Chapter 1

Introduction

1.1 Evolution of channeling concept:

In the beginning of 20th century, the X-ray diffraction experiments revealed that scattered photons propagate through the open crystal channels with relative ease[1]. This consequently lead to conjecture about the transmission of charged particles through these open channels in crystals. Thus X-ray diffraction experiments brought the fact into light that the crystals have open space, apart from their regular arrangement of atoms and hence contain open channels. In order that charged particles should pass through these crystallographic channels, they need to meet two essential requirements [2]. (1) The particle should find sufficient open space between the atomic rows (as realized from the Braggs diffraction). (2). As the particle propagates along the channel, there should be a driving force to prevent the possible close collisions with the atoms and at the same time steer the particle towards the middle axis of the open channel. Keeping these conditions in mind, Stark proposed an experiment in 1912 with protons [3]. However this suggestion was overshadowed by the intense activity in X-ray diffraction in crystals at that time. Much later in early sixties, a series of experiments were performed and this eventually lead to the discovery of the Channeling phenomena. These experiments are basically either measurement of the ranges [4] or sputtering experiments [5,6]. The later one showed that the sputtering ratio for ions impinging into single crystal depends upon the orientation of the crystal [5].
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The computer simulations by Robinson and Oen on 1-10 keV Cu atoms [7] in various targets indicated that the ions with initial velocities lying close to the principal axial directions penetrate to abnormally larger distances in the crystal.

The incident beam is effectively resolved into two components namely, channeled and random components. In general, the random component undergoes statistically independent atomic collisions during the process of its passage through a crystalline solid and suffers energy loss which is identical to that expected for an amorphous material. As shown in Fig. (1.1), the channeled component avoids all the close impact parameter phenomena and the particle gets steered along the axial or planar channels.

Fig. 1.1: The channeling phenomena showing how the particle is steered along an open channel in the crystal.
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The effects of these channeling and blocking are studied by defining a limiting distance of approach to the atomic rows/planes of atoms. Especially for the channeling studies, where we are interested in the successful transmission of these charged particles through the open channel, this closest distance of the approach depends on the angle of incidence. In order to avoid possible large angle scattering, we define a small limiting angle of incidence, within which a particle must enter before it can pass through the rows/planes of atoms. Providing the angle to these crystallographic scattering centers is always less than this \textit{limiting value}, the particle trajectory will be constrained to move in open space (regions of low electron density) and the large angle scattering will be avoided. On the other hand, those particles which do suffer large angle scattering, are deflected by these atomic rows and planes at an inclination which is always greater than this same \textit{limiting angle}. So in a perfect crystal, therefore, the channeled and random components are mutually exclusive and this angle decides the fate of the particle beam and hence called as \textit{Critical angle}. That means those particles which are injected into the crystal with an angle greater than this critical angle, suffer a total scattering. So critical angle and corresponding closest distance of approach discussed earlier are very essential parameters, in channeling situations.

This \textit{Channeling} phenomena is further demonstrated by the experiments with monocrystalline targets [8a]). This channeling technique has vide range of applications and significant amount of work on channeling and its applications has been done during last three decades as several review articles and books are already published. Lindhard's theory of channeling and continuum approximation are widely used to study the dynamics of the projectile particle during its propagation inside the crystal and these are discussed briefly in the following sections.
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1.2 Theory of Channeling - Continuum model:

When the charged particles incident nearly parallel to major crystal axis/plane, the ion trajectories are governed by correlated soft collisions with atoms. These collisions are in such a way that hard collisions are avoided. As mentioned in earlier section, channeling is basically the influence of the crystal on the ion - trajectories penetrating into the crystal. Hence this term so called Channeling visualizes atomic rows and planes “acts” as guides that steer the charged particles along the crystallographic channels by means of correlated small angle soft collisions. This condition is to avoid the processes like RBS, innershell excitation etc., which eventually lead to the scattering of the beam from the actual path of propagation. During the propagation of the charged particle along a channel, the projectile interacts with the free electron gas and some of the outer shell electrons of the target atoms.

