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CORRELATING STRUCTURAL DISORDER AND REFRACTIVE INDEX SENSITIVITY IN PMMA FIBERS

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INTRODUCTION & AIM

While Polymer Optical Fibers (POFs) are valued for their mechanical resilience, increasing their intrinsic sensitivity usually relies on harsh chemical etching. This process irreversibly damages the fiber surface and weakens its structural integrity.

We propose a physical, chemical-free alternative: **thermal bandgap modulation**. Our goal is to demonstrate that strictly controlled heat treatment can selectively tune the fiber's surface for enhanced sensitivity by manipulating its localized structural disorder.

METHOD

1.Thermal Processing: Polymethyl Methacrylate (PMMA) fibers were subjected to specific thermal stages: stress relaxation (100°C) and the onset of oxidative degradation (200°C).

2.Kubelka-Munk Transformation: Raw reflection data (R) was converted to the optical absorption coefficient using the Kubelka-Munk function: F(R) = (1-R)^2 / 2R.

3.Band Gap Extraction: The optical band gap (Eg) was calculated via the Tauc relation for indirect transitions: (F(R)hv)^{1/2} = A(hv - Eg).

4.Disorder Quantification: The localized energy states below the band gap were evaluated by calculating the Urbach Energy (Eu) from the exponential absorption tail: ln(F(R)) = (1/Eu)(hv) + constant.

RESULTS & DISCUSSION

The optical behavior of the PMMA fibers is heavily dictated by their thermal history. Applying linear regression to the Tauc and Urbach plots revealed distinct physical transitions:

- **100°C – The Stress Relaxation Phase:** At 100°C, the fiber simply undergoes thermal relaxation. It maintains high optical transparency with a stable, wide optical band gap of **Eg = 3.678 eV**. The calculated Urbach energy is remarkably low (**Eu = 0.121 eV**), indicating minimal structural disorder and a clean polymer matrix.

- **200°C – The Modulation Phase:** At 200°C, the material fundamentally transforms. The absorption edge shifts dramatically toward the visible spectrum, narrowing the optical band gap to **Eg = 2.129 eV**.

This drop in Eg perfectly aligns with a nearly threefold widening of the Urbach tail (**Eu = 0.313 eV**). In polymer physics, this specific increase in Eu validates the formation of localized, carbon-rich clusters.

