Green Nanotechnology

Oleg Figovsky
Dmitry Beilin

CONTENTS

Preface

Acknowledgement

Chapter 1

Nanostructured Composites Based on Interpenetrated Polymer Networks

1.1 KINDS, CLASSIFICATION, PROPERTIES, SYNTHESIS, APPLICATION

1.1.1 Introduction

1.1.2 Kinds of IPNs

1.1.3 Classification of IPN

1.1.3.1 IPN Based on Chemical Bonding

1.1.3.2 IPN Based on Arrangement Pattern

1.1.4 Properties of IPN

1.1.5 Synthesis of Some IPN

1.1.6 Dendripolymers based on the epoxy-amine reactions

1.1.7 Applications of IPN Technology

1.2 NANOSTRUCTURED LIQUID EBONITE COMPOSITION FOR PROTECTIVE COATINGS

1.2.1 Introduction

1.2.2 Structure and Properties of Oligobutadienes

1.2.3 Vulcanization

1.2.4 Strength and Hardness of Vulcanizate

1.2.5 Performance Characteristics of Vulcanizates

1.2.5.1 Thermo-Mechanical Properties

1.2.5.2 Sorption and Diffusion Properties

1.2.5.3 Chemical Resistance

1.2.5.4 Adhesion Stability of Ebonite Coatings

1.2.5.5 Electrochemical Protection Properties of Ebonite Coating

1.2.6 Technological Process of Manufacture and Properties of Ebonite Mixtures

1.2.6.1One-pot Composition

1.2.6.2Double-pot Composition

1.2.6.3 Examples of Prepared LEM Composition

1.2.7 Applications of Ebonite Coatings

1.2.8. Conclusion

References

1.3 NONISOCYANATE POLYURETHANES BASED ON CYCLIC CARBONATES AND NANOSTRUCTURED COMPOSITES FOR PROTECTIVE COATINGS

1.3.1 Introduction

1.3.2 State of the Art in NIPU: Brief Description of the Latest Discoveries and Developments

1.3.3 Recent Achievements in the Feld of NIPU

1.3.3.1 Polyhydroxyurethanes

1.3.3.2 Hybrid Non-Isocyanate Polyurethanes (HNIPU**)**

1.3.3.3 Application HNIPU for Flooring and Paints

1.3.3.4 UV curable HNIPU Floorings and Coatings

1.3.3.5 Hydroxyurethane Modifiers (HUM)

1.3.3.6 Hydroxyurethane Compounds from Renewable Plant-Based Raw Materials

1.3.3.7 Silane-Containing and Nano-Structured Hydroxyurethane Compounds

1.3.3.8 Sprayable Foam

1.3.4. Conclusion

References

Chapter 2

Nanocomposites Based on Hybrid Organo-Silicate Matrix

2.1 INTRODUCTION

2.2 SOL-GEL TECHNOLOGY3

2.2.1 Alkoxide Method of Sol-Gel Synthesis

2.2.2 Non-Hydrolytic Method of Sol-Gel Synthesis

2.2.3 Colloidal Method of Sol-Gel Synthesis

2.2.4 Soluble Silicates as Precursors are in the Sol-Gel Technology of Nanocomposites

2.2.5 Preparation of Nanocomposites through Aerogels

2.2.6 Modification Products Sol-Gel Synthesis by Polyurethanes

2.3 MIXING TECHNOLOGIES OF NANOCOMPOSITES

2.4 DIFFERENT TYPES OF NANOPHASES

2.4.1 Nano-Sized Filler

2.4.2 Nano-Sized Binder

2.4.3 Synthesis of Nano-Phase in the Matrix of the Composite Structure