If an incident charged particle happens to bombard the crystal along one of the crystallographic directions, (say for example < 110 > axial channel [86]) in diamond as shown in Fig. (1.2)), it is likely to penetrate into the crystal to much larger distances than a particle with random direction. When a charged particle moves along these directions, under certain conditions it may not be able to feel the interaction due to individual atoms sitting at various lattice sites but rather experiences a collective effect of all the atoms sitting along that particular axial or planar direction; so that the moving particle will experience only continuum strings or planes. Incorporating these points, Lindhard [9] and Erginsoy [10] obtained mathematical relationship between the time of flight and the collision time. The particle velocity component parallel to the axial or planar direction is such that the time of flight to cross one lattice spacing is less than the collision time with any individual atom. This collision time depends on transverse velocity with which particle approaches that particular atom.
Fig. 1.2: View down the <110> axial channel in a diamond structure showing the spiral path followed by a typical channeling particle.
That means by the time the particle can feel to be in the field of one atom, it is already in the field of next atom along the string or plane and it will see only continuum potential instead of individual atom field. This condition for continuum approximation can be written as

\[
\frac{r_{\text{min}}}{v \sin \psi} > \frac{d}{v \cos \psi}
\]  

(1.1)

As shown in Fig. (1.3), ‘\(r_{\text{min}}\)’ is distance of minimal approach to the string; ‘\(d\)’ is interatomic spacing along the axis; ‘\(\psi\)’ is angle that the incident particle moving with velocity \(v\), makes with the channel.

Fig. 1.3 : A channeled trajectory showing various quantities like incident angle minimum distance of approach and interatomic distance.
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Here ‘\( r_{\text{min}} \)’ is obtained by equating the repulsive interaction due to continuum string, with the transverse kinetic energy as

\[
U(r_{\text{min}}) = E \sin^2 \psi .
\]  

(1.2)

The continuum potential \( U(r) \) for axial case is given by

\[
U(r) = \frac{1}{d} \int_{-\infty}^{\infty} dz V(\sqrt{(z^2 + r^2)}),
\]  

(1.3)

where \( r \) is the distance from the string and \( V(R) \) is interatomic potential.

Comprehensive work has been done regarding the choice of interatomic potential. These potentials are derived by various methods and each of them has its own advantages and draw backs. Out of these potentials Lindhard’s potential, statistical potential and power law potential proposed by Pathak are most frequently used potentials. Lindhard’s standard potential is used for calculating various parameters like critical angle etc. This potential is given by

\[
V_{LS}(R) = Z_1 Z_2 e^2 \left[ \frac{1}{R} - \frac{1}{\sqrt{R^2 + C^2 a_{TF}^2}} \right] \tag{1.4}
\]

where \( C \) is Lindhard constant (= \( \sqrt{3} \)) and \( a_{TF} \) is Thomas-Fermi screening radius given

\[
a_{TF} = \frac{0.8853}{\sqrt{Z_1^{2/3} + Z_2^{2/3}}} a_o
\]  

(1.5)

where \( a_o \) is Bohr radius; \( Z_1 \) and \( Z_2 \) are the atomic numbers of the incident ion and target atom respectively.

Substituting in (1.3) and evaluating the integral one gets

\[
U(r) = \frac{Z_1 Z_2 e^2}{d} \ln \left[ (C a_{TF}/r)^2 + 1 \right]
\]  

(1.6)
In high energy limit, \( r \) values will be small because particle approaches closer to atom and rows so that \( C a_{T,F} / r \gg 1 \) for most of the \( r \) values, hence

\[
U(r) = \frac{2Z_{1}Z_{2}e^{2}}{d} \ln \frac{C a_{T,F}}{r}.
\]  

(1.7)

From Eqns. (1.1) & (1.6) the range of validity of continuum approximation is given by

\[
\psi < \frac{\sqrt{\frac{2Z_{1}Z_{2}e^{2}}{dE}}}{E} \quad \text{(for higher energies i.e., } E > \frac{2Z_{1}Z_{2}e^{2}d}{a_{T,F}^{2}})\). \tag{1.8}

