# Contents


**1. Introduction: Surfaces and interfaces in potential applications** **1**

**2. Ferroelectric materials and their nanoscopic features** **3**

2.1. Symmetry in solids and phase transitions . . . . . 3
2.2. Ferroics . . . . . 7
2.3. Nanoscopic features . . . . . 14
2.3.1. Twinning . . . . . 14
2.3.2. Ferroelectric domains . . . . . 15
2.3.3. Ferroelectric domain walls . . . . . 18
2.4. Spontaneous strain . . . . . 22
2.5. Mott insulators . . . . . 24
2.5.1. The Hubbard model . . . . . 26
2.5.2. The Mott metal-insulator transition . . . . . 29

**3. Nanoscale characterisation techniques** **33**

3.1. Scanning probe microscopy . . . . . 34
3.2. Piezoresponse force microscopy . . . . . 40
3.2.1. Basic principle of piezoresponse force microscopy . . . . . 41
3.2.2. Operation of piezoresponse force microscopy . . . . . 43
3.3. Conductive atomic force microscopy . . . . . 46
3.3.1. Basic principle of conductive atomic force microscopy . . . . . 46
3.3.2. Operation of conductive atomic force microscopy . . . . . 47
3.3.3. Local I(V)-spectroscopy . . . . . 48
3.3.4. Sample specific probe selection . . . . . 49
3.4. Scanning electron microscopy and the focused ion beam . . . . . 50
3.4.1. Principle of operation of the scanning electron microscope . . 51
3.4.2. Scanning electron microscopy detectors . . . . . 51
3.4.3. Focused ion beam . . . . . 55
3.5. Experimental equipment . . . . . 57
3.6. Samples . . . . . 57

**4. Multiferroic, Mott insulator $GaV_4S_8$** **59**

**5. Emergent mesoscale conductive patterns in $GaV_4S_8$ 65**
5.1. Strain driven conductivity of polar domain walls . . . . . 66
5.1.1. Conductive atomic force microscopy studies on $GaV_4S_8$ . . . . 67
5.1.2. Different tip work functions . . . . . 74
5.1.3. Discussion of the conduction mechanism . . . . . 75
5.2. Strain-induced conductivity of nano-cracks . . . . . 80
5.2.1. Local probe microscopy on strain driven conductive features . 81
5.2.2. Point I(V) spectroscopy on spontaneously forming cracks . . . 83
5.2.3. Influence on bulk resistance . . . . . 87

**6. Artificial mesoscale conductive patterns in $GaV_4S_8$ 93**
6.1. Brute force approach . . . . . 93
6.2. In-situ written conducting features . . . . . 99
6.2.1. Study on horizontal and vertical trenches . . . . . 100
6.2.2. Angular dependence of strain implantation . . . . . 107

**7. Outlook: Nanoscopic control of electronic conductivity in the future of nanotechnology 115**

**A. Further contributions to $GaV_4S_8$ 119**
A.1. FIB written features . . . . . 119
A.2. $GaV_4S_8$ lamella . . . . . 120
A.3. Machine learning approaches to disentangle electric contributions in $GaV_4S_8$ . . . . . 122

**Bibliography 125**

**Postface 141**

**Acknowledgements 143**