Chapter 1

Introduction

The discovery of magnetoresistance and oscillatory interlayer exchange coupling in metal multilayer has resulted in enormous increases the magnetic storage capacity by replaced the hard disk head by spin-valve giant mageetoresistance (GMR) based magnetic sensor. A new magnetic device, the magnetic tunneling junction (MTJ) devices, has led to development of an advanced high performance non-volatile magnetic random access memory (MRAM) with density as large as the dynamic random-access memory (DRAM) and read-write speed as fast as the static random-access memory (SRAM) [1-3]. In recent years, the rapid progresses in properties of MTJ have made the dream of "universal memory" more authentic. By replacing the tunneling barrier from amorphous Al_2O_3 to crystalline MgO [4-5], magnetioresistance (MR) ratio of MTJ is increased from 70 % [6] to higher than 300 % [7-9]. However, there are many essentials must be paid attention to for obtaining high performances during mass production processes. One of the factors influences the product properties is thermal stability [10]. To reduce the technology discrepancies, low-temperature process or high thermal stability is needed. Thus, it is an interesting issue worthy to study.

The focus of this dissertation is on improving the thermal stability of magnetic multilayer by using the new material, osmium (Os), as a diffusion barrier and a buffer layer. Besides, the buffer layer use of Os and its growth properties will be also systematically investigated. In this chapter, the motivations and scope of the dissertation are described.

1-1 Motivation

The thermal degrading resulted during the manufacturing process is a key factor to affect the performances of MRAM or other magnetic devices. Although it has been paid attention and noticed for over 20 years, the better resolution has been kept on researching. It is generally believed that the better thermal stability was meant the properties, such as MR ratio or exchange field, could be retained the same value with the as-deposited state or get better after high temperature process. The effects of short time and high temperature thermal treatments are still unknown up to now. In section 4-1-1, the thermal treatments of PtMn-based MTJ systems will be described. Some results of this experiment are worth noticeable and make us to search much better ways to improve the thermal stability of the magnetic devices. On the other hand, in 2002, S. S. P. Parkin et al. [11] suggested that OsMn is an antiferromagnetic (AFM) material with good thermal stability and a MTJ with OsMn as the pinned layer shows the largest MR ratio after 400°C annealing. However, R. Yamauchi et al. say that no γ-phase OsMn, i.e. fcc crystalline structure, is obtainable by quenching [12] and antiferromagnetic property is only appeared at low temperature in β-phase OsMn [13]. The technology how to obtain antiferromagnetic OsMn film was not clear and the real reasons why OsMn showed better thermal stability of MTJ were also unknown. Furthermore, Os is described as a good barrier layer to stop the Cu atoms diffusion in the Damascene process by D. Josell et al. [14]. Thus, it would be interest to study whether the Os can be a candidate to use in magnetic film as a barrier layer. The details of barrier properties of Os will be discussed in section 4-1-2. Besides, the hexagonal close-packed (hcp) Ru metal was reported to be suitable for fcc (111) magnetic film growth [15]. Due to the hcp (0002) plane, which has the same atomic arrangement with fcc (111) plane, has potential to use as the buffer layer for growing fcc (111) magnetic film. Thus, Os, an hcp metal like Ru, has been noticed and been taken as a buffer layer in this dissertation. In section 4-2, the buffer layer use and the epitaxial growth of Os (0002) film will be discussed, respectively.

1-2 Outline of this dissertation

The main part of this dissertation is a discussion of the uses in magnetic film and the epitaxial growth properties of the osmium. Chapter 2 presents the background and papers reviews relevant to the discussion in this dissertation. In this chapter, a summary of the magnetoresistance effects, exchange anisotropy and some common metallic FM/AFM exchanged biased systems, thermal degenerations and some improvements of the MRAM cells, and the general properties and some experimental results of Os were presented. Chapter 3 briefly summarizes the preparing procedures and the sample analysis. The chapter 4 shows the experimental results and discussions. In this chapter, there are two main topics are described. The first part is the magnetic results of magnetic films including of the thermal treatment of PtMn-based MTJ, and adding the Os diffusion barrier into the CoFe/OsMn systems. The second part is focused on the buffer layer use of Os in CoFe/IrMn systems and the growth of 6-fold Os (0002) films on different substrates. Finally, the dissertation is summarized in Chapter 5.