CHAPTER II.

EXPERIMENTAL.

The subject matter of this chapter is divided into the following sections:

2.1 Thin-Film preparation and measurement of resistance at different temperature under vacuum.

2.2 Percentage transmittance measurements in the visible wavelength region using spectrophotometer.

2.3 Polarization (optical constants) measurements at different wavelengths of incident light, using an ellipsometer with photomultiplier device.

2.4 Hall voltage (d.c.) measurements at different magnetic field strengths ranging from 1.4 to 19.9 kilo gauss.

2.5 Measurement of film-thickness.
2.1. **THIN-FILM PREPARATION AND MEASUREMENT OF RESISTANCE AT DIFFERENT TEMPERATURES UNDER VACUUM.**

Films can be prepared by various methods. Each method differs in many fundamental aspects and is advantageous for particular applications. Vacuum evaporation method is superior to other methods due to following reasons (59):

(a) The material dignifies and evaporates at lower temperature in vacuum.

(b) The effect of oxides on the boiling surface gets reduced.

(c) At low pressure, the evaporating atoms make few collisions with the atoms of the residual gas in the chamber. This reduces the number of impurities (to be trapped) in the deposit.

(d) With no other methods, films of uniform and of desired thickness can be prepared with so complete a measure of control.

For preparation of thin-film, an evaporation plant with provision for annealing the film, measuring its temperature and resistance inside vacuum, was designed and constructed in the laboratory (3), (24). (Figure 1-2)

It is evident that, with better understandings of the influencing parameters during film growth, one can prepare single-crystalline, poly-crystalline or amorphous film of the same thickness for a given metal. Single-crystalline
evaporated film (viz; compact & Homogeneous) possesses lower resistivity, and higher reflectivity than the amorphous or poly-crystalline (Viz, porous & non-homogeneous) evaporated films. The films of the same metal, prepared under different conditions of evaporation, will show wide variations in its physical properties. Therefore, to obtain reproducible and comparable results, it was necessary to evaporate the metal under identical experimental conditions (viz; rate of evaporation, vacuum etc). The following parameters are controlled to obtain identical films;

2.1.1 Purity of The Metal: - The purity which exists in the prepared film, depends on the initial purity of the evaporated metal. The select grade spectrographically pure silver and gold (procured from Johnson & Matthey Co. Ltd., London) are used. The chemical analysis as supplied by the firm ensures that (a) In the silver sample, a trace of not more than 1 ppm (parts per million) of Cd, Cu, Fe, Pb & Mg may be there, (b) In the gold sample, silicon is less than 3 ppm; and the only metals Ag, Cu, Ca, Fe, Mg & Na are less than 1 ppm.

A suitable amount of spec-pure metal, under investigation is placed in molybdenum boat having a dimple at the centre.

2.1.2. Cleanliness of The Substrate: - Selected 'Gold Seal' microscopic slides are used as substrates. For obtaining good adhesion of the films (on glass substrate), proper cleaning of glass substrate is of great importance,
Standard method of cleaning as described by Strong (62) is followed in each case. The plates are first treated in concentrated and boiling solution of chromic acid (35 c.c. saturated sodium dichromate + 1 liter concentrated sulphuric acid), for about two hours. The plate is then washed successively with distilled water, doubly distilled water and isopropyl alcohol. The alcohol treatment removes last traces of grease. Even fingers should not touch the edges of the glass substrate during the latter cleaning operations, because a layer of organic matter is apt to spread over the surface and render the coating uneven. The final cleaning of the substrate is followed by ionic bombardment inside vacuum.

Electrical contacts of thick silver coating (viz; 0.001 cm thick & 0.5 cm. wide) are made on the same side and along both the shorter edges of the cleaned glass substrate. Thus the substrate having two electrical contacts at the edge, with a clean glass surface at the centre, is mounted on a specially prepared holder (inside the chamber).

2.1.3. Evaporation Geometry of the Substrate:— A serious limitation of the evaporation method is that, the mean free path of vapour molecules must be larger than the distance between source to target. The collisions of the evaporating atoms with the residual gas atoms get reduced as the pressure decreases in the chamber.

