CHAPTER I

METALLIC HYDROGEN

1.1 METALLIZATION

Metals are characterized by high electrical conductivity, without a gap between valence band and conduction band, and a large number of electrons in metal, around Avogadro's number, are free to move about, usually one or two per atom [1]. The electrons available to move about are called conduction electrons. The valence electrons of the atom become the conduction electrons of the metal.

In some metals the interaction of the ion cores with the conduction electrons always makes a large contribution to the binding energy, but the characteristic feature of metallic binding is the lowering of the energy of the valence electrons in the metal as compared with that of the free atom.

1.2 HISTORY OF METALLIC HYDROGEN

In 1935 Wigner and his student Huntington predicted the existence of metallic hydrogen. Their calculations showed that, at high pressures, this associated form of hydrogen would conduct electricity. Three decades later, Ashcroft [2] predicted that above a certain density some monatomic form of metallic hydrogen would display high-temperature superconductivity. Yet 60 years after Wigner's original prediction, physicists are still waiting for a conclusive proof that hydrogen can be made to conduct electricity, never mind its superconducting behavior. Fowler of the University of Cambridge suggested that hydrogen would form dense plasma at high enough pressures of more than 25 GPa.

The scientists, especially astronomers, know that the planet Jupiter is largely composed of hydrogen and has a very substantial magnetic field. It is argued that the condition inside the planet must be such that hydrogen forms a highly conducting or metallic state.

Molecular dissociation creates H atoms, under high pressure and temperature, that behave similar to n-type donors in heavily doped semiconductors and undergo a nonmetal-metal transition [3,4]. In addition, a consequence of the large thermal disorder in the fluid ($k_B T \approx 0.2 - 0.3$ eV, where Boltzmann's constant $k_B = 1.38062 \times 10^{-16}\ erg\ K^{-1}$ and T absolute temperature) short-range molecular interactions lead to band tails that extends the band edges into the gap. Then the gap is closed at a lower pressure than in solid phase.

1.3 MEASURING A METALLIZATION OF LIQUID HYDROGEN

Diamond anvil cells are a favored way for reaching high pressures in hydrogen and other samples. In this cell small volume of liquid hydrogen is confined between two pointed diamonds and a metal gasket. The pressure of the liquid is increased by mechanically forcing the diamonds closer together. Weir et al. 1996[5] and Nellis 1997 [6] reported coincidentally the resistivity measurement of H_2 and D_2 at the pressure 140 GPa, the temperature of 3000 K, and the concentration of about 0.7 g cm^{-3}, they found that the resistivity decreases by almost 4 orders of magnitude to the value of 5×10^{-4} Ωcm as shown in Figure 1.1[6]. This resistivity is usually the kind of liquid alkali metals as shown in Figure 1.2[7]. Thus Ziman's theory [8], the electrical conductivity of monovalent metals, can be well used to describe this metal.