2.5 INFLUENCE OF VARIOUS FACTORS ON STRUCTURE AND PROPERTIES OF HYBRID MATERIALS

2.5.1 Packing of Spherical Nanoparticles of the Filler

2.5.2 Packing of Fibrous Nanoparticles of the Filler

2.5.3 Nanomaterials Based on Layered Particles

2.5.4 Special Organosilicate Additives and Modifiers

2.5.4.1 Tetrafurfuryloxysilane as Nanostructuring Agent

2.5.4.2 Modification of an Aqueous Dispersion of Chlorosulfonated Polyethylene and Other Polymers Compositions

2.5.4.3 Solid Alumina-Silicon Flocculants-Coagulants - Matrix-Isolated Nanocomposites

2.6 SYNTHESIS AND APPLICATION OF HYBRID MATERIALS BASED ON SILICA WITH GRAFTED POLYMERS

2.7 CONCLUSION

References 4

Chapter 3

Polymer Nanocomposites with High Resistance to Aggressive Environment

3.1. INTRODUCTION

3.2 MODELLING OF DIFFUSION IN POLYMERIC MATERIALS

3.3 MODELLING OF DIFFUSION IN A RANDOM POROUS SYSTEM

3.4 DECREASE OF THE RATE OF DIFFUSION

3.5 INFLUENCE OF ADDITIVES ON THE OPERATING CHARACTERISTICS OF POLYMERIC MATERIALS

3.6 DEVELOPMENT OF CHEMICAL RESISTANT POLYMER CONCRETES

3.7 APPLICATION

3.8 CONCLUSIONS

References

Chapter 4

Environmental Friendly Method of Production of Nanocomposites and Nanomembranes

4.1. INTRODUCTION

4.2 BRIEF REVIEW OF THE KNOWN MODELS OF SUPERDEEP PENETRATION (SDP)

4.3 INVESTIGATIONS OF SUPERDEEP PENETRATION (SDP)

4.4 EFFECTS APPEARING AT SUPERDEEP PENETRATION

4.4.1 Interaction Conditions Determining the Cratering Type

4.5 EXPENDITURE OF ENERGY IN A PROCESS OF SUPERDEEP PENETRATION

4.5.1 Clot of High-Speed Micro-Particles: Estimation of the Kinetic Energy

4.5.2 Formation of a Channel Structure During the Superdeep Penetration Process

4.5.3 Change of the Barrier Micro-Structure

4.5.4 Other Factors Causing the Energy Expenditures

4.5.5. Energy Balance

4.6 SDP METHOD FOR"GREEN" PRODUCTION TECHNOLOGY OF NANOCOMPOSITES

4.6.1 Features of Dynamic Reorganization in Steel at Superdeep Penetration

4.6.2 Nanostructured Composites Based on Metallic Matrix

4.6.3 Interaction of a Stream of Particles with Ceramics

4.6.4 Features of Interaction of a Stream of Discrete Particles with Plastic

4.6.5 Production of Polymer Nanocomposites

4.6.6 Development of the New Porous Materials

4.6.7 Production of Polymer Tracking Membranes

4.7. METHOD FOR TREATING THIN-FILM MATERIALS WITH

A FLOW OF SOLID PARTICLES IN ELECTRIC FIELD

4.7.1 Charging and Acceleration of Solid Micro- and Nanoparticles by the Action of Electrical Field

`4.7.2 Production of Tracking Membranes by Accelerated Particles of Powders

4.8 CONCLUSIONS

References 6

Chapter 5

Nanotechnology in Production of Bioactive Paints, oatings and Food Storage Materials