Three separate plates are used for the optical, electrical and thickness measurements and they are coated ---
simultaneously in one run of evaporation. The suitable geometry between the source and the target is maintained so as to obtain uniform coating over the three plates.

Plate 1. The glass plate of size 3.0 cm x 2.5 cm x 0.1 cm.
Plate 2. The glass plate having electrical constants, having size 7.5 cm x 2.5 cm x 0.1 cm.
Plate 3. The quartz plate (worked to \( \lambda/5 \)), with half portion covered using a stainless steel strip.

The plates are mounted on a specially constructed brass holder. This holder is such that the thick coatings on the opposite edges of the substrate are mechanically pressed between brass strips. This provides proper electrical constants for resistance measurement. All the three plates are mounted horizontally. The substrate holder and the furnace are now introduced into the vacuum chamber. The furnace is constructed in the laboratory, using molybdenum wire, mica and stainless steel case. The dimensions of the furnace is such that it covers the entire substrate (viz; deposited film).

Mean free path of vapour molecule (Ag) = 450 x 10^{-6} cm.
Distance between source and target = 13.2 cms.
Dimension of the target = 7.3 cm x 5.2 cm x 0.1 cm.
Vapour incidence angle = 3°
Thickness tolerance = ± 3%

2.1.4. Substrate Temperature: At higher substrate temperature, the deposit forms less number of larger crystallites, which do not have sufficient electrical contacts with each other.
This makes the film discontinuous and electrically non-conducting. In 1959, Smith (67) noticed from X-ray analysis, that the crystallite size in permalloy films, deposited on glass at pressure 10 torr, at room temperature, is about 50 Å. This increases to about 250 Å for films deposited at 300 °C. Films having highest specular reflection and highest electrical conductivity (Homogeneous films) can be grown only at low temperature (67). However, with the available experimental equipment, it was not possible for us to prepare films below room temperature. Substrate temperature during film preparation was approximately 25°C.

2.1.5 Pressure During Evaporation:— The presence of residual gases during film preparation, also affects the structure and the purity of the deposited film. The concentrations and mobilities of surface atoms are drastically reduced in the presence of active gases (viz; Oxygen, carbon dioxide etc), which can react with them or can be adsorbed. Thus the film becomes more porous and rough which consequently increases the film resistivity.

However, the available vacuum chamber attains a final vacuum of the order of 10⁻⁵ torr. For the vacuum system, Edwards speedivac oil diffusion pump having pumping speed 60 litres/sec is used. The diffusion pump is backed by rotary pump having pumping speed 50 litres/sec. Metals of silver and gold are selected on account of their less affinity for oxygen and other gases. The cleaned substrate is
degassed at 150°C and the metal is degassed at 400°C for 10 minutes at the pressure of \(10^{-2}\) torr. Then the substrate which is placed (in a bell-jar having height 15" and diameter 8") between anode and cathode, is ionically bombarded for 10 minutes at the pressure of 10 torr. An induction coil (10 Kilowatts) is used for d.c. glow discharge.

2.1.6 Rate of Evaporation:— The deposition at low temperature yields microcrystalline films with different types of imperfections (viz.; vacancies, interstitials, stacking faults and dislocations). Sennett and Scott (7) have reported from electron micrograph studies that slower the rate of deposition, greater is the aggregation, and hence increase in the light absorption. According to Foust (67), for silver films having thicknesses greater than 150 Å, the light absorption in the rapidly condensed films was much lower than that in the slowly deposited layers. Thin films of Cu, Ag and Au evaporated from Mo-boat at the evaporation rate of 1000 Å/sec (dist. from boat to substrate is 45 cms.) showed higher reflectance and lower absorption (of light) in the special range from extreme ultraviolet to far infrared (8). Thus at high rates of deposition, the proportional influence from residual gas molecules (on the film) reduces.

