Contents

Synopsis
List of Publications
List of Figures
List of Tables

Chapter 1	**Introduction**	1-11
1.1	**Natural bone**	1
1.2	**Biomaterial**	2
1.3	**Hydroxyapatite (HA), 45S5 bioglass and 1393 bioglass as the matrix**	2
1.4	**Sodium potassium niobate ($Na_{0.5}K_{0.5}NbO_3$; NKN) as piezoelectric secondary phase**	3
1.5	**Mechanical properties**	3
1.6	**Dielectric and electrical properties**	4
1.7	**Antibacterial behavior**	4
1.8	**Cellular response**	4
1.9	**Objectives**	5
1.10	**structure of the thesis**	6
Chapter 2	**Literature Review**	13-61
2.1	**Introduction**	13
2.2	**Toughening mechanisms**	15
2.2.1	Crack deflection	17
2.2.2	Crack bridging	17
2.2.3	Micro-crack toughening	18
2.2.4	Transformation toughening	19
2.3	**Piezoelectric contribution to the toughening mechanism**	20
2.3.1	Electromechanical coupling coefficient	21
2.3.2	Energy dissipation mechanism	21
2.3.3	Domain switching	22
2.3.3.1	Criterion for the domain switching	23
2.4	**Effect of piezoelectric secondary phase on mechanical properties**	24
2.4.1	Influence on fracture toughness of the bioceramics	24
2.4.2	Effect of piezoelectric secondary phase on other mechanical properties of bioceramics	29
2.5	**Effect of piezoelectric secondary phase on dielectric and electrical properties of bioceramics**	31
2.6	**Effect of piezoelectric secondary phase on antibacterial behavior of the bioceramics**	34
2.7	**Effect of piezoelectric secondary phase on**	38

	cytocompatibity of the bioceramics	
2.8	**Summary**	42
Chapter 3	**Experimental**	62-80
3.1	**Synthesis of Hydroxyapatite (HA)**	62
3.2	**Synthesis of Sodium Potassium Niobate ($Na_{0.5}K_{0.5}NbO_3$, NKN)**	63
3.3	**Synthesis of HA – NKN composites**	64
3.4	**Synthesis of 45S5 Bioglass (45S5 BG)**	64
3.5	**Synthesis of 45S5 BG- NKN composites**	66
3.6	**Synthesis of 1393 bioglass (1393 BG)**	66
3.7	**Synthesis of 1393 BG - NKN composites**	68
3.8	**Pelletization and sintering of composite samples**	68
3.9	**Density measurement**	69
3.10	**Phase evolution**	70
3.10.1	X-Ray diffraction	70
3.10.2	FTIR spectroscopy	70
3.11	**Scanning electron microscopy (SEM)**	70
3.12	**Mechanical characterization**	71
3.12.1	Vicker's hardness measurement	71
3.12.2	Fracture toughness	72
3.12.3	Flexural strength	72
3.12.4	Compressive strength	73
3.13	**Dielectric and electrical measurement**	74
3.14	**Polarization treatment**	74
3.15	**Polarization induced antibacterial behaviour**	75
3.15.1	Quantitative analysis	75
3.15.2	Live / dead assay	76
3.15.3	Nitro blue tetrazolium (NBT) assay	76
3.16	**Cell culture experiment**	77
3.16.1	Electrical stimulation	78
3.16.2	Quantitative analyses (MTT assay)	78
3.16.3	Morphological analysis	78
3.17	**Summary**	79
Chapter 4	**Synthesis, mechanical, electrical, polarization induced antibacterial and cellular response of HA - NKN composite**	81-131
4.1	**Particle size and density measurement**	81
4.2	**XRD analysis**	82
4.3	**Fourier transform infrared spectroscopic analysis**	83

4.4		**Scanning electron microscope**	84
4.5		**Mechanical behavior**	85
	4.5.1	Hardness and fracture toughness	85
	4.5.2	Compressive and flexural strength	87
4.6		**Dielectric measurement**	88
4.7		**AC conductivity behavior**	96
4.8		**Impedance analysis**	99
4.9		**Antibacterial response**	103
	4.9.1	MTT assay	103
	4.9.2	Live / dead assay	105
	4.9.3	Super oxide radical (SOD) assay	107
	4.9.4	Catalase Assay	109
	4.9.5	Lipid peroxidation (LPO) assay	111
	4.9.6	Protein estimation assay	113
4.10		***In vitro* cytocomapatibity**	116
	4.10.1	Cell viability	116
	4.10.2	Morphological study	118
4.11		**Closure**	121
Chapter 5		**Synthesis, mechanical, electrical, polarization induced antibacterial and cellular response of 45S5 BG - NKN composite**	132-166
5.1		**Phase evolution**	132
5.2		**Mechanical properties**	134
	5.2.1	Hardness and fracture toughness	134
	5.2.2	Compressive and flexural strengths	136
5.3		**Dielectric and electrical behavior**	137
	5.3.1	Dielectric measurement	137

	5.3.2	AC conductivity measurement	142
	5.3.3	Impedance Analyses	143
5.4		**Antibacterial behavior**	146
	5.4.1	MTT assay	146
	5.4.2	Kirby-Bauer test	148
	5.4.3	Live / dead ratio	151
	5.4.4	Nitro blue tetrazolium (NBT) assay	153
5.5		***In vitro* cytocomapatibity**	155
	5.5.1	Cell viability	155
5.6		**Closure**	158
Chapter 6		**Synthesis, mechanical, polarization induced antibacterial and cellular response of 1393 BG–NKN composite**	167-1
6.1		**Phase evolution**	167
6.2		**Mechanical properties**	169
	6.2.1	Hardness and fracture toughness	169
	6.2.2	Compressive and flexural strength	171
6.3		**Antibacterial behavior**	172
	6.3.1	MTT assay	172
	6.3.2	NBT assay	174
	6.3.3	Antibacterial ratio	175
6.4		***In vitro* cytocomapatibity**	180
	6.4.1	Cell viability	180
	6.4.2	Morphological analysis	181
6.5		**Closure**	185
Chapter 7		**Conclusions sand Future Scope**	190-1
7.1		**Conclusions**	190
7.2		**Scope for the future work**	194