Introduction

Photochromic materials are functional materials that reversibly change color when exposed to UV light. They are currently used in transition lenses, but there is a strong interest in these materials for use in smart windows.

Current Application: Transition Lenses

Proposed Application: Smart Windows for Energy Efficient Buildings

The materials available on the market today are primarily organic dyes and while they have excellent coloration and switching abilities, they suffer from degradation. This prohibits their use in long-term applications. To overcome this obstacle, this work focuses on developing a more resistant inorganic-organic hybrid material based on transition metal oxide clusters.

Objective: Synthesize a hybrid material that (a) exhibits strong and fast coloration under UV light and (b) can fade within a few hours when removed from UV light.

Methodology

Sample Preparation

Crystallization from a solution of tungstosilicic acid (H₄SiW₁₂O₄₀, abbreviated SiWA) and glycine (NH₂CH₂COOH):

- Prepare Solution
  - Dissolve H₄SiW₁₂O₄₀
  - Adjust with HCl
  - Stir for 30 min

- Glycine
- Crystalization
  - Oscillate
  - Wait for crystals
  - SiWA (1 week)
  - Grind into powder

Focus on the impact of two parameters on photochromic performance:

1. Glycine: SiW₄ molar ratio in solution  
2. Solution pH

Results

Coloration

When exposed to UV light, all of the samples undergo changes in their absorbance spectra, signaling photochromic activation. The samples form three distinct groups with different behaviors:

- Group 1: Very low coloration
- Group 2: Strong coloration
- Group 3: Very strong coloration

Saturation after: 3 hours

Characterization: UV-Visible Spectroscopy

The coloration and fading behavior of the samples were studied by measuring the reflectance of a thin layer of powder immobilized on a transparent substrate.

Measurements were taken:

- Prior to exposure
- During UV exposure until saturation
- During fading after saturation

The reflectance measurements, r, were treated with the Kubelka-Munk function to obtain the pseudo-absorbance F(r∞):

\[ F(r_\infty) = \frac{(1 - r_\infty)^3}{2r_\infty} \]

Fading

When removed from UV light, all of the samples gradually lose their color, signaling reversible photochromism. Again the samples form the same three groups as during coloration:

- Group 1: Fast fading, complete after 2 hours
- Group 2: Slow fading, complete after ≈ 1 week
- Group 3: Very slow fading, complete after > 1 week

Discussion

1. Photochromism & pH
   The photochromic behavior is related to the pH of the mother solution, but it is independent of the solution molar ratio.

   1 hour in the dark
   2 hours in the dark
   6 hours in the dark

2. pH & Glycine
   The solution pH determines the nature of the glycine molecules available to form the crystal.

   At low pH, cationic glycine is dominant, but anionic glycine gradually forms as pH increases.

3. Glycine & Structure
   Electrostatic interactions lead to crystal formation and are affected by the nature of the glycine molecules.

   Schematic of glycine free orientation
   Schematic of anionic glycine oriented interaction

4. Structure & Photochromism
   The crystal structure determines which functional groups are available to participate in the photo-induced coloration reaction.

Conclusions

1. Silicotungstate-glycine hybrid materials exhibit reversible photochromism, but the intensity of coloration as well as the kinetics of activation and fading depend on processing conditions.

2. Of the two parameters tested in this work, the solution pH used to synthesize the crystals appears to play a strong role in photochromic behavior:
   - Low pH: Very low coloration
   - Mild pH: Relatively fast and strong coloration and reasonable fading times
   - High pH: Excellent coloration speed and intensity, but very slow fading

3. Hybrid materials synthesized between pH 1.6 and 2 have the most attractive compromise of properties when it comes to applications like smart windows.

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