However for low energies i.e., \( E < \frac{2Z_{1}Z_{2}e^{2}d}{a_{T,F}^{2}} \); \( r \) is generally large (including \( r_{\min} \)) and one should use full expression (1.6); so that the condition (1.1) leads to

\[
\psi < \frac{C a_{T,F} \psi_{1}}{d \sqrt{2}} \tag{1.9}
\]

A planar channeled positively charged particle travels large distances before its transverse momentum is significantly altered. Consequently it is a good approximation to regard the force exerted on the channeled particle as arising from a conservative, one dimensional potential which is the planar average of the electrostatic potential with in the lattice. So for planar case the continuum potential is obtained by averaging over the particular plane and given by

\[
V(y) = 2\pi N_{p} \int_{0}^{\infty} r V(\sqrt{r^{2} + y^{2}}) dr \tag{1.10}
\]

For Lindhard standard potential (Eqn. 1.4), the above potential takes the form

\[
V(y) = 2\pi Z_{1}Z_{2}e^{2}N_{p}[\sqrt{y^{2} + c^{2}a_{T,F}^{2}} - y] \tag{1.11}
\]

where \( N_{p} = N d_{p} \) is planar density of atoms, \( N \): bulk density of atoms in the crystal, \( d_{p} \): Interplanar spacing, \( y \): distance measured from the plane.

The critical angle for planar channeling is given by

\[
\psi_{p} = \sqrt{\frac{2\pi N_{p}Z_{1}Z_{2}e^{2}a_{T,F}}{E}} \tag{1.12}
\]
1.2.1 Interatomic potentials:

A thorough knowledge of the interatomic potential is essential for better understanding of various physical phenomena in the field of ion-solid interactions in general and channeling in particular. The choice of potential for use in the atomic scattering calculations has been discussed by Lindhard et al. [11]. For most of the scattering calculations, where overall effects are involved, the Thomas-Fermi statistical model is good enough in accuracy for most of the experimental situations. Anything beyond this statistical model of Thomas-Fermi, requires computer calculations.

Other forms of interatomic potentials [12] used include Moliere potential, Born-Mayer potential etc.

\[
V_{M_0}(R) = \frac{Z_1 Z_2 e^2}{R} \left(0.35e^{-bR} + 0.55e^{-4bR} + 0.1e^{-20bR}\right)
\]  

(1.13)

where \( b = 0.3/a_{T,F} \)

\[ a_F = \frac{0.8853}{(Z_1^{1/2} + Z_2^{1/2})^{2/3}} a_o \]

(1.14)

For \( Z_1 \ll Z_2, a_F \approx a_{T,F} \).

Sometimes Born-Mayer [13] and Bohr [14] potentials have also been used.

\[
V_{BM}(R) = A_{BM} \exp(-R/a_{BM}) ,
\]

(1.15)

\( a_{BM} \) is Born-Mayer screening radius.

Bohr potential is a simple potential of screened Coulomb type and given by

\[
V_{BO}(R) = \frac{Z_1 Z_2 e^2}{R} \exp(-R/a_b)
\]

(1.16)

\[
a_b = a_o (Z_1^{2/3} + Z_2^{2/3})^{-1/2}
\]

(1.17)
Here $a_b$ has the drawback of excessive screening at large distances so that potential decreases too rapidly to fit actual ion-atom interactions. There is no single potential which can be used for all analytical calculations in the context of ion solid interactions in general and for effects of defects in particular. Alternative mathematical approximations of both planar [15] and axial [16] potentials have been made in order to get some analytical results in complicated problems involving the effects of defects like dislocations and stacking faults [17] etc., on channeling. Another form of potential proposed by the Pathak [18] is analytically simple, especially for the study of defects and dechanneling of the particles and hence it has been used extensively. So we use this potential throughout the thesis which is given by

$$V_{PM}(R) = \frac{Z_1 Z_2 e^2}{R} \frac{Ca_{T.F}^2}{(R + a_{T.F})^2} \quad (1.18)$$

