Chapter III

Experimental Techniques
CHAPTER-3
EXPERIMENTAL TECHNIQUES

Preparation of the sample for each characterizing technique is as important as obtaining or synthesizing a good quality sample. All compounds presented in this thesis are synthesized at home and characterized for various properties using the following instruments:

(A) Techniques available in the department

1. X-ray powder diffractometer (PANalytical make X’Pert PRO MPD model PW 3040/60) for structural characterization.

2. Energy Dispersive X-ray Analysis (EDAX) using SEM (CAR ZEISS EVO-18)

(B) Techniques from other institutions

1. Transmission Electron Microscopy (TECNAI FE 12 TEM 120 KV) used at IICT Hyderabad.

2. SQUID Magnetometer TIFR Mumbai.

Here we describe the instruments used for characterization of the samples in detail:

3.1 X-ray Powder Diffractometer

3.1.1 General

In order to explore crystal structure we use diffraction patterns of waves that interact with atoms and that have a wave length comparable to the inter-atomic spacing. Diffraction pattern of a compound is a map of the atoms and electron distribution in the Fourier space giving the valuable information about overall structure of the crystal. Diffraction pattern depends on the crystal structure and the wavelength of incident beam. One can use photons, neutrons as well as electrons for creating diffraction pattern.
3.1.2 Basics of X-ray Diffraction

Fig. 3.1 illustrates the diffraction phenomena from the lattice plane of the crystal. Consider a wave incident on a crystal. If the different planes of the crystal (A, B and C) are d distance apart then the path difference between the waves scattered from two consecutive planes would be $2d\sin \theta$. In order that the scattered rays be completely in phase with each other their path difference should be integral multiple of wavelengths i.e. $2d \sin \theta = n\lambda$. $\theta$ is the scattering angle and $\lambda$ is the wavelength of x-ray beam. This is known as Bragg’s law.

![Fig. 3.1: Bragg reflection from a particular family of lattice planes separated by a distance d. Incident and reflected rays are shown for two neighboring planes.](image)

Diffraction takes place from the crystal only when Bragg condition is fulfilled [1]. This condition can be achieved by continuously changing either $\lambda$ or $\theta$ during the experiment. There are mainly three experimental methods for recording X-ray diffraction.

<table>
<thead>
<tr>
<th>Method</th>
<th>$\lambda$</th>
<th>$\theta$</th>
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<tbody>
<tr>
<td>Laue method</td>
<td>variable</td>
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<tr>
<td>Rotating crystal method</td>
<td>fixed</td>
<td>variable</td>
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<tr>
<td>Debye-Scherrer powder method</td>
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<td>variable</td>
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In the Debye-Scherrer powder method the sample to be examined is placed in the path monochromatic X-rays. In the crystalline powder specimen various reciprocal lattice vectors are randomly oriented with respect to the incident beam and Bragg diffraction occurs over a set of cones, known as Debye-Scherrer cones (Fig. 3.2). The incident monochromatic radiation strikes on a fine powdered sample or a fine grained polycrystalline specimen contained in a sample holder. Diffracted beam emerging out of the individual crystallites, oriented with planes making an incident angle $\theta$ with beam satisfying the Bragg equation leave the specimen along the generators of the cones concentric with original beam. Making an angle of $2\theta$, the sample is rotated by an angle $\theta$ and the detector by $2\theta$ continuously in such a way that only the crystals whose planes are parallel to the sample surface take part in the diffraction and result in constructive interference. The advantages of this method are: (1) small amount of powder required, (2) practically complete coverage of all the reflection produced by the specimen and (3) relative simplicity of the apparatus [1, 2].

Fig. 3.2: Diffraction of x-ray from a flat powder cake.
3.1.3 Indexing and determination of lattice constants

In the powder diffraction measurements, the observed data comes in the form of the intensity of diffracted rays as a function of angle $2\theta$. The exact $2\theta$ angle at which Bragg peaks are observed are carefully noted down and then with the help of Bragg’s law the corresponding $d$ values are calculated. If one has knowledge of the crystal structure, then with an initial guess of cell constants, ‘$d$’ values for various (hkl) reflections can be calculated using the following relations

