from the effect of the electrostatic force. Base on the analysis, the finding of the experiment reflects to the results of simulated calculations in Chapter 3 as a result of the effect from electrostatic force. In Chapter 5, it demonstrates the use of thermal oxidation method on the Si(111) surface to make an ultra thin oxide layer. Then, by heating parts of the oxide layer, causes the SiO molecular to escape and reveals the Si(111) substrate. As a result, the surface will have different regions of the Si(111) and the silicon oxide layer. We research the height variation of the measurements from the electrostatic force by using Si-tip and PtIr5-tip observing the surface. The results are in good agreement with the calculated results from Chapter 3 and thus, the calculated results validate this research. In Chapter 6, it evaluates and summarizes the results of the experiments from Chapter 4 and Chapter 5. As a conclusion, when different sample distances contain different materials, the surface height measurement of frequency-modulated atomic force microscopy will generate a sizable deviation due to the effect of the electrostatic forces. The height deviations depend on the bias polarity, bias voltage, radius, and conducting state of the tip. The functional relationships are analyzed in terms of the electrostatic and van der Waals interactions between the tip structure and sample. The experimental results are well explained by model calculation.