Chapter 8

USE OF PHOTOEMISSION AND RELATED TECHNIQUES TO STUDY DEVICE FABRICATION

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I. INTRODUCTION

This paper will be different from many of the others in this book. Although we share the interest of all the authors in the performance and testing of semiconductor devices, our approach is somewhat different. Rather than concentrating on examining completed devices, our approach is to examine, on a fundamental and atomic basis, the formation of a device structure or even a subcomponent of a device structure. The work was motivated by the realization of two factors: (1) that so many steps in a semiconductor device fabrication had become highly empirical, and (2) new tools have appeared which could be developed to investigate the device components and their fabrication on a detailed (atomic) level which had not been previously available. Rather than writing in the abstract, we will concentrate in this chapter on two major device components—the semiconductor-oxide interface and the Schottky barrier.

The performance of MOS devices, so essential to integrated circuits, can be dominated by states at the interface between the semiconductor and insulator. Electrical measurements can provide information on the position, energy, and density of the states, but can give us little direct information on the physical nature of the defects or impurities which give rise to these levels. In fact, we know precious little about the detailed chemical and physical makeup of the interfaces between the semiconductor and the passivating oxide. If nature is generous, as is the case with the Si-SiO₂ interface, a strictly empirical approach may be the
most reasonable as technology is being built up. However, as the demands of that technology become more and more exacting (in terms of performance, size, reliability, production yield, etc.), the cost of using a purely empirical approach becomes more and more important and the need for more basic knowledge (if only to help guide empirical approaches) becomes increasingly valuable. For example, if basic knowledge can help choose the one or two most promising of a number of empirical approaches, the savings can be very large.

An interestingly different case is that of Schottky barriers in particular and metal-semiconductor contacts in general. Schottky barriers have been in use for about four decades and there is an extensive literature concerning the physics (as well as other aspects) of these devices. However, it has become clear recently that the conventional ideas concerning the mechanism by which the Fermi level of these devices is pinned is definitely incorrect for the 3-5 compound semiconductors and is highly suspect for both compound semiconductors and for silicon. This is a result of studies reported within the past year. As will be discussed in detail later, these studies have lead to new models of Schottky barrier pinning.

In this chapter we will emphasize the work which, in recent years, has begun to give us fundamental insight into both the oxide-semiconductor interface and the Schottky barriers. The theme of this chapter is the use of photoemission spectroscopy, and thus we will place particular emphasis on this technique. However, to give overall perspective we will also mention other critical techniques such as Auger spectroscopy which can be combined with ion sputtering techniques to mill away material to give a chemical analysis as a function of depth into the material (depth profiling). In the last two years these sputtering techniques have reached the stage where, with extreme care, depth resolutions of a very few atomic or molecular layers has been achieved even after milling through as much as 1000 Å of material. For brevity these are usually described as sputter-Auger techniques.

In accord with the outline given above, this chapter will be organized as follows: In Section II we will discuss the physics of photoemission. This chapter will also include a short description of conventional radiation sources. This will be followed by a section (III) in which the new synchrotron radiation sources will be discussed and the unique capabilities they bring to these studies discussed. Next, a short section giving a description of sputter-Auger techniques.

After building this necessary foundation, we will next discuss in Section V the use of synchrotron radiation and allied experimental techniques to study oxide formation on the 3-5 compounds. In that