For cubic systems

$$d^2 (hkl) = \frac{a^2}{(h^2 + k^2 + l^2)}$$

For tetragonal system

$$d^2 (hkl) = \left( \frac{h^2 + k^2 + l^2}{a^2 + c^2} \right)^{-1}$$

For hexagonal systems

$$d^2 (hkl) = \left( \frac{4h^2 + 4hk + k^2}{3a^2 + c^2} \right)^{-1}$$

For orthorhombic systems

$$d^2 (hkl) = \left( \frac{h^2 + k^2 + l^2}{a^2 + b^2 + c^2} \right)^{-1}$$

where $a$, $b$ and $c$ are the cell parameters. The calculated values are compared with those experimentally observed and thus the observed Bragg reflections are assigned hkl values. The success of the indexing procedure depends on the accuracy of the experimental values and on the purity of the sample. Presence of any low intensity peaks that cannot be indexed could be indicative of the existence of some impurity phase in the sample. Using the above standard formula and using least square refinement program the crystal symmetry of a specimen can be determined [1, 2].

3.1.4 Determination of Particle Size

In order for a crystal to give constructive interference, all the reflecting plane must meet the incident X-ray beam at one set of specified angles in phase. When the diffracting crystal is large, containing thousands of parallel planes, this condition is satisfied very precisely to show sharp diffraction maxima. However, when the crystallites become smaller; this condition is somewhat relaxed. Finally, when the crystallites are so small that they contain only a few planes in phase, diffraction by these planes is no longer capable of producing sharp
diffraction minima. If the path difference between rays scattered by the first two planes differs only slightly from an integral multiple of wavelength then the planes scattering a ray exactly out of phase with the ray from the first plane will lie deep within the crystal. There is a connection between the amount of ‘out of phaseness’ the particle size suppose the crystal has (m+1) planes. Let $\theta_B$ be the angle which exactly satisfies the Bragg’s law.

$$2dsin\theta = n\lambda$$

In Fig. 3.3 A, D,…………..M makes angle $\theta_B$ with reflecting planes. Thus D’ and A’ have path difference $\lambda$ and M’ and A’ have that of $m\lambda$. So rays A’, D’, M’, etc. those are in phase give a beam of maximum intensity. But if glancing angle is slightly larger than $\theta_B$ i.e., $\theta_1$, the ray L’ is $(m+1)\lambda$ out of phase with B’. This means that midway in the crystal there is a plane scattering a ray which is an integer plus $\frac{1}{2}$ wavelengths out of phase with ray B’ giving rise to destructive interference between similar pairs having $\lambda/2$ path difference. Similarly if glancing angle is slightly less than $\theta_B$ i.e.$\theta_2$ as in figure for ray C and N such that diffracted C’ and N’ have path difference $(m-1)\lambda$, then also it will give rise to the destructive interference between similar pairs having path difference $\lambda/2$. Thus beams diffracted at $2\theta_1$ and $2\theta_2$ is not zero and maxima (at $\theta_B$).

![Fig. 3.3: Effect of crystallite size on X-ray Diffraction](image)
The width $B$ is measured in radians at an intensity equal to half the maximum intensity. As a rough measure of $B$, we can take half the difference between the two extreme angles where intensity is zero, so

$$B = \frac{1}{2} (2\theta_1 - 2\theta_2) = \theta_1 - \theta_2$$

Therefore the path difference equation for these two angles related to the entire thickness of the crystal:

$$2t \sin \theta_1 = (m+1) \lambda$$

$$2t \sin \theta_2 = (m-1) \lambda$$

So

$$t (\sin \theta_1 - \sin \theta_2) = \lambda$$

If $\theta_1 + \theta_2 \sim 2\theta_B$ and $\sin (\theta_1 - \theta_2)/2 \sim (\theta_1 - \theta_2)/2$

Then $2t (\theta_1 - \theta_2)/2 \cos \theta_B = \lambda$

Thus

$$t = \frac{\lambda}{B} \cos \theta_B$$

More exact treatment of the problem gives $t = 0.9 \frac{\lambda}{B} \cos \theta_B$ this is known as Scherrer formula.

Broadening $B$ is essentially zero when particle size exceeds 1000Å. All diffraction lines have a measurable breadth $B_M$ even when the crystal size exceeds 1000Å due to Doppler broadening. According to Warren’s formula apparent width is

$$B^2 = B_M^2 - B_S^2$$

Where $B_S$ is the measured breadth at half maximum intensity of the line from the standard (in our case Si) sample of bulk sized particles (> 1000Å) [3-5].

