

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Introduction	1
1.2	Geometry of Monolayer Graphene	2
1.3	Tight Binding Model for Monolayer Graphene	2
1.4	$k \cdot p$ Model for Graphene	4
1.5	Symmetries of Graphene	6
1.5.1	Geometrical Symmetries	6
1.5.2	Matrix Representation of $c_{6v''}$	6
1.5.3	Symmetries and Degeneracies	8
1.5.4	Time Reversal Symmetry	9
1.6	Coupling to the Electromagnetic Field	9
1.7	Landau Level Spectra	10
1.8	Spectra of Bilayer Graphene	11
1.9	Hexagonal Boron Nitride	12
1.10	The Moiré Pattern	13
1.11	The Moiré Magnifying Glass	15
	References	17
<b>2</b>	<b>Monolayer Graphene on a hBN Underlay</b>	<b>19</b>
2.1	Introduction	19
2.2	Superlattice Hamiltonian	19
2.3	Generic Miniband Spectra of Graphene-hBN Heterostructures	23
2.4	Effect of the Miniband Spectra on the Hall Coefficient	25
2.5	Symmetry of the Moiré Superlattice	25
2.6	Microscopic Models	27
2.6.1	Point Charge Model	27
2.6.2	Graphene-hBN Hopping Model	30
2.6.3	Inversion Asymmetric Microscopic Models	30
2.7	Conclusion	31
	References	32

<b>3</b>	<b>Optical Absorption in Graphene-hBN Heterostructures . . . . .</b>	<b>33</b>
3.1	Introduction . . . . .	33
3.2	Optical Absorption Spectra . . . . .	35
3.3	Conclusion . . . . .	38
	References . . . . .	39
<b>4</b>	<b>Fractal Spectrum of Magnetic Minibands in Graphene-hBN Heterostructures . . . . .</b>	<b>41</b>
4.1	Introduction . . . . .	41
4.2	Magnetic Translational Symmetry and Calculation of Zak's Magnetic Minibands . . . . .	42
4.3	Generic Features in the Magnetic Miniband Spectra . . . . .	45
4.4	Conclusion . . . . .	49
	References . . . . .	49
<b>5</b>	<b>Experimental Realisation of the Graphene-hBN Heterostructure . .</b>	<b>51</b>
	References . . . . .	53
<b>6</b>	<b>Bilayer Graphene on hBN . . . . .</b>	<b>55</b>
6.1	Introduction . . . . .	55
6.2	Moiré Superlattice Hamiltonian . . . . .	56
6.3	Symmetries in the Miniband Structure . . . . .	58
6.4	Low-Energy Hamiltonian for BLG-hBN Heterostructures . . . . .	58
6.5	Miniband Spectra of BLG-hBN Heterostructures . . . . .	59
6.6	Conclusion . . . . .	63
	References . . . . .	63
<b>7</b>	<b>Monolayer Graphene with Almost Commensurate <math>\sqrt{3} \times \sqrt{3}</math> Hexagonal Crystals . . . . .</b>	<b>65</b>
7.1	Introduction . . . . .	65
7.2	Phenomenological Superlattice Hamiltonian . . . . .	66
7.3	Microscopic Models . . . . .	67
7.4	Parameter Space of the Superlattice Perturbation . . . . .	68
7.5	Translational Symmetries and Zone Folding . . . . .	68
7.6	Characteristic Miniband Spectra . . . . .	69
7.7	Conclusion . . . . .	72
	References . . . . .	72
<b>8</b>	<b>Resonant Tunnelling in Graphene-Insulator-Graphene Heterostructures . . . . .</b>	<b>75</b>
8.1	Introduction . . . . .	75
8.2	Graphene-Graphene Tunnelling . . . . .	76
8.3	Energy and Momentum Conservation . . . . .	77
8.4	Electrostatics . . . . .	79

8.5	Tunnelling in a Perpendicular Magnetic Field . . . . .	80
8.6	Conclusion . . . . .	85
	References . . . . .	85
<b>9</b>	<b>Conclusion . . . . .</b>	<b>87</b>
	References . . . . .	88
<b>Appendix A: Minibands in the Vicinity of <math>\kappa</math> and <math>\mu</math>-Points of Graphene-hBN Heterostructures . . . . .</b>		<b>89</b>
<b>Appendix B: Minibands of Graphene with Almost Commensurate <math>\sqrt{3} \times \sqrt{3}</math> Hexagonal Crystals . . . . .</b>		<b>93</b>
<b>Appendix C: Graphene-hBN-Graphene Tunnelling . . . . .</b>		<b>95</b>

Electronic Properties of Graphene Heterostructures  
with Hexagonal Crystals

Wallbank, J.

2014, XIII, 95 p. 38 illus., 22 illus. in color., Hardcover

ISBN: 978-3-319-07721-5