Functionalization of Textile surfaces by Growth of ZnO Nano Rods

Objectives

- Development of Multifunctional Textile
  - Lotus Effect
  - UV absorption
  - Photocatalytic Effect

- Growth of ZnO nano rods on textiles by using hydrothermal process
Plan of Presentation

- Introduction
- Growth of nano rods
  - Seedless growth
  - Seeded growth
  - Characterization of nano rods
- Study of functional properties of textiles
  - Lotus Effect
  - UV absorption
  - Antibacterial properties
- Conclusion

Introduction

- A textile which has one of the following characteristics like antibacterial, moisture management, flame-retardancy, antistatic effect, water repellancy, and so on, is called functional textile.
Growth of Nano Rods

- **Seedless**
- **Seeded**

Growth of Nano Rods

- 1st step in seedless growth is nucleation
- Formation of nuclei from zinc oxide precursor solution
- Nucleation is of two types

- **Homogeneous Nucleation**
  - Nucleation takes place within nucleating material

- **Heterogeneous Nucleation**
  - Nucleation takes place on some external materials
Homogeneous Nucleation

Heterogeneous Nucleation

**Nucleation**

- Minimum energy required for nucleation is called Nucleation Energy Barrier
- NEB for heterogeneous nucleation is much less than homogeneous nucleation

**Homogeneous Nucleation**

$$\Delta G = \frac{4}{3} \pi r^3 G_v + 4 \pi r^2 \sigma$$

**Heterogeneous Nucleation**

$$\Delta G_{\text{het}} - \Delta G_{\text{hom}} \approx f(\theta)$$

$$f(\theta) = \frac{1}{2} + \frac{3}{4} \cos \theta - \frac{1}{4} \cos^2 \theta$$
**Nucleation**

- **Two Extreme Cases**

  \[ \text{If } \theta = 0; \quad f(0) = 0; \quad \text{then } \Delta G_{\text{mix}} = 0 \]

  \[ \text{If } \theta = 180^\circ; \quad f(\theta) = 2; \quad \text{then } \Delta G_{\text{mix}} = \Delta G_{\text{mix}} \]

  Example of heterogeneous nucleation

  Bubbles of carbon dioxide nucleating on thumb

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**Seedless growth of Nano Rods on Cotton**

- For nucleation on substrate \( \theta < 180 \)
- Modification of cotton fabric with hydrophobic chemicals

  ![Chemical layer diagram](image)

  Application to Textiles

  - Methyltrimethoxysilane
  - Fluorinated polymer (Unidyne)
Seedless growth of Nano Rods

Procedure for growth of nano rods

Zinc nitrate hexahydrate
Hexamethylenetetramine

Conditions
Temperature 90°C
Time 2 hours

Reactions

\[(\text{CH}_2)_6\text{N}_4 + 6\text{H}_2\text{O} \rightarrow 6\text{HCHO} + 4\text{NH}_3\]
\[
\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^- 
\]
\[
2\text{OH} + \text{Zn}^{2+} \rightarrow \text{Zn(OH)}_2 
\]
\[
\text{Zn(OH)}_2 \rightarrow \text{ZnO} + \text{H}_2\text{O} 
\]

Seedless growth of Nano Rods

SEM image of Nano rods grown Cotton modified with Methyltrimethoxysilane

Flower like structures grew on scattered with nano rods as their petals
Seedless growth of Nano Rods

- Fluorinated polymer (Unidyne)

Nano rods grew on scattered places

As nano rods grew on scattered places on modified cotton fabric.
The possible reason is the nonuniformity of surfaces
PET film was chosen as substrate for nano rods growth
Seedless growth of Nano Rods

- Growth on untreated PET Film

Nano Rods grew as Petals of flowers

Seedless growth of Nano Rods

- Growth of nano rods on Plasma treated PET Film

No Nano rods grew on Plasma treated Film
Seedless growth of Nano Rods

- Growth of nano rods on PET film modified with CVD

Seedless growth of Nano Rods

- Atomic Force Microscopy
Conclusion and Perspective

- Untreated PET Film ---> No growth ---> surface is too hydrophobic
- Plasma treated PET film ---> No growth ---> surface is too hydrophilic
- Plasma treated PET Film Modified with CVD ---> Growth of Nano Rods
- Presence of both hydrophobic and hydrophilic groups is necessary for growth
- Working to grow Nano rods on cotton and PET fabric using these conditions

Seeded Growth

- A layer of nano seeds is deposited on substrate
- Nano rods are grown on these seeds
Seeded Growth on PET Fabric

Polyester Fabric → Plasma Treatment → Seeding → Growth of Nano Rods

Study of Functional Properties → Characterization of Nano Rods

Lotus Effect → UV Absorption → Photocatalytic properties → SEM → AFM

Nano rods grew uniformly on seeded PET Fabric
Lotus Effect

- Lotus effect is cleaning of a surface when water droplet rolls over it
  - Surface roughness
  - Superhydrophobicity $\theta > 150^\circ$
Lotus Effect

• Superhydrophobicity

Modification with Octadecyltrimethoxysilane

Solution method

Chemical vapor deposition

At 40°C for 24 Hours

ODS

At 150°C for 2 Hours

Sample

ODS

Lotus Effect

Characterization of Lotus Effect

1. Water Contact Angle
2. Water Sliding Angle

Water Contact Angle

Water Sliding Angle

$\alpha$
Superhydrophobicity

- Characterization of Superhydrophobicity

Water Contact angle

Solution Modification
$153^\circ \pm 3^\circ$

Chemical vapor deposition
$158^\circ \pm 2^\circ$

Water Sliding Angle

Solution Modification
Sliding angle $\approx 3^\circ - 4^\circ$

Chemical vapor deposition
Sliding angle $\approx 1.2^\circ$

Conclusion

- We successfully grew the Nano Rods on PET Fabric with uniform surface roughness
- Very small water sliding angle was obtained which implies minimum Contact Angle hysteresis
- We obtained LOTUS EFFECT
- Working to improve water contact angle
- Working to study the UV absorption and other Photocatalytic related Properties
THANKS A LOT FOR YOUR ATTENTIONS