3.2 **Description of the PANalytical, X’Pert PRO MPD Diffractometer**

X-ray Diffractometer (PANalytical, X’Pert PRO MPD) using monochromatic x-ray ($\text{CuK}_\alpha = 1.5418\text{Å}$) radiation (curved graphite monochromator, fixed slits and Xe proportional counter) in a wide range of Bragg angle ($5 \leq \theta \leq 110^0$) at room temperature was used for studying synthesized sample. Commercial software High Score Plus from firm PANalytical was used for data evaluation, qualitative and quantitative phase
analysis and measurement of lattice parameters. Fig. 3.4 displays experimental set up with all its components and Fig. 3.5 indicate working of X-ray diffractometer schematically.

![Experimental Setup of X-Ray Diffractometer](image1)

**Fig. 3.4: Experimental Setup of X-Ray Diffractometer**

![Schematic and working of X-Ray Diffractometer](image2)

**Fig.3.5: Schematic and working of X-Ray Diffractometer**

### 3.2.1 X-ray Tube

X-ray tubes are devices for bringing about the interaction of high speed electrons with matter for the purpose of producing X-rays. The type of X-ray tube used in X' Pert PRO is the ceramic diffraction X-ray tube. It consists of a metal body containing a ground anode, four beryllium windows, an electronic tube, recognition connector, a shielded High Tention (HT) connection, a
radiation shield and water cooling facilities and of a ceramic insulator part, containing a focusing cylinder, a cathode and an ion getter pump. A point focus mark indicates the position of the point focus window. The ceramic tube fits in the tube shield so that the position of X-ray tube in the shield with respect to line or point focus is automatically recognized.

![X-Ray Tube](image)

**Fig.3.6: X-Ray Tube**

### Working of X-ray Tube

X-rays are part of the electromagnetic spectrum, an ionizing radiation with wavelength shorter than ultraviolet light. X-rays are generated in a cathode ray tube by heating a filament to produce electrons. Accelerating the electrons towards a target by applying a voltage and bombarding the target material with electrons, when electrons have sufficient energy to dislodge inner shell electrons of the target material characteristic X-ray spectra are produced. These spectra consist of several components, the most common being Kα and Kβ. Kα consists of Kα1 and Kα2. Kα1 has slightly shorter wavelength and twice the intensity as Kα2. The specific wavelengths are characteristic of target material (Cu, Fe, Mo, and Cr). Kα1 and Kα2 are sufficiently close in wavelength such that a weighted average of two is used. Copper is the most common target material for single crystal diffraction, with Cu Kα radiation =1.5418Å. These X-rays are collimated and directed on to the sample. As the sample and detector are rotated the
intensity of the reflected X-rays is recorded. When the geometry of the incident X-rays impinging the sample satisfies the Bragg equation, constructive interference occurs and a peak in intensity occurs. A detector records and processes this X-rays signal to count rate which is then output to computer monitor.

3.2.2 Divergence Slits:

Divergence slits are fitted in the incident beam path to control the equatorial divergence of the incident beam, and thus, the amount (length) of the sample that is irradiated by the incident x-ray beam. These have major effects on intensities and minor effects on resolution. The size of the divergence slit depends on the size of the sample. A smaller divergence slit gives a smaller illumination on the sample and less diffracted intensity. The divergence slit, used in this system, PW3081/60 is an incident beam Prefix module with a programmable divergence slit (PDS). PDS is software controlled to operate in one of the two modes:

1. The fixed divergence slit mode, to provide a defined divergence of 4°, 2°, 1°, 1/2°, 1/4°, 1/8° or 1/32°.
2. The automatic divergence slit mode, to provide a defined irradiated length of 20 to 0.5mm steps, with the divergence changing automatically as a function of the angle between the incident beam and the sample surface.
3.2.3 Beam Masks

Beam masks are fitted in the incident beam path to control the axial width of the incident beam, thus defining the amount (width) of the sample that is irradiated by the incident X-ray beam. The size of the beam mask opening must be such that the incident X-ray beam is completely accepted by the sample during the complete measurement. They are available in widths of 5, 10, 15 and 20 mm.

3.2.4 Soller Slits

Soller slits are a set of parallel planes which are fitted into the incident and diffracted beam path parallel to the diffraction plane to control the axial divergence of the X-ray beam.
The X-ray beam can also diverge in the perpendicular direction along the axis of the goniometer which is termed as axial divergence. This is remedied by placing a soller slit between the divergence aperture and its corresponding anti scatter aperture. A soller slit is a collimating optic consisting of parallel foils separated by spacers. This collimator limits the extent of axial divergence, this reduction of axial divergence error is at the expense of transmitted intensity, one of the things that characterize the axial divergence is asymmetry of the peaks.