Substituting $V_{PM}(R)$ in Eqn. (1.10), one gets

$$V_{PM}(y) = 2\pi Z_1 Z_2 e^2 N_p \int_0^\infty r \frac{1}{\sqrt{r^2 + y^2}} \frac{Ca_{T,F}^2}{(\sqrt{r^2 + y^2} + a_{T,F})^2} dr \quad (1.19)$$

Evaluation of this integral is straightforward and one gets as

$$V_{PM}(y) = \frac{2\pi Z_1 Z_2 e^2 N_p C a_{T,F}^2}{u + a_{T,F}} \quad (1.20)$$

As shown in Fig. (1.4), $l$ is half width of planar channel ($l = d_p/2$); $d_p$ being the interplanar distance, $x$ is the distance measured from the axis of the channel in the transverse direction, $x_c \approx a_{T.F}$ is distance of closest approach. The potential experienced by the particle in the channel is superposition of the potential due to both the planes (i.e., $V_{PM}(l \pm x)$) which is given by

$$V_{PM}(x) = 2\pi Z_1 Z_2 e^2 Ca_{T,F}^2 N_p \left( \frac{1}{l + a_{T,F} - x} + \frac{1}{l + a_{T,F} + x} \right) \quad (1.21)$$
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1.3 Applications of Channeling:

The radiation damage studies on charged particle propagation have been essentially motivated by the technological importance of radiation damage in materials science. Charged particle propagation through damaged solids has been used mostly either as a probe for studying the defects themselves or for changing structural, mechanical or electrical properties of materials by implanting the required species into the host.

1.3.1 Study of defects (radiation damage):

Channeling technique is very useful in the study of both point and as well as extended defects in the solid. One can really pin point the exact position of the foreign impurity by performing channeling experiments [19] in various crystallographic directions. The channeling back-scattering technique has now been extended even to identifying the orientations formed by the foreign atoms or self interstitials with the irradiation-induced interstitial of the host lattice. One can study the nature and concentration of damage already present depending upon energy; dechanneling cross-section etc and these are discussed in the next section.
1.3.2 Surface Studies:

The application of ion beams to surface physics has been investigated by several authors [20, 21], both for pure and clean surfaces. Using channeling technique, one can deduce information on the structure of a few surface layers. At the same time one can measure the amount of strain present in these defective and damaged surfaces. This is very important especially in fabrication of semiconductor devices, where the knowledge and control of damage can be enormous value in technological applications.

1.3.3 Ion implantation in technology:

By ion-implantation it is possible to change various kinds of properties especially in semiconductor technology. The most important and useful application is to devices where, mainly three effects are used:

(i) Impurity doping, where the doping amount as well as the depth distribution is required to be known for optimum use of the doped material.

(ii) Compound formation at the surface and in the bulk of silicon crystals to get known thickness and concentration.

(iii) Disorder introduction.

Ion implantation technique is also used in solar cell fabrication.

1.3.4 Channeling Radiation:

The idea that the oscillatory motion of channeled charged particles should lead to emission of radiation has been discussed from the very beginning, on the basis of electrodynamics. However since the oscillatory frequencies $\omega_c$ are low, the corresponding energies $\hbar \omega_c$ are of the order of a few eV only, the observation of the radiation seemed
difficult. The realization that relativistic effects will shift the photon energy into keV or even Mev region was a turning point, and the radiation was in fact observed for the case of positrons about 20 years ago [22]. This channeling radiation has been studied for the past 20 years and the subject has been reviewed by several authors [23]. Theory was formulated [24] in the relativistic quantum mechanical framework and the experimental confirmation is made for the case of positrons [22] and electrons [25]. Another interesting phenomena so called quasi-channeling is discussed by Henry Makowitz [26], with specific reference to positrons and electrons, where it has also been outlined regarding their feasibility to construct a short wave length laser. The radiation as a result of scattering of the channeled electrons by the point defects has been shown to be coherent [27] which again can be applied for generating tunable lasers.