5.1 INTRODUCTION

5.2 PRODUCTION AND ANTIMICROBIAL CHARACTERISTICS

OF NANOPARTICLES OF SILVER

5.3 EXPERIMENTAL INVESTIGATION OF NEW BIOACTIVE NANO-MODIFIED PAINTS AND COATINGS

5.4 NEW WATER- DISPERSION PAINT COMPOSITION WITH BIOCIDE PROPERTIES

5.5 NANO-SILVER AS A POTENTIAL PROTECTIVE MATERIAL

FOR FOODSTUFF

5.6 CONCLUSION

References

Chapter 6

Green Nanostructured Biodegradable Materials

6.1 INTRODUCTION

6.2 NANO-CELLULOSE AND ITS APPLICATIONS

6.2.1 Materials and Methods

6.2.2 Using of the Viscometry Method for NanoCell Investigations

6.2.3 Investigation of the NanoCell by XRD Method

6.2.4 Method of Laser-Light Scattering (LLS)

6.2.5 Using of the SEM-method for NanoCell investigations

6.2.6 Potential Application, Preparation and Investigation of Composite Materials Based on Nanocell7

6.3 PROCESSING OF BIODEGRADABLE PACKAGING MATERIALS

6.3.1 Biodegradable Packaging Material GreetCoat™

6.3.2 Biodegradable packaging materials BHM

6.3.3 Basic Principles for Biodegration of Polymers

6.3.4 Application of the novel biodergadadle packaging materials

6.4 NANO-CELLULOSE AS PROMISING BIOCARRIER

6.4.1 Activity of the Nanocarrier

6.4.2 Applications of the Cellulose Nano-Carriers

6.5 CONCLUSION

References

Chapter 7

Nanotechnology in Agriculture

7.1 INTRODUCTION

7.2 BIOLOGICALLY ACTIVE MULTIFUNCTIONAL NANOCHIPS AND METHOD OF APPLICATION FOR PRODUCTION OF HIGH-QUALITY SEED

7.2.1 Biologically Active Nanochips: Species and Compositions

7.2.2 Carriers , Stabilizers and Solvents as the Components of BANs

7.2.3 Use of BANs for Treating Plant Seeds

7.2.4 Practical Preparation of Biologically Active Nanochips for Seed Germination

7.2.4.1 Composition of BANs for RICE seed preparation for planting

7.2.4.2 Composition of BANs for WHEAT seed preparation for planting

7.2.4.3 Composition of BANs for COTTON seed preparation for planting8

7.2.4.4 Composition of BANs for SUGAR BEET seed preparation for planting

7.2.4.5 Composition of BANs for SOYBEAN seed preparation for planting

7.2.4.6 Composition of BANs for CORN seed preparation for planting

7.2.4.7 Composition of BANs for TOMATO seed preparation for planting

7.3 DETOXICATION OF PESTICIDE AND OTHER TOXIC SUBSTANCE IN SOIL BY THE USE OF NANOMATERIALS

7.4 APPLICATION OF NANOCHIPS AS INDUCERS OF DISEASE RESISTANCE DURING PRESOWING SEED TREATMENT

7.5 THE RISKS CONNECTED WITH USE OF POLYMERIC NANOSTRUCTURES IN TECHNOLOGIES OF SEEDS TREATMENT BEFORE SOWING

7.5.1 **Toward Theory of Water Sorption by Seeds Using Memory Functions Method**

7.5.2 On Mechanisms of Water Transport into Seed Across Polymer Cover

7.5.3 Role of Polymer Cover in the Seeds Water Sorption

7.5.4 Seed is Dissipative System.

7.6 CONCLUSION

References

Preface

Green nanotechnology has two goals: producing nanomaterials and products without harming the environment or human health, and producing nanoproducts that provide solutions to environmental problems. It uses existing principles of green chemistry and green engineering to make nanomaterials and nanoproducts without toxic ingredients, at low temperatures using less energy and renewable inputs wherever possible, and using lifecycle thinking in all design and engineering stages1.

Green nanotechnology aims to develop clean technologies to minimize potential environmental and human health risks associated with the manufacture and use of nanotechnology products, and to encourage replacement of existing products with new nanomaterials that are more environmentally friendly.

There are two key aspects to green nanotechnology. The first involves nanoproducts that provide solutions to environmental challenges. These green nanoproducts are used to prevent harm from known pollutants and are incorporated into environmental technologies to remediate hazardous waste sites, clean up polluted streams, and desalinate water, among other applications. The second aspect of green nanotechnology involves producing nanomaterials and products containing nanomaterials with a view toward minimizing harm to human health or the environment2.

Green nanotechnology involves the following3:

• Use of less energy during manufacture

• Ability to recycle after use

• Using eco-friendly materials

The most important component of nanotechnology is nanomaterials, i.e. materials with the ordered structure of their nanofragments having size from 1 to 100 nm. The production and process aspects of green nanotechnology involve both making nanomaterials in a more environmentally benign fashion and using nanomaterials to make current chemical processes more environmentally

1 https://en.wikipedia.org/wiki/Green_nanotechnology
2 B.Karn, L. Bergeson, *Natural Resources & Environment* Vol.24, No.2,2009
3 http://www.azocleantech.com/article.aspx?ArticleID=330

acceptable. A 2003 estimate by the Nanobusiness Alliance identified nanomaterials as the largest single category of nanotech start-ups

According to recommendation of 7th International Conference on Nanostructured Materials, Wiesbaden, 2004 nanomaterials are classified:

- Nanoporouse structures,
- Nanoparticles,
- Nanotubes and nanofibers,
- Nanodispersions (colloids)
- Nanostructured surfaces and films
- Nanocrystals and nanoclusters
- Nanocomposites

There are two basic ways to create of nanoobjects:

1. Reduce the size of macroscopic objects (dispersing, disintegrating, grinding to the cluster level using a ball mills or using the mechanochemical synthesis);

2. Creating nanostructures from atoms and molecules (crystallization) clustering, nanostructuring, nucleation, condensation, coagulation, polymerization, etc.