3.2.5 Anti Scatter Slit

Anti scatter slits are fitted in to the diffracted beam path to control the amount of the diffracted x-ray beam (in the equatorial plane) that is accepted by the detector. They define the length of the sample that is “seen” by the receiving slit. Another function is to reduce level of background radiation, these slits are mainly used when amount of sample powder is very less in that case there is big chance of scattering the X-rays so by minimizing the sample length using anti scatter slit.

3.2.6 Goniometer

The mechanical assembly that makes up the sample holder, detector arm and associated gearing is referred to as goniometer. The system works on the principle of THETA-THETA goniometer where the sample is stationary in the horizontal position while both the X-ray tube and the detector move simultaneously over the angular range theta.
3.2.7 Receiving Slit

In Bragg-Brentano geometry, the incident beam diverges from the tube focus until it irradiates the sample [1]. The diffracted X-ray beam converges from the sample until it reaches its natural focusing point. Receiving slits are fitted on the diffractometer circle at the focal point of the diffracted beam to control the resolution of the measurement. Programmable receiving slit PW 3093/60 is software controlled to provide a defined receiving slit height which can be varied between 0.1 mm and 3.0 mm in steps of 0.01 mm.

3.2.8 Diffracted Beam Monochromator

Diffracted beam Monochromator is situated between the receiving optics and the detector. They are used to reduce the background radiation efficiently, eliminate unwanted line such as $K_{\beta}$ completely and reduce the effect of sample fluorescence. Most common way x-rays are filtered on diffractometers, by choosing a crystal with the d-spacing to focus only on the desired radiation, undesired radiation of all other wavelengths is dispersed and does not enter the detector. Whereas a filter selectively attenuates $K_{\beta}$, a monochromator selectively passes the desired wavelength attenuating other wavelength like high-level bremsstrahlung and other errant radiation from anode contamination. This allows the operation of the x-ray generator optimal accelerating voltages without significantly increasing background “noise” in the detected signal. Curved crystal monochromator consists of a curved (Johann) pyrolytic graphite crystal in a housing with a built in 0.8 mm detector slit. The curvature of the crystal is such that the crystal surface, the receiving slit and the detector slit, all lie on the focusing circle of the monochromator. The monochromator is aligned in a way that it ensures that only the required wavelength passes the detector slit to be collected by the detector.

3.2.9 Detector

The X-ray detector Xenon proportional counter is used to count the number of photons i.e. the intensity of the diffracted beam at the certain 2θ position of the goniometer. X-ray photon ionizes gas (xenon) accelerating
electrons towards the central electrode and during the passage more gas atoms are ionized. This leads to an “avalanche” of electrons at the electrode. Electrical pulse generated by pulse forming circuit are counted by the counting electronics.

3.2.10 Sample Holder and Calibration

   The sample holder is made up of aluminium. It is a plate with a rectangular opening having an area of 15 mm x 25 mm. Powder sample is filled in this rectangular space and compacted by pressing the surface with flat plate. A standard high purity Silicon pellet (circular disk of diameter 25 mm) is used for calibration.

3.2.11 X-ray rating

   The X-ray operating conditions are 45 KV and 40 mA, for routine measurement of powder samples either phase identification or quantitative analysis.

3.3 Energy Dispersive X-ray analysis (EDAX)

   Energy Dispersive X-ray Analysis an integrated feature of a scanning electron microscope (SEM) is a technique used for identifying the elemental composition of the specimen.

   During EDAX analysis, the specimen is bombarded with an electron beam inside the scanning electron microscope. The bombarding electrons collide with the electrons of the specimen atoms, knocking some of them off in the process. A position vacated by an ejected inner shell electron is eventually occupied by a higher-energy electron from an outer shell. The amount of energy released by the transferring electron depends on which shell it is transferring from, as well as which shell it is transferring to. Moreover, the atom of every element releases X-rays with unique amounts of energy during the transferring process. Thus, by measuring the energy released by a specimen the identity of the atom from which the X-ray was emitted can be established. An EDAX spectrum normally displays peak, the higher a peak in a spectrum, the more is the concentration of the element in specimen.
3.4 Transmission Electron Microscopy

Transmission Electron Microscopy (TEM) is a versatile technique to study the particle shape and size distribution of particles of solutions and dry origin. Identification of crystal structure of crystalline particles is done by studying patterns of electron diffraction in TEM.