Apart from their direct application, this observation of radiation from channeled ions has opened possibilities of new applications in the fields of laser physics and medicine as a source of hard X-rays and 7-rays for nuclear pumping, hence for possible construction of a γ-laser. These X-rays created as part of channeling, opens new perspectives in plasma physics research, laser technology and medicine. This lead to new phenomena namely photon channeling and related X-ray optics [28].

1.3.5 Beam extraction by bent crystal channeling:

The deflection of the charged particle beam using a curved crystal is distinctly different from deflection with a magnet. The amount of deflection is entirely determined by the physical curvature of the crystal planes, along which the particles are channeled. This effect namely steering of high energy (GeV) particles through bent crystals has tremendous practical applications [29]. A well channeled positive particle will follow the curved path along the bent channel, provided the curvature of the crystal is not too large to cause heavy dechanneling of the particle beam. However, dechanneling still
occurs due to ordinary dechanneling as well as because of the bending process. Bending of the crystal is basically equivalent to introducing a centrifugal energy potential and thereby lowering one side of the potential well and raising the other. So actual potential well in the channel is modified by this linear centrifugal energy barrier which depends upon the local curvature. As a result the channeled fraction of the beam followed the direction of the downstream end of the crystal. Tsyganov [30a]) estimated the critical radius of bending as $R_T = E/eE_c$, where $E$ is total energy of the particle and $E_c$ is the interatomic electric field intensity at a distance from the plane at which the particle is unstable due to interaction with individual atoms. This critical radius can be related to an equivalent magnetic field for a relativistic particle in a magnetic field as $R = p/0.03B; p \text{ in GeV}/c$, $B$ is in kG and $R$ in m. This crystal field is very strong and exceeds by many orders of magnitude as compared to external magnetic field produced in the laboratory. A more important selection involves incident particle direction. To be deflected, the particle must be incident within the critical angle for channeling along the particular plane being used. Even for the particles incident within the planar angle, those with large divergence will be lost more rapidly, as the critical curvature or the particle momentum are increased. This technique is very useful, especially for bending and focussing of the particle beam. Baublis et. al. [306]) reviewed regarding these bent crystal channeling experiments and preparation of the suitable crystals for these experiments.

1.4 Dechanneling by defects:

It is well known fact that real crystals are never perfect as they contain lattice defects which lead to dechanneling. The most general kinds of defects found in solids are vacancies, self interstitials, foreign atoms, stacking faults, grain boundaries, dislocations,
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voids, gas bubbles, etc.. Even if the defects are not present before irradiation of the crystals, they are created during particle propagation and hence affect the propagation of the particles self-consistently. This reflects the importance of the ion beam interaction with the defects.

A charged particle propagating through real solids can see the presence of the defects through the effects these defects will produce in the solids. Classically the particle can see the presence of defects by either direct obstruction of the particle path, or distortion produced in the crystals. When the projectile is affected by the potential of the defect, its trajectory is modified. These effects are of obstruction type. Examples are stacking faults, interstitial atoms, grain boundaries etc. If the defects give rise to distortion in a certain region of the crystal, disturbing the regularity of the material in that region, the effects are of distortion type, for example dislocations. These two kinds of defects give rise to obstruction dechanneling and distortion dechanneling respectively.

