Table of contents

Table of contents 6
1. Introduction 9
1.1 Motivation: sustainable materials for electrical insulation 9
1.2 Research approach, goals, and structure of the thesis 12
2. Insulation in electrical generators 15
2.1 Electrical insulators – an unavoidable part of electrical generators 15
2.2 Requirements for insulating materials for generators /motors 17
2.3 Ceramic/polymer composites for electrical insulation 20
2.3.1 Thermosetting and thermoplastic polymer-based insulators 20
2.3.2 Polysiloxane as matrix materials for electrical insulation 23
2.3.3 AlN-containing composites 26
2.3.4 Mica-containing composites 27
2.3.4.1 Composition of mica minerals 27
2.3.4.2 Cystallochemistry of mica minerals 33
2.3.4.3 Mica-containing insulators 36
2.4 Fabrication of insulating parts from ceramic/polymer composites 39
2.4.1 Casting and coating methods 39
2.4.1.1 Surface requirements and surface wettability 45
2.4.2 Additive manufacturing methods 49
2.5 Robocasting of insulating materials 51
2.5.1 Rheology of slurries 51
2.5.2 Interactions in ceramic/polymer slurries 53
2.5.3 Concepts of printable ceramic slurry 54
2.5.4 Technical realization of conventional robocasting 55
2.5.5 UV-assisted robocasting and mechanism of curing 57
2.5.6 Robocasting of ceramic/polymer composites: achievements and challenges 61
2.5.7 Robocasting of electrical insulators: achievements and challenges 63
3. Materials and methods 65
3.1 Materials 65
3.2 Specimen compositions 67
3.2.1 Calculation of the fraction of ceramic particles in composites 67
3.2.2 Mica/Epoxy resin L composites for conventional robocasting 68
3.2.3 Mica/Silres H62C silicone composites for conventional robocasting 69

3.2.4 Photo-curable mica/Silres H62C silicone composites 70
3.2.5 AlN/epoxy and AlN/Silres H62C silicone composites 72
3.3 Preparation of AlN- and mica- containing slurries 72
3.4 Cross-linking of epoxy resin L and Silres H62C based composites 73
3.5 Fabrication of electrical insulation layers 74
3.5.1 Mold casting 74
3.5.2 Robocasting 75
3.5.2.1 Conventional robocasting 75
3.5.2.2 UV-assisted extrusion 80
3.5.2.3 Optimization of printing conditions 80
3.6 Characterisation methods 83
3.6.1 TG/DTA (Thermogravimetric analysis and differential thermal analysis) 83
3.6.2 Thermal diffusivity measurements 83
3.6.3 Dielectric strength and dielectric loss tangent characterization 83
3.6.4 Volume resistance measurement 84
3.6.5 Relative permittivity measurement 85
3.6.6 Particle size distribution measurement 85
3.6.7 Measurement of surface roughness and thickness of insulating layer 86
3.6.8 Particle density analysis 86
3.6.9 XRD (X-ray diffraction) 86
3.6.10 FTIR (Fourier transform infrared spectroscopy) 87
3.6.11 OM (Optical microscopy) 87
3.6.12 SEM (Scanning electron microscopy) 87
3.6.13 Shore hardness measurement 88
3.6.14 Rheological characterization 88
3.6.15 Contact angle measurement 88
3.7 Data managements 89
3.8 Use of AI tools 89
4. Results and discussion 90
4.1 Properties of starting materials 91
4.1.1 Particle morphology and particle size distribution of mica and AlN powders 91
4.1.2 Composition of Silres H62C and Epoxy resin L polymers 93
4.1.3 Rheological behavior and thermal stability of Silres H62C 96
4.1.4 Cross-linking of Silres H62C and Epoxy resin L polymers 97
4.2 Mold casting of mica/Silres H62C and mica/Epoxy resin L insulation composites 101
4.2.1 Optimization of rheology and composition of insulating pastes 101
4.2.2 Composition and structure of ceramic/polymer insulation layers fabricated by molding 102
4.2.2.1 Mica/Silres H62C and mica/Epoxy resin L composites 106
4.2.2.2 AlN/Silres H62C and AlN/Epoxy resin L composites 107
4.2.3 Summary 108

4.3 Conventional and auger-supported robocasting of mica/Epoxy resin L and mica/Silres H62C insulation composite layers 109
4.3.1 Optimization of robocasting process 109
4.3.2 Composition and structure of mica/Epoxy resin L and mica/Silres H62C insulation composite layers fabricated by robocasting 111
4.3.2.1 Thermal stability 111
4.3.2.2 Adhesion to the substrates 114
4.3.2.3 Morphology and microstructure 115
4.3.2.4 Surface roughness and particle size distribution of mica and AlN based thermosetting composites 119
4.3.3 Summary 128
4.4 UV assisted robocasting of photocurable mica/silicone insulation composite layers 129
4.4.1 Rheology of photocurable mica/Silres H62C paste 129
4.4.2 Optimization of UV assisted extrusion process 130
4.4.3 Composition and structure of mica/Silres H62C insulation layers fabricated by UV assisted robocasting 137
4.4.3.1 Morphology and microstructure of cross-linked mica/Silres H62C composites 137
4.4.3.2 Surface roughness and particle distribution of mica/Silres H62C layers 141
4.4.4 Summary 144
4.5 Properties and performance of insulation layers 145
4.5.1 Shore hardness 145
4.5.2 Electrical insulation properties 147
4.5.2.1 Relative permittivity 147
4.5.2.2 Dielectric strength 150
4.5.2.3 Dielectric loss tangent 152
4.5.2.4 Volume resistance 154
4.5.3 Thermal properties 156
4.5.4 Summary 158
5. Conclusions and outlook 160
6. References 168
List of figures 194
List of tables 200
List of symbols and abbreviations 202
List of quantities and units 204
Acknowledgements 206