3.4.1 Principle

Transmission electron microscopy (TEM) is a microscopy technique in which a beam of electrons is transmitted through an ultra thin specimen interacting with specimen. As it passes through sample an image is formed from the interaction of the electrons transmitted through specimen. High energy electrons (up to 300KV accelerating voltage) accelerated to nearly the speed of light behaves like a wave front with wavelength about a million times shorter than light waves. Through a thin-section specimen of a material, electrons are scattered. A sophisticated system of electromagnetic lenses focuses the scattered electrons into an image or a diffraction pattern depending on the mode of operation. The imaging mode provides a highly magnified view of the micro- and nanostructure and ultimately in the high resolution imaging mode, a direct map of atomic arrangements can be obtained. The diffraction mode displays accurate information about the local crystal structure. The nanoanalytical modes (x-ray and electron spectrometry) tell researchers which elements are present in the tiny volume of material. These modes of operation provide valuable information for scientists and engineers in search of stronger materials, faster microchips, or smaller nanocrystals.

3.4.2 Components of TEM

(a) Electron Gun
(b) Electromagnetic Lenses
(c) Apertures
(d) Goniometer
The function of the electron gun is to provide an intense beam of high energy electrons. There are two main types of gun: the thermionic electron gun [3.13(a)] (the most commonly used) and the field emission gun [3.13(b)]. In the thermionic electron gun electrons are emitted from a heated filament and then accelerated towards anode. While in the field emission gun a very strong electric field \((10^9 \text{ Vm}^{-1})\) is used to extract electrons from a metal filament. This gives much higher source brightness than in thermionic guns but requires very good vacuum.
This section describes the working of lenses; it covers the effect of the Electromagnetic, condenser, objective and projector lens in the TEM. The lens is basically used to do two things: (i) Either take all the rays emanating from a point in an object and recreate a point in an image or (ii) focus parallel rays to a point in the focal plane of the lens. In **Electromagnetic Lens** a strong magnetic field is generated by passing a current through a set of windings. This field acts as a convex lens bringing off axis rays back to focus. The image is rotated to a degree that depends on the strength of the lens. **First Condenser lens** create a demagnified image of the gun crossover, control the minimum spot size obtainable in the rest of the condenser system **Second condenser lens** affects the convergence of the beam at the specimen and the diameter of the illuminated area of the specimen. **The Objective Lens** forms an inverted initial image which is subsequently magnified. **Intermediate Lens** magnifies the initial image that is formed by the objective lens. **Projector Lens** is used to vary the magnification in the electron microscope by varying the strength of projector lens and intermediate lens.
Along with different type of lenses various apertures are used for different purpose. Condensed aperture controls the intensity of illumination. Objective aperture is placed in the back focal plane of the image and its function is to select those electrons which will contribute to the image affecting the contrast of image. By inserting the aperture or tilting the beam different type of images can be formed.
(d) **Goniometer**

A Goniometer stage allows the specimen to be traversed and tilted simultaneously so that every part of the specimen can be examined at a variety of angles.

### 3.4.3 Sample Preparation for TEM

Due to strong interaction between electrons and matter in transmission mode of TEM, the specimens have to be rather thin (less than 100 nm). This is achieved with several methods, depending on materials. In the present study samples for TEM were prepared by adding a drop of very dilute solution of the nanoparticles in solvent (methanol/ethanol) directly on the Formvar polymer-coated grids (mesh size 100) using micropipette. The nanoparticles present in the aqueous mixture were allowed to settle and the extra solvent was subsequently removed by placing TEM grid on a neat filter paper and dried it at ambient temperature condition for half day.

### 3.4.4 Formation of Image

When we form images in TEM, we either form an image using the central spot, or we use some or all of the scattered electrons. The way we choose by which electrons form the image is to insert an aperture into the back focal plane of the objective lens, thus blocking out most of the diffraction pattern except that which is visible through the aperture. We use the external drives to move the aperture so that either the direct electrons or some scattered electrons go through it. If the direct beam is selected we call the resultant image a bright-field image, and if we select scattered electrons of any form, we call it a dark-field image.

