# CHAPTER I

# INTRODUCTION

The metal-semiconductor contact, often referred as the Schottky barrier, is one of the earliest semiconductor models. Braun (1874) was the first who discovered the asymmetric nature of the electrical conduction between a metal wire point brought in contact with natural semiconductors such as copper and iron sulphide. These point contact rectifiers were used without complete understanding until in 1939, when Schottky (1939) developed the first acceptable theory of the rectification of this devices. He proposed that the barrier region contained a constant density of charged impurities. Such charges would give rise to a potential barrier which is the cause of the asymmetric conduction.

The realization that evaporation of metal films in a high-vacuum system could produce contacts which were much more stable and reproducible than the point contacts cause a great activity in the 1950s and 1960s and laid the foundation for extensive knowledge on this subject. Now, the metal-semiconductor contacts is one of the simplest semiconductor devices used in electronics system.



Copper indium diselenide ($CuInSe_2$) is a promising semiconductor material for efficient polycrystalline thin film solar cells (Wagner et al., 1975; Mickelsen and Chen, 1982; Rockett and Birkmire, 1991). In most of these polycrystalline solar cells, molybdenum is used as a low-cost back (presumably ohmic) contact metal, although formation of a small Schottky barrier with molybdenum had been reported (Russell et al., 1982; Damaskinos et al., 1987; Mitchell and Liu, 1988; Bowron et al., 1991; Raud and Nicolet, 1991). For measuring p-$CuInSe_2$ bulk properties, gold has long been referred to as the best ohmic contact. However, there has not been any systematic study to support such belief.

Ohmic contact at ordinary temperatures and/or low current density may become blocking at a lower temperature and/or at a higher current density(Tantraporn, 1970). Frequently the bulk properties, such as activation energy measurement of impurity levels, are measured at low temperatures. Whether gold can be referred as ohmic contact at such temperatures is questionable. To date, to our knowledge, this question has not been clearly resolved in the literature. This seems to be due to a lack of an appropriate technique.

If Au forms a depletion layer contact with p-$CuInSe_2$,measuring the existence of a Schottky barrier of Au/p-$CuInSe_2$, would not be trivial, for the study of the small barrier needs to be referenced to a reliable back ohmic contact. The traditional techniques, such as C-V and forward I-V are generally not applicable. This is because both techniques need back ohmic contact.

This problem is overcome by the measurement technique that will be described in section 3.2.1. However, most previous works, which will be seen in text, deal with ideal Schottky contacts. This is not the case for practical contacts, including Au /p-$CuInSe_2$ which tends to have a thin insulator layer between metal and the semiconductor. In dealing with contacts which may include a thin insulator layer, a new theoretical analysis is needed.

In addition to Au, Ni was studied in this work because it is referred as a good ohmic contact for p-$CuInSe_2$. Mo was also studied because it is widely used for solar cells back contact.

It is the purpose of this thesis to study a new technique and its ability to solve the problems mentioned above.