In the present investigations, the metal charge is first melted in the Mo-boat, and a movable shutter is kept in the path of the vapour beam. Any layer of impurity on the melted bead surface, evaporates and is deposited on the shutter. By removing the barrier from the vapour path, the
metal is deposited as rapidly as the equipment permits. The rate at which, the films are evaporated was about $80 \text{ Å/sec}$. It is observed that evaporation of silver takes place from a globle.

2.1.7. Measurement of Resistance at Different Temperature (Annealing the Deposit) under vacuum:— The resistance of the film is measured immediately after the deposition, at the interval of 0.5 minutes up to 20 minutes. The resistance measurements are carried out inside vacuum to prevent the film surface from Oxidation, chemisorption and adsorption of gas molecules. For resistance measurement, a Kohlrausch bridge in conjunction with a sensitive ($10^{-5}$ amp/div.) galvanometer, is used. It is observed that the initial resistance of the film falls rapidly with time and attains nearly a steady value, 20 minutes after film deposition (refer: table 4.2.1.). This is a common feature observed with all films of silver and gold.

According to Frenkel theory (23) of gas adsorption, "at room temperature, a deposited layer of atoms is covered by succeeding layers before reaching to the thermal equilibrium with the substrate. This results in many vacancies and crystal defects to be trapped in the deposit. Literature reveals that heat treatment of films promote the removal of strains, occluded and absorbed gases, and the growth of crystallites in the film. In 1954, Schulz (66) reported that, in the case of Cu, Ag, Au and Al properly annealed films are free from strains and defects which increases the real part of the film index,
increases the specular reflection and transmittance of the film. Yoshibumi Fujiki (69) studied the changes in thickness and resistivity of vacuum deposited gold films by X-ray interference method. He stated that at all stages of annealing process, the specimen thickness and resistivity decreases and these changes are due to the migration of vacancies to the surface of the specimen.

In the present investigations, the films are annealed by the method as suggested by Vand (22). As the deposited film attained the steady resistance, it is heated by means of the furnace, kept just above it. Temperature is gradually increased by regular steps at the intervals of 15 minutes, and the corresponding temperature and the resistance are noted. The annealing temperatures are recorded by means of iron-constantan thermo-couple. It is observed that the resistance decreases rapidly with the increase of temperature and reaches a minimum value. The heating is stopped just when the resistance reaches a minimum value. The film is then kept at the temperature of minimum resistance for one hour. Then it is allowed to cool gradually upto room temperature (refer Table: 4.2.2, 4.2.3). When annealed deposits are cooled upto room temperature, all the three specimens are taken out of the vacuum chamber.

2.1.8. Oxidation And Ageing of the Film:— When a thin metallic film is taken out in air, usually a thin oxide layer is formed on the film surface. The thickness of oxide layer depends on the nature of the metal. As the oxide layer on the
film has a very large modifying effect on the optical properties of the metallic film, the ageing of the film becomes important. For example (67) freshly prepared Al film of thickness 15 Å, grows in air to a thickness of 30 Å to 40 Å in one hour. Again (6) the formation of 20 Å thick, oxide layer on 280 Å thick Al film results in a drop of reflectance from 50% to 13% for wavelength (of light) \( \lambda = 735 \text{ Å} \). The results of difference in the physical properties due to oxidation are discussed in detail by Madden, Canfield and Hass (6).

Films of SiO, SiO₂, Al₂O₃, MgF₂ and Ge are the most suitable as protective and interference layers. For preparation of protective layers, MgF₂ is used in many laboratories, because it provides a very hard anti-reflection coating on glass.

All films are investigated within two days of their preparation. While not using, the films are preserved in a deccicator, as higher humidities may cause a rapid deterioration.

The three annealed specimens prepared simultaneously in one evaporation; are used in the following order:

Specimen 1, is used for percentage transmittance measurements (Refer 2.2.1.)

Specimen 2, is used for electrical resistance measurement inside the vacuum chamber. The same is used for homogeneity check, for polarization measurements
and for Hall voltage measurements (refer: 2.1.7, 2.2.2, 2.3 & 2.4) outside the vacuum chamber.