### 3.5 SQUID Magnetometer

#### 3.5.1 General description and theory

SQUID (Superconducting quantum interference devices) are the most sensitive detectors of magnetic flux. It consists of a superconducting ring interrupted with either one or two Josephson junctions.
SQUID combines two physical phenomena,

(i) **Flux quantization**: The fact that the flux $\phi$ in a closed superconducting loop is quantized in the units of $\Phi_0$.

(ii) **Josephson tunneling**.

A SQUID is a flux to voltage transducer. It can measure any physical quantity that can be converted to a flux, e.g. magnetic field, magnetic field gradient, current, voltage displacement and magnetic susceptibility. As a result their applications are wide ranging from the detection of tiny magnetic fields produced by the human brain and the measurement of fluctuating magnetic fields in remote areas to the detection of gravity waves and the observation of spin noise in an ensemble of magnetic nuclei.

![Fig 3.16: Photograph of quantum design (MPMS XL) at TIFR (Mumbai)](Image)

Quantum Design SQUID (MPMS XL) magnetometer has been used in present study to measure the magnetic properties [Fig.3.16]. The MPMS system comprises of two main sections; SQUID assembly and the electronic control system. The probe contains a high precision temperature control system, allowing measurements from 1.9K to 400K with an accuracy of 0.01K. Typically, the sample temperature is controlled by helium gas flowing slowly
past the sample. The temperature of this gas is regulated using a heater located below the sample measuring region and a thermometer located above the sample region. This arrangement ensures that the entire region has reached thermal equilibrium prior to data acquisition. The helium gas is obtained from normal evaporation in the Dewar, and its flow rate is controlled by a precision regulating valve. The dewar consists of an inner liquid helium reservoir and outer liquid nitrogen jacket to reduce excessive liquid helium boil off. Liquid helium system provides refrigeration for the superconducting detection system and magnet, as well provides the operation down to 1.9K.

![Fig. 3.17: Schematic diagram of SQUID](image)

The superconducting magnet system which provides reversible field operation up to ± 7 Tesla uses an oscillatory technique to minimize magnetic drift immediately following field changes. The sample handling system (sample translator and sample transport) allows automatic sample measurements and position calibrations using a microstepping controller having a positioning
resolution of 0.0003 cm. Sample is mounted within a plastic straw and connected to one end of a sample rod which is used to position the sample within the center of the SQUID pickup coils. The SQUID detector system includes SQUID amplifier control electronics, sensing pick up loop and specially design filtering with computer control via the interface computer.

SQUID magnetometers have a homogeneous superconducting magnet to create a very uniform field over the entire sample measuring region and the superconducting pickup loops. The magnet induces a moment allowing a measurement of magnetic susceptibility. The superconducting detection loop array is rigidly mounted in the center of the magnet. This array is configured as a gradient coil to reject external noise sources. The detection coil geometry determines what mathematical algorithm is used to calculate the net magnetization.

An important feature of SQUID is that the induced current is independent of the rate of flux change. This provides uniform response at all frequencies i.e., true dc response and allows the sample to be moved slowly without degrading performance. As the sample passes through a coil, it changes the flux in that coil by an amount proportional to the magnetic moment M of the sample. The peak-to-peak signal from a complete cycle is thus proportional to twice M. The SQUID sensor shielded inside a niobium can is located where the fringe fields generated by the magnet are less than 10 mT. The detection coil circuitry is typically constructed using NbTi. This allows measurements in high applied fields while maintaining sensitivity.

3.5.2 MultiVu : Measurement Software for SQUID

MPMS MultiVu is a 32-bit, Windows 95 based application that controls and monitors the operation of the MPMS hardware and the operation of installed MPMS options. It integrates all system operations into one versatile and easy-to-use Windows 95 interface. System operation is simplified; multiple commands that open files, run measurements, or set parameters are always enabled. The
control center and status bar in the MPMS Multi Vu interface display status information. Menu options and command buttons in the MPMS MultiVu interface perform all manual and automated MPMS tasks. Immediate instrument status feedback information displayed in the interface indicates the current system status. The interface allows immediate control of the MPMS for performing a wide variety of standard tasks, such as changing the temperature or magnetic field, running measurements, or logging system data. The interface also allows most functions of the MPMS and the MPMS options to be automated by using a series of simple commands, called a sequence. MPMS MultiVu provides the sequence editor and the commands that initiate and control the running sequence. Data can be viewed in a graphic, tabular, or raw data format in real time during automated operation, or it can be viewed after it has been collected.
REFERENCES

5. PANalytical Make X’ Pert PRO MPD manual.