The prospect of a new materials technology that can function as a low-cost alternative to high-performance materials has, thus, become irresistible around the world. By this means nanotechnology presents a new approach to material science and engineering as well as for design of new devices and processes.

According to the Congressional Research Service USA world industry uses nanotechnology in the production of 80 groups of consumer goods and more than 600 kinds of raw materials, component items and the industrial equipment. Figure below can give some imagine of the global business segments of nanotechnology.

Global nanotechnology

BCC Research provides an updated analysis of the nanotechnology products market in its report, Nanotechnology: A Realistic Market Assessment (NAN031F). The global market for nanotechnology products was valued at about $26 billion in 2014. This market is expected to reach about $64.2 billion in 2019, with a compound annual growth rate of 19.8% from 2014 to 2019.

American Association of National Science Foundation predicts that in the next 10-15 years, the market growth of nanogoods and services up to $ 1 trn:

This book contains information about advanced nanomaterials can be produced without harming the environment or human health. This encompasses the production of nanomaterials without environmental toxicity, at room temperature and with the use of renewable energy sources. The book contains the descriptions and results of theoretical and experimental researches in the field of environment friendly nanotechnology carried out over the past decade by scientific team of company Polymate Ltd.-International Nanotechnology Center (*www.polymateltd.com*, Israel) under leadership of Prof. O. Figovsky. Developments of the Company have been used in industry and agriculture and protected by more than 25 patents of USA, Germany and Russia.

Let’s summarize contents of the monograph.

First chapter is concerned with interpenetrating polymer networks (IPN) principle in production of composite materials provides an unique possibility to regulate their both micro- and nano- structures and properties. The chapter discusses principal features and characteristics of IPN composites. Formation of rubberizing ebonite coatings on samples of oligobutadienes are examinated. Recent advances in chemistry and technology of nonisocyanate polyurethane (NIPU) materials based on cyclic carbonate oligomers are reviewed in this chapter. The use of NIPU materials as coatings, adhesives, and foams is described.

Second chapter presents a few methods of sol-gel synthesis: alkoxide, non-hydrolytic and colloidal. Sol-gel technology of nanocomposites based on the use of soluble silicates as precursors is discussed. Different types of nano-phase used for producing of the nanocomposites are examined. The various models of packaging of nanoparticles (spherical, fibrous and layered) introduced into the nanocomposite structure during its preparation are studied. Polymeric materials for structures and coat-ings are increasingly dominating corrosion- protection technology.

Chapter three describes the most effective method of improving protective properties by the use of additional components reducing the rate of diffusion of electrolytes in polymers and anti-corrosive silicate compounds. It is proposed the set of inorganic substances of composite polymeric materials which selectively interact with the water or water solutions of acids, salts, and alkalis in order to decrease their penetrability and increase their chemical resistance simultaneously.

Chapter fourth contains description of the new "green" manufacturing process of the nanostructured composite materials based on using physical phenomenon –superdeep penetration (SDP). Synthesis of a skeleton and formation of nanostructure is realized in metals, polymers and ceramics. Physical anomalies at the impact, which appearing in conditions when relative depth of a crater exceeds 10 determining sizes of striker are considered . Superdeep penetration is used for manufacturing of special composite metal materials with an unusual complex of properties. The SDP method of polymer tracking membranes production was developed.

Chapter five is devoted to creation of a new bioactive composite on a basis of silver nanoparticles. The biocidal effect of nanoparicles-modified paints and coatings is investigated. The structure and technology of biologically active nano-composites preparation is offered.

Sixth chapter presents a brief overview of the work in producing and studying of environment friendly nanostructured polymeric composites. Preparation technology and main applications of the nanocellulose is described. Novel environment friendly hydrophobic polymer composites were developed.

Various types of the layer composites and their applications in production of packaging materials are described. The proposed biodegradable nanocomposite coating increases strength of the natural packaging materials and serves effective barrier against water and grease. Wastes of the novel polymer materials can be utilized in two ways: by repulping and by biodegradation.

Chapter seven is concerned with the problem of improving of seed germination conditions and development of plants and protecting plants from anticipated and averaged adverse conditions with help of biologically active nanochips

The major results of the works presented in this monograph were published mainly in the journal "Scientific Israel-Advanced Technology" (*www.sita-journal.com*) during 2005-2016 period.

The book will be useful to specialists in the field of chemical technology and materials engineering.