Specimen 3 is used for metrical thickness measurement (refer: 2.5).

1. EVAPORATION PLANT

2. WORKING OF EVAPORATION PLANT.
Evaporation plant.

For Explanation of the figure See. OPPOSITE PAGE
EVAPORATION PLANT.

(ExPLANATION)

B — BELL JAR.

Q₁ & Q₂ — AL. DISCHARGE PROBES.

Q — QUARTZ PLATE.

S — SHUTTER.

F — MICRO FURNACE.

M — GLASS SUBSTRATE.

T — THERMO COUPLE.

M₀ — MOLYBDENUM BOAT.

N — NEOPRENE RUBBER RING.

A₁ & A₂ — AIR RELEASE VALVES.

(1)

(2) VACUUM GLASS STOP COCKS.

(3)

(4) METAL STOP COCK.

P — P₂O₅ TRAP.
2.2. PERCENTAGE TRANSMITTANCE ( % T ) MEASUREMENTS IN
THE VISIBLE WAVELENGTH REGION USING SPECTROPHOTOMETER:

2.2.1. Spectral Dependence of Transmitivity of Thin-Films
of Silver and Gold: For measurements of transmittance
S. P. 500 Unicam Spectrophotometer is used. The film under
investigation, (specimen 1. having dimensions 3.0 cm x 0.1 cm x 0.25 cm)
is mounted on a specially prepared stand, which can be fitted
only in one position. Transmitted intensity of incident light
through the film, is recorded with respect to a clean glass
plate; in the wavelength range 4,000 Å to 10,000 Å (refer:
tables 4.5.1, 4.5.2).

2.2.2. Checking of Film-Thickness Homogeneity: For every
film a single wavelength is selected, which gives about 50%
transmittance (of light) for it. The film (specimen 2.,
having dimensions 7.5 cm x 2.5 cm x 0.1 cm) is mounted on a
stand and at a selected wavelength, transmittance is recorded
at five different points. (refer: table 4.5.3).

The same film is then used for the polarization
measurements of the reflected light by means of an ellipsometer;
as described in the preceding Section 2.3 of this Chapter.
2.3. POLARIZATION (OPTICAL CONSTANTS MEASUREMENTS AT DIFFERENT WAVELENGTHS OF INCIDENT LIGHT, USING AN ELLIPSOMETER WITH PHOTOMULTIPLIER DEVICE).

2.3.1. Ellipsometer Setting:— For carrying out the polarimetric analysis, the following instruments and accessories are used.

(a) A Leitz-monochrometer with a cadmium-mercury tube is used as light source.

(b) A spectrometer is converted into an ellipsometer by suitably modifying the collimator and the telescope; having least count 1°.

(c) A polarizer and a quarter wave (\(\gamma/4\)) plate are mounted in circular discs, which are then fixed on the collimator arm.

Least count of a disc having a polarizer =0.1° and Least count of a disc having \(\gamma/4\) plate =5°.

(d) An analyzer is mounted in a circular disc, which is then fixed on the telescope arm. The telescope arm is supported on a vertical rod, which can be moved on a ball bearing support, on a glass plate base.

Least Count of a disc having an analyzer =0.6°.

(e) A photomultiplier tube attached with the analyzer, is mounted on the telescope arm. The tube is energised by a 900 V (d.c.) stabilised power supply and is attached to a multiflex galvanometer (10 amp/div.).
The usual method of determining optical parameters by using ellipsometer, involves the use of compensator which introduces a measurable phase difference between the $\mathbf{E}$- and $\mathbf{g}$- component of reflected light beam. The $\frac{\lambda}{4}$ plate is one of the most sensitive ($5 \times 10^{-2} \times 2\pi$ radians) compensator. For highest accuracy, the compensator plate should be exactly a quarter wave plate for the wavelength used. According to Drude (25), at principal angle of incidence (vis, an angle at which the phase difference between the two components of reflected elliptically polarized light is $90^\circ$) the ellipticity is greatest, and therefore the errors of measurements will be least.