But the dechanneling may also be caused by the combination of the both, and in such cases this dechanneling is neither purely of obstruction type nor of distortion type and this phenomena is called composite dechanneling. This happens because of the fact that the defects produced in the solid are not uniquely of one type but a combination of different kinds of defects or because the defect itself gives rise partly to obstruction effects and partly to distortion effects, for example gas bubbles, Guinier-Preston zones etc. There are enormous applications of study of gas bubbles in nuclear reactors. During the process of nuclear fission, fragments are released into the fuel which have some atomic mass distribution and few of these fragments consist of inert gasses such as Kr, Xe. These inert gas atoms are not able to form compounds and take the form of an agglomerate provided their mobility in the solid is sufficient. These agglomerates are called gas bubbles. The effects of these gas bubbles on the channeled particles have been studied by Quere et al.[31]. Two main sources of dechanneling
by these gas bubbles are (i) The charged particle is scattered in the bubble by gas atoms which causes change in trajectory and transverse energy $E_\perp$ of the particle. (ii) it may touch the exit surface and get dechanneled, though there is no change in ‘$\psi$’. Another very important application of gas bubbles in materials science relevant to reactor physics is, in connection with blistering studies[32] where the escape gas bubbles from the material surface induces drastic changes in the surface properties. In contrary to these gas bubbles, another kind of imperfections namely Guinier-Preston(G.P.) zones distort the lattice and give rise to hardening. These zones are basically small clusters formed by super saturated solute atoms in several alloys. The dechanneling method is a fairly sensitive method for observing and studying the precipitation of these G.P. zones [33].

Channeling and back scattering experiments with energetic ions have been widely employed for defect analysis in *Ion-implanted semiconductors* [34]. In the aligned spectra, a well resolved disorder peak is usually observed at the range of the implanted ions, originating from the direct back scattering of the probe particles from the displaced atoms. However, aligned back scattering spectra from the ion bombarded metals indicated an increase in dechanneling yield and show no damage peak [35]. The simultaneous use of channeling, back scattering and TEM [36], is a promising procedure to correlate the dechanneling observations with damage configurations. In addition, dechanneling analysis itself is effective technique by which different types of defects may be separated out. This differentiation is possible on the basis of the qualitative energy dependence on dechanneling cross sections [37] and dechanneling yields obtained by defect analysis [38]. The qualitative energy dependence of these yields carry the information on the kind of defects present in the material. For example, $\sqrt{E}$ dependence indicate dislocations, $E^0 \rightarrow$ stacking faults, gas bubbles [39] and $E^{-1} \rightarrow$ randomly distributed atoms.
1.5 Quantum-Mechanical Effects:

Lindhard's classical theory of channeling provides a complete description of channeling phenomena for relatively heavy ions. However when the work on electron microscopy especially TEM with crystalline materials was being extended to channeling phenomena, there were clear indications of quantum and diffractional effects dominating the patterns. The quantum mechanical treatments [40] indicated that it is the product of the mass of the particle and the strength of the interaction between the particle and the crystal which determines applicability of classical or quantum picture. The classical features start becoming dominant as this product increases. This product should be small for the validity of quantum mechanical treatments. These have been revealed infact in electron and positron channeling; the angular dips for these particles show a fairly oscillating structure [41]. Thus protons and all other heavier ions behave classically whereas electrons, positrons, neutrons and mesons would be expected to behave quantum-mechanically [42]. Chadderten [43] outlined that even protons also exhibit wave particle nature when their energy is very low (~ few keV). Though neutrons are as heavy as protons, the Fourier component of the potential strength is still weak so that the product of mass and potential strength remains small and hence diffraction effects are dominant.

Moreover, inorder that diffractional effects to be observed, it is necessary that dimensions of the regions/obstacle, limiting the motion of the particle (normally this is ~ lattice period) must be appreciably larger than the de Broglie wave length associated with the particle [44], similar to the situations in wave optics. This de Broglie wave length can be estimated by the equation $\lambda = \frac{hc}{E}$ where, $h$ is plank constant, $c$ is speed of light and $E$ is energy of the particle. This de Broglie wave length, say for example 12Mev positrons is $\sim 10^{-3}\text{Å} [45]$. It is well known that GeV electrons ($\lambda \sim 10^{-14}\text{cm}$) are
used to study the nuclear structures, because these are of the dimensions of \(\sim 10^{-12}\text{cm}\) and the particle wavelength here is much smaller than \(10^{-12}\text{cm}\).

