論文 / 著書情報
Article / Book Information

題目(和文)	空気除湿のための膜の開発です
Title(English)	Development of membranes for the air dehumidification applications
著者(和文)	KUDASHEVA Alina
Author(English)	Alina Kudasheva
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第10624号, 授与年月日:2017年9月20日, 学位の種別:課程博士, 審査員:伊東 章,久保内 昌敏,多湖 輝興,谷口 泉,下山 裕介
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第10624号, Conferred date:2017/9/20, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

An Outline of Dissertation

entitled

Development of Membranes for the Air Dehumidification Applications

by

Alina Kudasheva

A thesis submitted in partial fulfillment

of the requirements for the degree

Doctor of Science

in

Chemical Engineering

Graduate School of Science and Engineering

Tokyo Institute of Technology

2017

Contents

List of figures 8
List of tables 12
List of abbreviations 13

CHAPTER 1. INTRODUCTION 15
Air dehumidification 15
Conventional technologies for the air dehumidification 16
Problem statement 18
Membrane - based air dehumidification 19
Research objectives 21
Scope of the thesis 22
References 23

CHAPTER 2. MEMBRANES FOR THE AIR DEHUMIDIFICATION 25
Membrane module 25
Selection of the membrane materials 26
Experimental 27
Air dehumidification test 27
Water adsorption measurement 28
Viscosity measurement 29
Membrane performance parameters..........29
Membrane permeability obtained from experimental data 30
References 31

CHAPTER 3. BIOPOLYMER COMPOSITE MEMBRANES 33
Abstract 33
Biopolymer/LiCl composite membranes 34
Introduction..........34
Materials and membrane preparation 36
Results and discussion 37
Sorption of water vapor 37
Conclusions 48
Biopolymer/MOFs mixed matrix membranes 49
Introduction..........49
Materials and membrane preparation 50
Results and discussion 51
Prediction of water solubility of mixed matrix membranes 51
Air dehumidification performance 53
Conclusions 56
Summary 57

References 57
Chapter 4. AQUEOUS SALT SOLUTION MEMBRANES 63
Abstract 63
Aqueous salt solution based liquid membranes 64
Introduction..........64
Materials and membrane preparation 65

Liquid membrane stability analysis 68
Results and discussion 69
Sorption of water vapor 69
Effect of the membrane supporting material type on the membrane's selectivity 71
Water recovery from the air 72
Water recovery vs. permeate pressure 75
Membrane permeability 76
Liquid membrane stability 78
Conclusions 82
Halide salt composite liquid membranes 84
1. LiBr salt, confined in silica spheres, membrane 84
Introduction....................84
Materials and membrane preparation 85
Results and discussion 85
Conclusions 86
2. Aqueous LiBr/Alkali metal formate composite liquid membrane 87
Introduction....................87
Materials and membrane preparation 88
Results and discussion 88
Conclusions 89
3. Aqueous LiCl/TEG composite liquid membrane 90
Introduction....................90
Materials and membrane preparation 91
Results and discussion 91
Conclusions 93
Summary 93
References 94

Chapter 5. IONIC LIQUID MEMBRANES 99
Abstract 99
Supported Ionic Liquid Membranes 100
Introduction....................100
Materials and membrane preparation 101
Water sorption of Ionic Liquid containing membrane supporting additive 103
Results and discussion 104
Sorption of water vapor 104
Water recovery from the air 109
Membrane permeability 112
Conclusions 118
Supported Ionic Liquid - Amine mixed membranes 119
Introduction....................119
Materials and membrane preparation 120
Results and discussion 120
Water recovery 120
Conclusions 122
Summary 123
References 123

Chapter 6. THE EFFECT OF OPERATING CONDITIONS ON THE AIR DEHUMIDIFCATION PERFORMANCE 128

Introduction..128
Effect of operating conditions 129
Sweep air flow rate 129
Temperature 130
Permeate side total pressure 132
The effect of membrane thickness 133
Summary 134
Conclusions 135
References 135

Chapter 7. WATER PERMEABILITY AND OVERALL EFFICIENCY OF THE AIR DEHUMIDIFCATION MEMBRANES 136
Abstract 136
Water permeability of the air dehumidification membranes 137
Effect of boundary layer and concentration polarization 139
Introduction 139
Discussion 143
Evaluation of the membrane-based air dehumidification efficiency 148
Coefficient of performance (COP) 150
Conclusions 151
Future directions 151
References 153

The main disadvantage of the air dehumidification with conventional technologies is high energy consumption. In particularly, additional energy is required for reheating of the air from dew point temperature to the desired dry-bulb temperature in case of the dehumidifier with cooling coil and the regeneration of the desiccant in case of dehumidifier with desiccant cycle. Since regeneration of the solid desiccants requires higher temperatures (160-200 °C) when compared to that (73 °C) of the liquid desiccant system, the gas dehydration process with liquid desiccants is less expensive. However, one of the drawbacks of the liquid desiccant system is the carryover of desiccant solution droplets into the air stream, which can have a negative impact on the health of occupants. To avoid such consequence, researchers proposed to immobilize desiccant solution into polymers**,** however this led to the reduction of desiccant's water sorption capacity. Another way to limit carryover of desiccant droplets can be done by droplet filters, but at the expense of additional pressure drop, which will affect the water removal efficiency of the dehumidifier. Therefore, modification of the existed dehumidifiers or development of a new dehumidification system is essential to overcome high power consumption and safety/environmental risks in the air dehumidification process.

This thesis investigates the potential of membranes for the effective dehumidification of air. The work focuses on preparation of membranes from various hygroscopic materials and its composites for the dehumidification of room air. The efficiency of the membrane-based dehumidifier was evaluated in terms of the condensed water recovery, water permeability and membrane selectivity of water vapor over the air.

The overall aim of this research is to develop a membrane-based air dehumidification system, which has potential to be more effective from economic and technical point of view when compared to the conventional dehumidification technologies. The ways to improve the process is to study the effect of the membrane material on the air dehumidification performance. These can be realized through the following objectives:

- to obtain and apply highly hygroscopic materials in membranes, and test it in the dehumidification of air;
- to successfully synthesize composite membranes and evaluate their water sorption ability;
- to investigate the effect of the membrane's supporting material nature on the membrane

performance;

- to successfully fabricate membranes with the reduced thickness to achieve higher permeation rates;
- investigate the liquid membrane long term performance and stability;
- to analyze membrane's solubility and water diffusivity across the membrane;
- to fundamentally understand the mass transport mechanism through the liquid membranes;
- to analyze the effect of operating conditions on the membrane dehumidification performance;
- to analyze coefficient of efficiency of the developed membrane-based dehumidifier;
- to conduct quality analysis of the recovered water extracted from the air with dehumidification membrane.