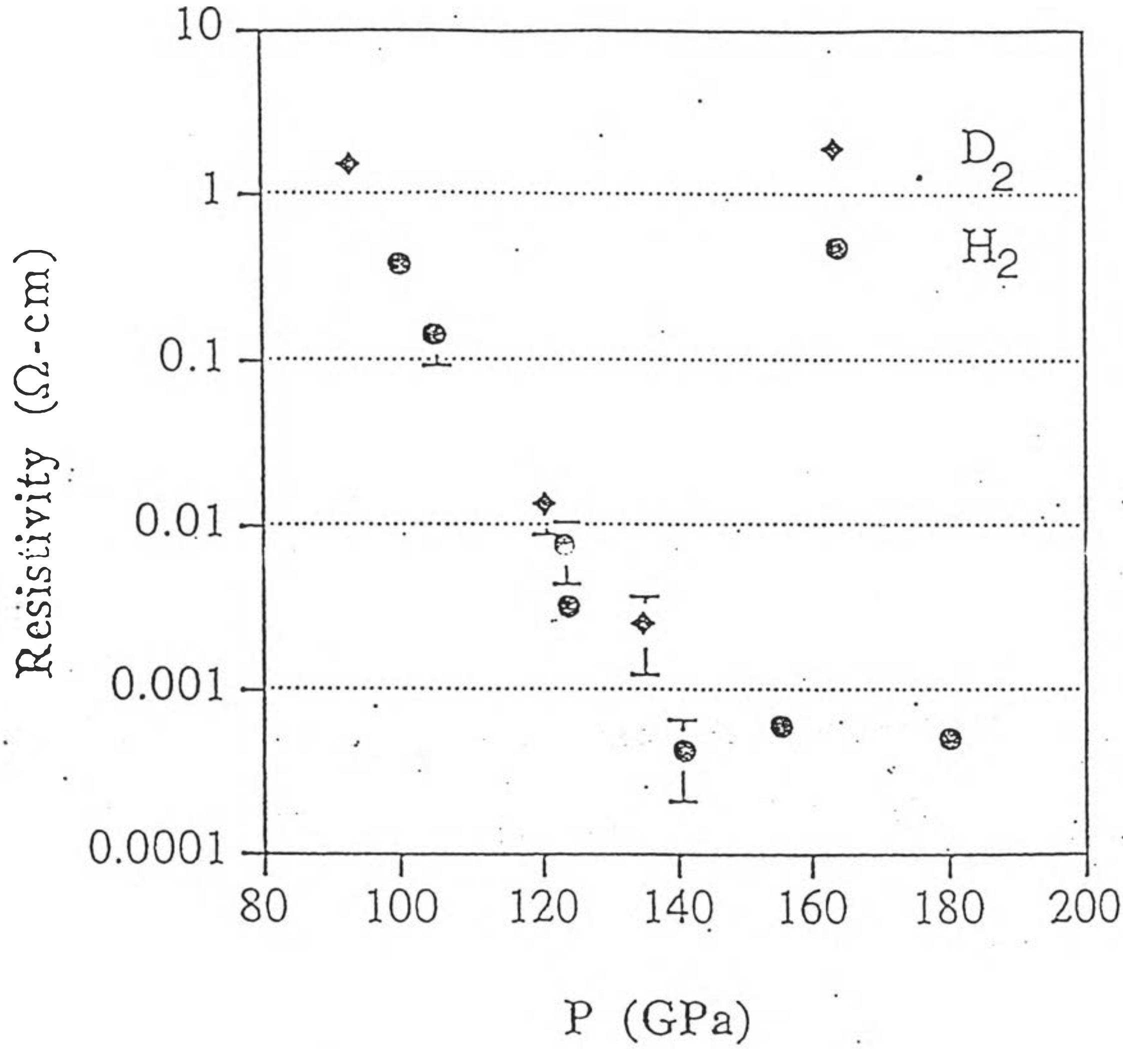

Figure 1.1 The metallic phase of liquid hydrogen has initially occurred at Pressure 140 GPa and temperature 3000 Kelvin taken from [6].

