ARRANGEMENT OF LIQUID CRYSTALS NEAR SURFACES

ANIL KUMAR

DEPARTMENT OF CHEMICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY DELHI

JANUARY 2016

ARRANGEMENT OF LIQUID CRYSTALS NEAR SURFACES

by

ANIL KUMAR

Department of Chemical Engineering

Submitted

in fulfillment of the requirements of the degree of Doctor of Philosophy

to the

Indian Institute of Technology Delhi

January 2016

Certificate

This is to certify that the thesis entitled "**Arrangement of Liquid Crystals Near Surfaces**", being submitted by Mr. Anil Kumar to the Department of Chemical Engineering, Indian Institute of Technology Delhi, for the award of degree of **Doctor of Philosophy** is the record of bonafide research work carried out by him under my supervision and guidance. The work presented in this thesis have not been submitted either in part or in full to any other university or institute for the award of any degree or diploma.

Sudip K Pattanayek

Associate Professor

Department of Chemical Engineering

Indian Institute of Technology Delhi

Acknowledgements

I express sincere gratitude and indebtedness to my supervisor Dr. Sudip K Pattanayek for his guidance and valuable suggestions throughout this research work and for his encouragement, support and cooperation. His guidance helped me in all the time of research and writing of thesis. I could not have imagined having a better advisor and mentor for my Ph.D. study.

I would like to express my inner sense of gratitude to Prof. Rajesh Khanna, Prof. Jayati Sarkar, Prof. Alok Ranjan Ray (Centre for Biomedical Engineering) and other faculty members of chemical engineering department, IIT Delhi, for their care and encouragement.

My sincere thanks goes to Prof -Tigran Galstian and Prof Simon Rainville at Laval University, Canada for offering me the research opportunities in his Group and leading me working on diverse exciting project.

I would like to thank Professor V. Perumal of School of Biological Science, Indian Institute of Technology Delhi for providing bacteria used for my research work.

I wish to acknowledge my friends and lab mate Dr. Lalit Mohan Pandey, Mr. Sunil, and Mrs. Indu for extending their help during the period of experimentation and thesis preparation.

I would like to express my sincere gratitude to my wife and family member who has given me indescribable and endless supports throughout my study.

Above all, I thank Almighty God for bestowing good health to me and my family members throughout the course of the study.

Anil Kumar

Abstract

Scientists have been trying to use liquid crystal (LCs) in various bio detection applications such as bacteria, nucleic acids, protein etc. for the last two decades. The arrangement of liquid crystals near surfaces is important in these applications. LCs are classified broadly into thermotropic and surface inactive lyotropic (also known as chromonics or LCLCs) liquid crystal. The organization LCs are strongly dependent on the nearby surfaces and its chemical functionality. The most importantly, the initial organization of the LCs may lead to the organization of subsequent layers of LCs near the surface. This origination enables the detection of molecules present near surfaces.

We have taken glass substrates and modified with organo-silane modifiers to get well defined surfaces. We explored the organization of thermotropic and nematic phase of LCLCs near the well defined surfaces. The organization of the LCLCs are dependent on ageing time near the surface. The organization of LCLCs are strongly dependent on near the surface at short time but weakly dependent on the surface at long time. Next the modified surfaces are used to see the alignment of LCs near nonspecifically adsorbed protein. We have compared the response of a thermotropic liquid crystal, 5CB and a chromonic liquid crystal, DSCG near the adsorbed proteins. The response of LCs is correlated with the adsorbed protein and its characteristics at the surfaces.

We have used the above LCs to understand its organization near adsorbed bacteria on a positively charged surface. It is found that a critical number of adsorbed bacteria is required to get a distinct variation of response. We also have observed the movement of bacteria in the anisotropic medium formed by DSCG in solution. It is found that the behaviour of living microorganism is dramatically different in the anisotropic medium.

Table of Contents

List of Figures

List of Tables

Abbreviations

AHSA	Anti-human serum albumin
AFM	Atomic force microscopy
AHSA	Anti-Human serum albumin
APTES	3-Aminopropyl triethoxysilane
APTMS	3-Aminopropyl trimethoxysilane
ATR-IR	Attenuated total reflection infrared spectroscopy
BiSH	Biotin-$(CH_2)_2[(CH_2)_2O]_2NHCO(CH_2)_{11}SH$
BSA	Bovine serum albumin
5CB	4-cyano-4' -pentylbiphenyl
8CB	Octylcyanobiphenyl
C_8SH	Octanethiol
$C_{15}SH$	Pentadecanethiol
$C_{16}SH$	Hexadecanethiol
CPCl	Cetylpyridinium chloride
CsPFO	Cesium pentadecafluorooctanoate
DMOAP	N,N-dimethyl-n-octadecyl-3-aminopropyltrimethoxysilyl chloride
DOGS-NTA	1,2-dioleoyl-snglycero-3-{[N(5-amino-1-carboxypentyl) iminodiacetic acid] succinyl} (ammonium salt)
DOGS-NTA-Ni	1,2-dioleoyl-sn-glycero-3-{[N(5-amino-1-carboxypentyl) iminodiacetic acid] succinyl} (nickel salt)
DSCG	Disodium chromoglycate
DSS	Disuccinimidyl suberate
E.Coli	Escherichia Coli
EDC	N-(3-dimethylaminopropyl)- N-ethyl carbodiimide hydrochloride
EPS	Extracellular polymeric substances
FCM	Fluorescent confocal microscopy

FITCHSA	Fluorescein isothiocyanate-labelled human serum albumin
FITC-AHSA	Fluorescein isothiocyanate-labelled antihuman serum albumin
FITC-HTrf	Fluorescein isothiocyanatelabelled human transferrin
FTIR	Fourier transformation infrared spectroscopy
GNP	Gold nanoparticles solution
HPLC	High-performance liquid chromatography
HSA	Human serum albumin
HTrf	Human transferrin
LCs	Liquid crystals
LCLC	Lyotropic chromonic liquid crystals
LSZ	Lysozyme
MI	Di-iodomethane
MBBA	N-(4-methoxybenzylidene)-4-butylaniline
MPA	3-mercapto propionic acid
NHS	N-hydroxy succinimide
OSM	Organo-silane modifiers
OTMS	Octyltrimethoxysilane
OTS	Octadecyltrichlorosilane
PBS	Phosphate-buffered saline
PDMS	Poly-(dimethylsiloxane) elastomeric stamp
PEI	Poly(ethylene imine)
PLL	Poly-L Lysine
PLM	Polarized light microscopy
PM-IRRAS	Polarization modulation-infrared reflectance absorbance spectroscopy
POM	Polarized optical microscopy
SAMs	Self assembled monolayers

SSMCC	Sulfo-succinimidyl4-(*N*-maleimidomethyl) cyclohexane-1-carboxylate
STM	Scanning tunneling microscopy
SSY	Sunset yellow (Disodium salt of 6-hydroxy-5-[(4-sulfophenyl)azo]-2-naphthalenesulfonic acid)
TEA	Triethoxysilane aldehyde
TMMS	Trimethoxy-methylsilane
XPS	X-ray Photoelectron Spectroscopy
XRD	X-ray diffraction