The vibration direction of E-vector of the linearly polarized light is determined by Brewster's method. Polariser and analyser with photomultiplier attachment are adjusted in a line with the monochromatic light; and then both are put in a crossed position. The $\frac{\lambda}{4}$ plate is mounted between the polarizer and the analyser and is oriented until a complete extinction is obtained. In this position, one of the axes of the $\frac{\lambda}{4}$ plate is parallel or perpendicular to the axis of the polarizer. Readings on the circular scales of the $\frac{\lambda}{4}$ plate and of the analyser are noted. The ellipsometer is set for the angle of incidence (vis; $\Theta_0 = 75^\circ$), which is near about the principal angle of incidence; for silver and gold metals, and for all selected wavelengths of light. Now the ellipsometer is set for measurements of the azimuth $\psi$ and the phase difference $\Delta$.

2.3.2. Working of Ellipsometer and Method of Finding Optical Constants of Thin-Films:
The Cd-Hg tube is used as a source for the selected wavelengths of light (viz; 4348 Å, 5461 Å, 5790 Å). A black paper is attached at the back surface of the specimen, by means of canada balsam. This reduces completely, the out of phase reflections from the back surface of the specimen. The film is then mounted on a holder, and it is put on the prism-table of the ellipsometer in such a way that the monochromatic beam is incident in the middle of the film. The reflected light is collimated on the grid of a photomultiplier through an analyser.

When a monochromatic beam of a linearly polarized light (having its electric vector at an angle of 45° with the plane of incidence) is incident (through air) on a plane boundary of a metallic film (under investigation), the reflected light becomes elliptically polarized. The optical state of this reflected elliptically polarized light depends on the nature of the film, angle of incidence (of light) and on the wavelength of light used. In the present investigations the reflected light (from the film) is analysed using Menard's method, which is a modification of the method described by Archer (70).

'Menard's method which is described below, provides the measurement of an azimuth Ψ and a phase difference Α.

(a) A plate is rotated so that its fast axis makes an angle of 45° with the plane of incidence (viz; an angle of 45° in the first quadrant).
(b) The reflected light is incident on the photo-multiplier after reflection (at the selected angle of incidence).
(c) The first extinction of the reflected light is judged in a following way. The polarizer is oriented in the first quadrant and the analyser is also oriented simultaneously in the first or second quadrant. The reflected light (from the film) which is incident on the photo-multiplier is viewed on the multiflex galvanometer for the minimum intensity. Let the polarizer reading be \( p \) and the analyser reading be \( A \).

(a) The second extinction is also obtained by having the polarizer azimuth in fourth quadrant and the analyser azimuth adjusted in first or second quadrant. Let the polarizer reading be \( p' \) and the analyser reading be \( A' \).

All orientations of the plate, polarizer and of analyser are made with respect to cartesian system, as shown by Menard (29). All angles are measured in a counter-clock wise direction from the plane of incidence as zero axis. The transmission axis of the polarizer is taken as its azimuth, and the anti-transmission axis of the analyser is taken as its azimuth.

The azimuth and the phase difference are calculated from the extinction orientations of polarizer (\( p \)) and of analyser (\( A, A' \)) using the following equations:

\[
\tan \varphi = \cot A - \cot A' \\
\tan \Delta = \sin \delta \cdot \cot 2p
\]
Where $\delta$ is the phase difference produced by $\frac{1}{4}$ plate. In the present case, $\delta = 90^\circ$ because each wave plate used was a quarter wave plate for the respective wavelength of light.

From the knowledge of azimuth $\psi$ and of phase difference $\Delta$, the optical constants of a film for a particular wavelength of light are determined by using the method as described in chapter III of this thesis. (Refer tables from Section 4.4.).

After these measurements are over, the same film is then used for the Hall voltage measurements, as described in the preceding section 2.4 of this chapter.