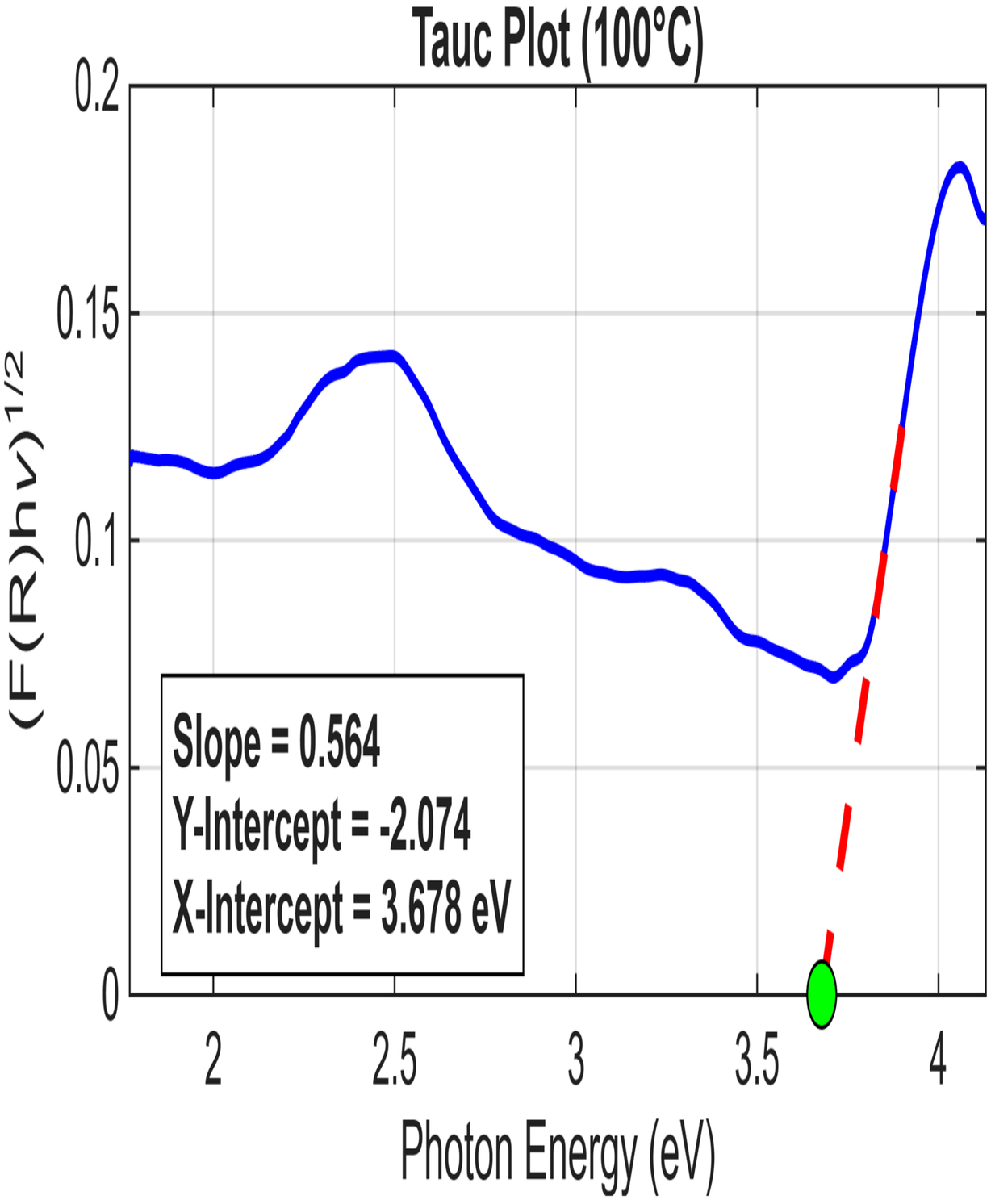
CONCLUSION

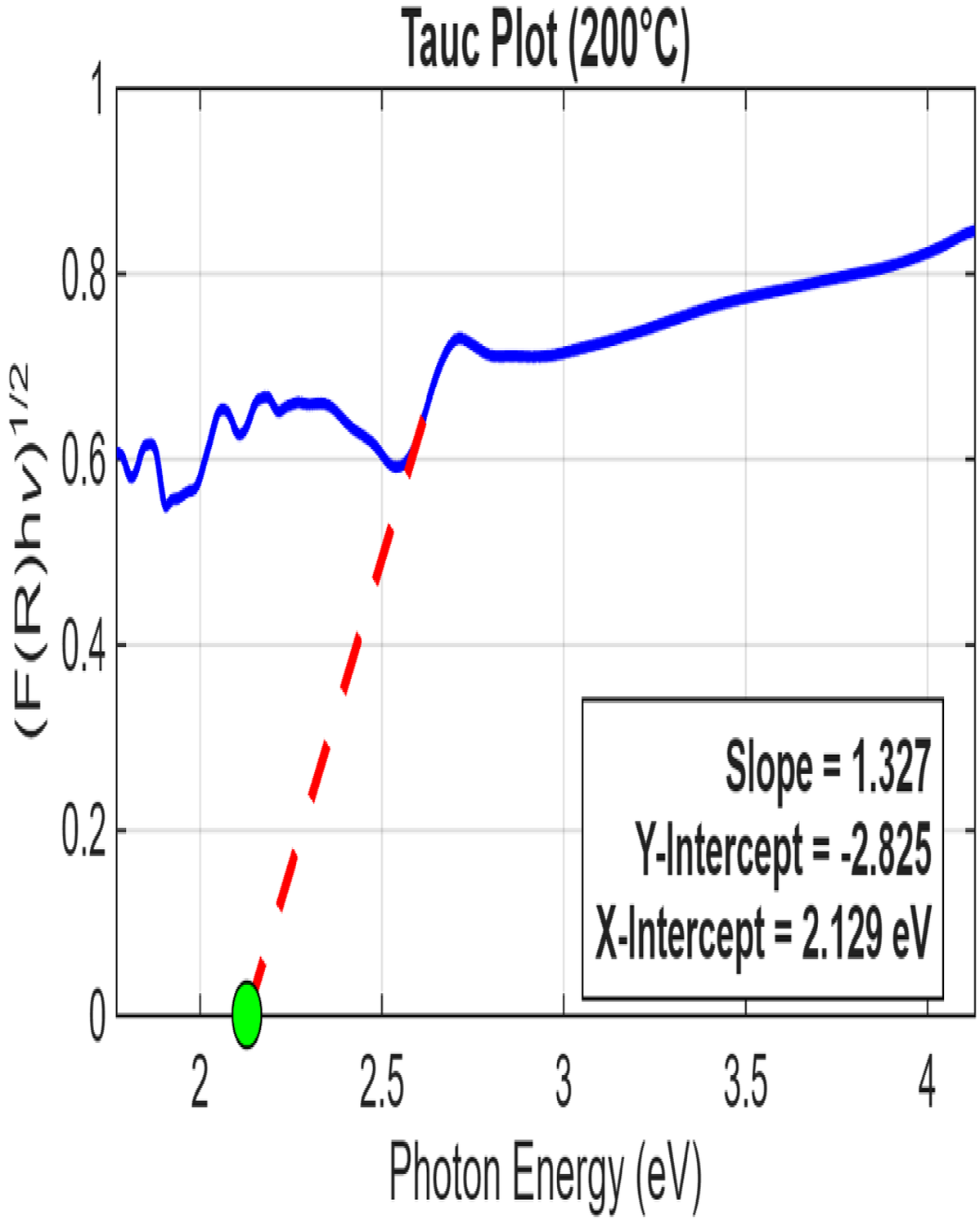
we directly modulated its optical properties - shifting the band gap to 2.129 eV and increasing localized disorder (Eu = 0.313 eV)-to successfully create an intrinsically sensitive surface