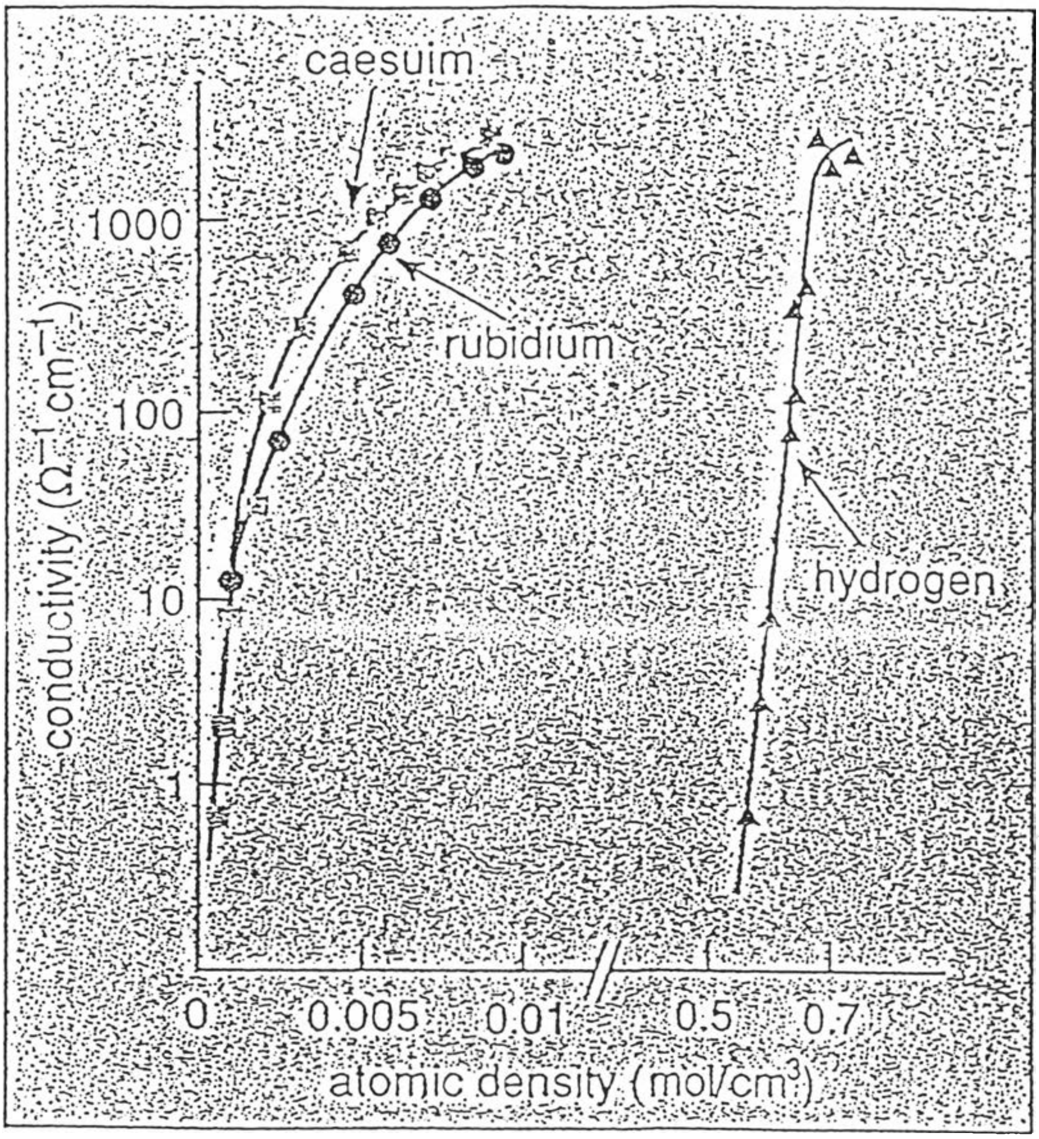

Figure 1.2 The electrical conductivity of caesium, rubidium and hydrogen as a function of atomic density at temperature of about 1750 K. Hydrogen becomes conducting at a much higher density than the two alkali metals [7].

1.4 THE ORGANIZATION OF THIS THESIS

In this thesis, we will construct a model of the electrical conductivity of liquid metallic hydrogen based on the Ziman theory and then calculate it using the numerical techniques. In Chapter II, we review the theory of electrical conductivity based on the Boltzmann transport equation and the method of relaxation time. We then present a brief review of the Ziman theory in Chapter III. In Chapter IV, we apply the Ziman theory to calculate the electrical conductivity of liquid metallic hydrogen. Finally, the conclusion and discussion is made in Chapter V.