3. ELLIPSOMETER.
SCHEMATIC DIAGRAM of ELLIPSOMETER.

Fig. No. 3

S: Source
P: Polarizer
F: Film
A: Analyzer
O: Objective
Q: Quarter plate
2.4. HALL VOLTAGE MEASUREMENTS AT VARIOUS MAGNETIC FIELD STRENGTHS RANGING FROM 1.4 to 19.9 KILO GAUSS.

For Hall voltage measurements, a sensitive experimental set-up is made and the entire circuit used for that is shown in figure 4.

The film (viz: specimen 2, having dimension 7.5cm x 2.5cm x 0.1cm.) is placed on a specially prepared plastic holder and then the current and the potential leads are soldered using indium metal. An electro-magnet energized by 120 V(d.c.) generator, is used and is calibrated by means of (a) bismuth spiral and by (b) search coil and flux meter;

In the block diagram as shown in figure 4, in which \( I_x \) is the primary current, \( E_y \) is the Hall voltage and \( H_z \) is the magnetic field. The potential and the current leads (of the Hall sample) are of a metal other than that of a specimen. Now due to slight unevenness of sheet resistivity, it is difficult to attach the potential leads, exactly on equipotential points. This will give rise to a misalignment voltage. Then the Hall voltage developed perpendicularly to the direction of applied magnetic field and that of applied primary current is given by

\[
E_{y1} = E_y + E_G + E_m + E_N + E_{RL}
\]

where \( E_{y1} \) is the total voltage and \( E_y, E_G, E_m, E_N \) and \( E_{RL} \) are respectively voltages due to Hall effect, Ettingshausen effect, Nernst effect and Righti-Ludec effect. The peltier heating at A and
cooling at \( B \) (or vice versa), gives rise to heat flow along with the current flow. The junctions at \( C \) & \( D \) gives rise to a temperature gradient and thereby thermo-electric voltage (viz; \( E_E + E_{RL} \)):

\[
\begin{align*}
E_y2 &= E_y + E_m - E_N - E_{RL} + C_E \quad \text{(if \( I_x \) is reversed)} \\
E_y3 &= E_y + E_N + E_{RL} \quad \text{(if \( H_Z \) is reversed)} \\
E_y4 &= E_y + E_N - E_m - E_{RL} \quad \text{(if \( I_x \) & \( H_Z \) are reversed)}
\end{align*}
\]

The three measurements with \( I_x \) or \( H_Z \) reversed, are made in rapid succession, so that the longitudinal temperature gradient due to Peltier heating does not have time to reverse. The mean of four observations gives

\[
E_y + E_E = \frac{E_{y1} + E_{y2} + E_{y3} + E_{y4}}{4}
\]

The voltage \( E_E \) cannot be eliminated, but in principle could be avoided by making the leads of the same material as the film. And this procedure is followed in the present investigations.

For measurement of Hall voltage, the presence of

(a) misalignment voltage is eliminated by using the secondary circuit as suggested by Davis (74)

(b) Ettingshausen effect is eliminated by using the current and the potential leads of the same metal as the film.

(c) Errors due to misalignment voltage, and
thermo-magnetic effects (viz; Nernst effect and Bighi-Hudec effect) are eliminated by taking four observations for a given current and field strength, as suggested by Cusack (75).

(d) Hall breadth effect is eliminated, using the relation (54).

\[
\text{Correct Hall voltage} = \frac{(\text{observed Hall voltage}) \times (\text{Sample width})}{(\text{Separation of Hall contacts})}
\]

Keeping in view the effect of finite length of the Hall sample, the ratio of length to width, for the film is maintained at three approximately (76,77). The standard size of gold seal microscope slide (7.5cmx2.5cm.) has fulfilled the requirement. The primary current flowing through the film is measured to the fourth decimal place by allowing it to pass through a standard one ohm resistance (having four terminals); and measuring the potential across the standard resistance; by means of a precision potentiometer.

Residual zero field potential is taken into account, which is added or subtracted from the developed potential. Knowing the polarity of magnetic field, and the direction of the current in the film and in the potentiometer; the algebraic sign of the current and hence of Hall voltage is determined.

