

---

---

# CONTENTS

---

---

<b>Acknowledgements</b>	<b>V-VI</b>
<b>Table of Contents</b>	<b>VII-XII</b>
<b>List of figures</b>	<b>XIII-XVI</b>
<b>List of tables</b>	<b>XVII</b>
<b>Abbreviations</b>	<b>XVIII-XIX</b>
<b>List of symbols</b>	<b>XX</b>
<b>Preface</b>	<b>XXI-XIII</b>
<b>CHAPTER 1 Introduction</b>	<b>1-41</b>
1.1 Raman spectroscopy.....	1
1.2 Theory of Raman spectroscopy.....	3
1.2.1 Classical theory of Raman spectroscopy .....	3
1.2.2 Quantum theory of Raman spectroscopy.....	5
Vibrational Raman spectra.....	6
1.3 Surface enhanced Raman spectroscopy.....	10
(a) Electromagnetic effect.....	12
(b) Chemical effect.....	16
1.3.1 Plasmon-induced CM.....	18
1.3.2 Enhancement factor calculation.....	19
(a) Based on analytical chemistry.....	20
(b) Based on SERS substrate.....	20
1.4 Material selection for SERS substrates.....	21
SERS active substrate.....	22

	(a) Coinage metals.....	22
	(b) Transition metals.....	23
	(c) Post-transition metals.....	23
	Bismuth-based substrate.....	24
	(d) Semiconductors.....	25
	(i) Metal oxides.....	26
	(ii) Metal heterostructure.....	26
1.5	Reproducibility.....	27
1.5.1	Uniformity of substrate.....	28
1.5.2	Stability of the Substrate.....	28
1.6	Characterization Techniques for SERS substrates.....	29
1.6.1	X-ray diffraction pattern (XRD).....	29
1.6.2	Fourier Transform Infrared Spectroscopy (FT-IR).....	30
1.6.3	Scanning Electron Microscopy (SEM).....	31
1.6.4	X-ray Photo Electron Spectroscopy (XPS).....	31
1.6.5	UV-Visible Spectroscopy.....	31
1.6.6	Raman spectroscopy.....	32
1.7	Summary of the thesis.....	32
	References.....	35-41
	<b>Bismuth-based novel substrate for surface enhanced Raman</b>	<b>42-72</b>
<b>CHAPTER 2</b>	<b>spectroscopy</b>	
2.1	Introduction.....	42
2.2	Experimental section .....	44
2.2.1	Materials used.....	44

2.2.2	Synthesis of $\beta$ -Bi <sub>2</sub> O <sub>3</sub> /Bi <sub>2</sub> O <sub>2</sub> CO <sub>3</sub> .....	45
2.2.3	Characterization.....	45
2.2.4	Raman measurement.....	46
2.3	Results and Discussion.....	46
2.3.1	XRD pattern.....	46
2.3.2	SEM analysis.....	48
2.3.3	XPS analysis.....	49
2.3.4	Vibrational spectra of the as-synthesized samples.....	51
2.3.5	SERS analysis.....	54
2.3.6	SERS study of PATP.....	61
2.3.6.1	SERS of PATP on bismuth heterostructure.....	61
	Genuine SERS measurement of PATP.....	63
2.4	Conclusion.....	66
	References.....	69-72
	<b>Bismuth oxybromide based novel substrate for surface</b>	<b>73-96</b>
	<b>enhanced Raman spectroscopy</b>	
<b>CHAPTER 3</b>		
3.1	Introduction.....	73
3.2	Experimental section.....	75
3.2.1	Materials used.....	75
3.2.2	Synthesis of Bismuth oxybromide (Bi <sub>24</sub> O <sub>31</sub> Br <sub>10</sub> ).....	75
3.2.3	Characterization.....	75
3.2.4	SERS Measurement of substrate.....	76
3.3	Results and Discussion.....	76
3.3.1	XRD pattern.....	76

3.3.2	SEM analysis.....	77
3.3.3	XPS analysis.....	79
3.3.4	Vibrational Raman spectra .....	80
3.3.5	SERS measurement of $\text{Bi}_{24}\text{O}_{31}\text{Br}_{10}$ .....	82
	Enhancement Factor.....	89
3.4	Conclusion.....	91
	References.....	93-96
	<b>Bismuth oxybromide based novel SERS substrate for label-free, non-invasive quantitative detection of detrimental synthetic food colorants</b>	97-142
<b>CHAPTER 4</b>		
4.1	Introduction.....	97
4.2	Experimental section .....	100
4.2.1	Materials.....	100
4.2.2	Synthesis of CTAB-AgBr- $\text{Bi}_3\text{O}_4\text{Br}$ /BiOBr.....	100
4.2.3	Characterization.....	101
4.2.4	Raman measurement.....	101
4.3	Results and Discussion.....	101
4.3.1	XRD pattern.....	101
4.3.2	UV-Visible spectra.....	103
4.3.3	SEM analysis.....	104
4.3.4	XPS analysis.....	105
4.3.5	FTIR analysis.....	107
4.3.6	Raman study of CTAB-AgBr- $\text{Bi}_3\text{O}_4\text{Br}$ /BiOBr.....	108
4.3.7	SERS study of the prepared composites.....	109
4.3.8	Analysis of binary mixture of food colors .....	118

4.4	In situ detection of organic dye Sudan I (SuI) in Chilli powder...	122
4.4.1	Pretreatment of chili powder and spiked chili powder.....	122
4.4.2	Raman analysis of chilli fruits, chili seeds, and chilli powder.....	123
	Chilli fruits.....	124
	Chilli seeds.....	125
	Chilli powders.....	126
4.4.3	SERS studies of Sudan I dye.....	126
	Effect of solvent.....	127
4.4.4	Detection of spiked Sudan I in chilli powder.....	130
4.5	Conclusion.....	133
	References.....	138
	<b>Quantitative estimation of isatin and its derivative and</b>	143-172
<b>CHAPTER 5</b>	<b>acetylcholine neurotransmitter on bismuth based SERS</b>	
	<b>substrate</b>	
5.1	Introduction.....	143
5.2	Experimental section.....	145
5.2.1	Materials and method.....	145
5.2.2	Synthesis of SERS substrate.....	145
5.2.3	Raman and SERS measurement.....	146
5.2.4	Computational details.....	146
5.3	Results and Discussion.....	147
5.3.1	SEM analysis.....	147
5.3.2	pH dependent Raman study on Isatin and its derivative.....	148
5.3.3	SERS measurement of Isatin and its derivatives.....	152
5.3.4	pH dependent Raman and SERS study on acetylcholine (Ach)...	157

5.3.5	Interaction of Isatin and its derivative with Ach.....	158
5.3.6	SERS study of Ach on bismuth oxide.....	160
5.4	Conclusion.....	163
	References.....	170-172
	<b>Summary and future scope of the work</b>	173-176
6.1	Summary	173
6.2	Future scope of the work	175
	List of Publications	177