Heavy-Ion-Irradiation-Induced Disorder
in Indium Phosphide and Selected
Compounds

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This thesis does not incorporate any material previously submitted for a degree or a diploma at any university and to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

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Ali Khalil
February 2007
In the name of God, the most Gracious, the most Merciful

Dedicated to
My parents, my son Saied
and
the loved ones no longer in our world whose
presence is constantly felt

Believe those who are seeking the truth; doubt those who find it

André Gide (1869-1951)
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ABSTRACT

Indium phosphide (InP) is an important III-V compound, with a variety of applications, for example, in light emitting diodes (LED), InP based photonic crystals and in semiconductor lasers, heterojunction bipolar transistors in integrated circuit applications and in transistors for microwave and millimeter-wave systems. The optical and electrical properties of this compound can be further tailored by ion implantation or prospectively by swift heavy ion beams.

Thus knowledge of ion-induced disorder in this material is of important fundamental and practical interest. However, the disorder produced during heavy ion irradiation and the subsequent damage accumulation and recovery in InP is far from being completely understood. In terms of the damage accumulation mechanisms, the conclusions drawn in the numerous studies performed have often been in conflict with one another. A factor contributing to the uncertainties associated with these conflicting results is a lack of information and direct observation of the “building blocks” leading to the ultimate damage created at high ion fluences as an amorphous layer. These building blocks formed at lower fluence regimes by single ion impacts can be directly observed as isolated disordered zones and ion tracks for low energy and swift heavy ion irradiation, respectively.

The primary aim of this work has thus been to obtain a better understanding of the disorder in this material through direct observations and investigation of disorder produced by individual heavy ions in both energy regimes (i.e. elastic and inelastic energy deposition regimes) especially with low ion fluence irradiations. In this thesis the heavy ion induced disorder introduced by low energy Au ions (100 keV Au⁺) and

high energy Au (200 MeV Au^{+16}) ion irradiation in InP were investigated using Transmission Electron Microscopy (TEM), Rutherford Backscattering Spectrometry (RBS/C) and Atomic Force Microscopy (AFM).

The accumulation of damage due to disordered zones and ion tracks is described and discussed for both low energy and swift ion irradiation respectively.

The in-situ TEM annealing of disordered zones created by 100 keV Au^{+} ion irradiation shows that these zones are sensitive to electron beam irradiation and anneal under electron energies not sufficient to elastically displace lattice atoms, i.e. subthreshold energies for both constituent atoms In and P.

Ion tracks due to swift heavy ion irradiation were observed in this material and the interesting track morphology was described and discussed. The surface nanotopographical changes due to increasing fluence of swift heavy ions were observed by AFM where the onset of large increase in surface roughness for fluences sufficient to cause complete surface amorphization was observed.

In addition to InP, the principle material of this project, a limited amount of TEM observation work has been performed on several other important compounds (apatite and monazite) irradiated by 200 MeV Au^{+} ions for comparative purposes. Again the observed segmental morphology of ion tracks were shown and possible track formation scenario and structure were discussed and similarities were drawn to the previously observed C_{60} cluster ion tracks in CaF_{2} as more knowledge and data base exist about defect dynamics and formation in that material.
PART II: Swift heavy ion irradiation of InP................................................. 67

CHAPTER 5: General Overview................................................................. 69
5.1. SHI damage and ion tracks: Description of track formation.................... 69
5.2. Ion tracks in SHI irradiated elemental and compound semiconductors:
   Direct TEM observations........................................................................ 76

CHAPTER 6. Experimental techniques..................................................... 80
6.1. Sample preparation............................................................................. 80
6.2. SHI Irradiation for track formation.................................................... 82
6.3. Transmission Electron Microscopy (TEM).......................................... 84
6.4. Atomic Force Microscopy (AFM)......................................................... 84

CHAPTER 7. Ion track registration in InP.................................................. 87
7.1. Ion tracks in InP.................................................................................. 87
7.2. On the track morphology in InP.......................................................... 93
7.3. HRTEM of ion tracks cores in InP....................................................... 104
7.4. Inelastic collision-induced amorphization in SHI irradiated InP............ 109
7.5. Thermal and electron beam-induced annealing of tracks in InP............ 113
7.5.1. Thermal annealing of tracks............................................................ 113
7.5.2. Electron-beam induced annealing of tracks..................................... 115
7.6. Observations of track peculiarities: Do close tracks interact?................. 118
7.7. Summary............................................................................................ 119

CHAPTER 8. Surface modifications due to high inelastic energy loss in InP.... 120
8.1. SHI induced modifications of semiconductor surfaces........................ 120
8.2. SHI induced modification of the InP (001) surface............................... 124
8.3. Summary............................................................................................ 136
PART III: Swift heavy ion irradiation of further selected compound crystals... 137

CHAPTER 9. TEM observation of SHI tracs in further selected compound crystals: apatite and monazite………………………………………………………… 139
9.1. Some general remarks…………………………………………………………… 139
9.2. SHI irradiated apatite…………………………………………………………… 144
9.3. SHI irradiated monazite………………………………………………………… 149
9.4. Track formation in apatite and monazite……………………………………….. 159
9.5. Summary………………………………………………………………………… 166

CHAPTER 10. Conclusions and Future work…………………………………… 167
10.1. Conclusions……………………………………………………………………. 167
10.2. Future work……………………………………………………………………. 171

APPENDIX I. Image formation in the Transmission Electron Microscope……… 173
A.I.1. The multi-slice model and the phase grating approximation………………. 173
A.I.2. Two-beam dynamical diffraction and the column approximation…………… 175

APPENDIX II. SRIM simulations………………………………………………… 179

APPENDIX III. Analogues to hydrodynamics in several solid state phenomena… 181

REFERENCES……………………………………………………………………… 185