Keeping primary current constant \((I_x=40\, \text{ma.})\), the Hall voltage \(E_y\) is measured using pye-potentiometer \((0.5\, \mu\text{V})\)
in conjunction with dead beat pye-galvanometer (0.3 μV/div), for various magnetic field strengths ranging from 1,400 to 19,000 gauss. (Refer tables from section 4.3).

4. EXPERIMENTAL SET-UP FOR HALL-VOLTAGE MEASUREMENTS.

5. INTERFEROGRAM FOR THICKNESS 236 Å.
2.5. MEASUREMENT OF FILM-THICKNESS:

The thicknesses of a thin-film are determined by using the following different methods.

2.5.1. Thickness measurement \( (\text{MBI}) \), using multiple beam interference method based on the principle of Fizeau fringes.

2.5.2. Thickness determination \( (\text{cond.}) \), using electrical conductance measurements.

2.5.3. Thickness determination \( (\text{Hall}) \), using Hall effect measurements.

2.5.4. Thickness determination \( (\text{MFP}) \), using mean free path data from electrical and magnetic measurements.

2.5.1. Film-Thickness Measurement using MBI Method as described by Tolansky, S(78):

The interference methods of film-thickness determination, have gained a wide importance due to the work of Tolansky (1950). These methods give directly the metrical thickness without the knowledge of optical constants of coated material; and they can be applied to transparent and absorbing films with equal facility.

The most important factors in obtaining sharpness of fringes are (a) The absorption of the reflecting layer. When a beam of light strikes the metal film at normal incidence, a phase change at the reflection produces discrepancy in the measurement of film-thickness. This can be eliminated by
coating a high reflecting layer on the film. (b) Separation between two silvered surfaces (for obtaining interference effects). The sharpness of the fringes depends on the air-gap between two silvered surfaces. Smaller the air-gap, better will be the sharpness (viz; quality) of the fringes.

There are two types of interference fringes (a) Fringes of equal chromatic order (viz; Peco fringes) (b) Fringes of equal thickness (viz; Pisefu fringes). In order to produce Peco fringes, the reference and the test (film) surfaces must be parallel to each other. In this case, white light is to be used, which reflects from the interference region to the slit of a spectrometer. In order to produce Pisefu fringes, a wedge shaped air-gap must be formed between the reference and the test (film) surfaces. Compared to its experimental simplicity, the method is of high accuracy.

For measurement of film-thickness, half coated quartz (viz, specimen 3.) and the multiple beam interference method based on the principle of Pisefu fringes are used. A cadmium mercury tube in conjunction with a green filter ($\lambda = 5460 \AA$), is used as a light source. The differential screw arrangement is used for the control of wedge shaped air-gap (formed between two silvered surfaces). With this arrangement, the wedge angle can be controlled upto the height of 10 cm.

The half coated quartz is silvered (completely) with about 1000 $\AA$ thickness. The reference flat (worked to $\lambda/40$ Leitz Wetzler) is coated on one side by a semi-transparent
silver film.

The reference flat and the quartz are kept into close proximity with silver surfaces facing one another. The reference flat is rested on three pin-points which are attached to the respective differential screw. And the same flat is kept, pressed (from above) with the quartz plate, by means of three springs of stainless steel. The monochromatic light is illuminated from above. The screws are rotated simultaneously, in such a way that the back reflected Fizeau fringes can be obtained through a low power microscope (Interferogram for the film having thickness 236 Å is shown). The fringe width and the fringe displacement are measured, using low power microscope (P.T.I. London, having least count 0.002 cm.) Film thickness is measured up to the accuracy of ± 10 Å. (Refer Table 4.1.1.)

Throughout the studies of electrical, magnetic and of optical properties of metallic films (chapter V, of this thesis), thickness of MBL is used as an standard means of measuring the thickness.

Sections 2.5.2; 2.5.3; and 2.5.4 are discussed in chapter III of this thesis. The comparison of film thickness obtained by various methods is shown in Section 5.3.