Quantum mechanically, the longitudinal and transverse components are separated out [46], the transverse motion for positively charged particles (like positrons) is described by one dimensional Schrodinger equation with a harmonic oscillator potential where, the potential minima are located at middle axis of the axial/planar channel. For electrons, the potential minima are at the center of the atomic strings or planes and channeled electrons have an increased probability for hard collisions with atoms. So the transverse potential for electrons is approximated to one dimensional hydrogen atom [47]. This implies that channeling states for electrons are much less stable than for positrons [48] and the maximum number of quantum states supported by the transverse potential (say \(n_{\text{max}}\)) for positrons is smaller than that for the electrons. So the solutions of the corresponding Schrodinger equations for electron as well as positron, gives rise to quantized transverse energies. Hence number of quantum states are formed and the transverse energy assumes a series of discrete values. The maximum number of bound states supported by transverse continuum potential increases with the relativistic particle mass i.e., \(n_{\text{max}} \propto \sqrt{\gamma m}\), where the Lorentz factor, \(\gamma = 1/\sqrt{1 - v^2/c^2}\) and \(m\) is the rest mass of the particle.

The validity of classical or quantum picture has also been discussed on the basis of correspondence principle [49]. As mentioned earlier, when the particle energy or the mass of the particle increases, the number of quantum states supported by the transverse potential also increases \((n_{\text{max}} \propto \sqrt{\gamma m})\). So obviously, for heavy ions and high energy electrons/positrons, the motion becomes more classical. However quantum effects are dominant when the number of quantum states supported in the potential well is small and this is the case for light particles (electron/positron) of Mev energy. The assumption of separation of transverse and longitudinal motion is fairly accurate
and we continue to use it in our present Quantum descriptions also.

As mentioned in the earlier section, charged particle can be used as probe to study various defects present in the crystals. In this connection the light particles especially positrons are found to be very useful as they are more sensitive to probe various kinds of defects present in the solid [50]. More over these light particles can also be used for the possible construction of the three dimensional holography [51], which is another potential area of current research.

1.6 Outline of the Thesis:

The most of the work on dechanneling by defects is based on several simplifying assumptions restricting the validity of the results. For example, although qualitatively the results on energy dependence etc., are reliable, quantitatively the accuracy is poor. Therefore more work, possibly using quantum mechanical and/or field theoretical techniques is needed to treat the whole defect problem in a more accurate way. In this spirit quantum mechanical formulations have been made and theoretical descriptions for extended defects like stacking faults and dislocations are given.

In Chapter 2, we discuss about the evolution of dechanneling concept in quantum mechanical framework. We present a quantum mechanical formulation for effects of stacking faults on dechanneling. At the stacking fault boundary, the quantum states in the transverse potential make transitions for which probabilities have been calculated using sudden approximation. However, the continuum potentials in particular used in the discussion are in principle valid for infinite planes where in the case of stacking fault we had half planes i.e., those ending at the fault and those starting from the fault. So the transverse potential is slightly complicated just at the interface and one has to match the appropriate basis wave functions at the interface of the stacking fault
boundary. An estimation regarding the effects of periodicity of transverse potential on dechanneling probabilities is made.

In chapter 3, a quantum mechanical treatment of the effects of dislocations on planar dechanneling is given. The effects of channel distortion due to dislocation are incorporated through a relativistic centrifugal energy term. We evaluated the number of quantum states supported by this distorted channel and the transition probabilities among these states due to distortions in the planar channel; the resulting dechanneling probabilities for varying distortion are calculated using sudden approximation. The energy dependence of these dechanneling probabilities for initially well channeled particles has been estimated and we show that it varies linearly with energy for relativistic particles.

In chapter 4, a quantum mechanical formulation is developed by relaxing the sudden approximation used in the chapters 2 and 3, where bound-bound transitions are considered. In this chapter we consider the transitions from these bound states to scattering states due to lattice distortions in the planar channel, using time dependent perturbation theory. The resulting expressions for dechanneling probabilities and hence for dechanneling cross-section for initially well channeled particles has been estimated and qualitative features like dechanneling radius, energy dependence etc., are discussed.

Chapter 5 contains a summary of work, concluding remarks and comments on possible future directions of research work in this field.
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