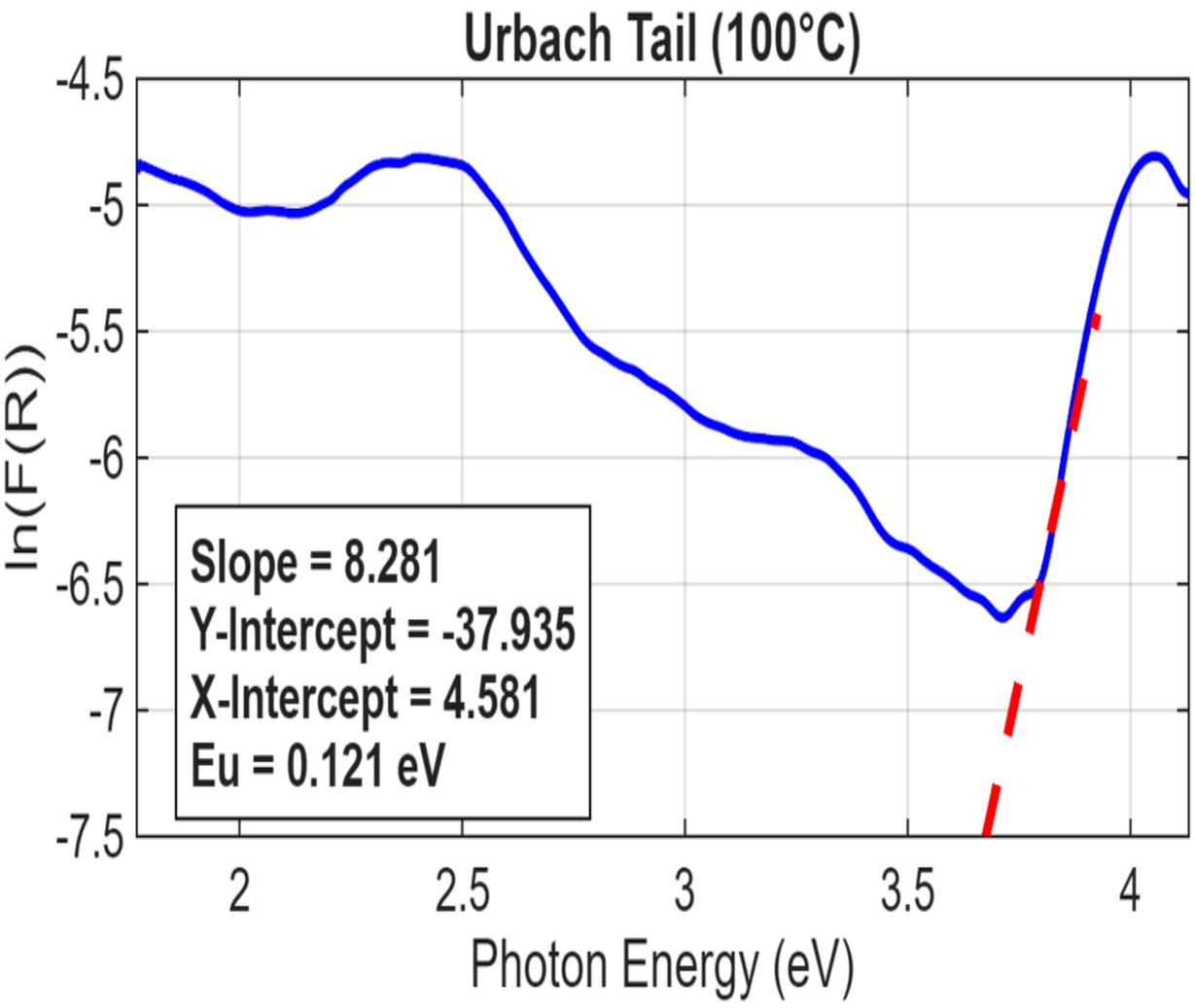
REFERENCES

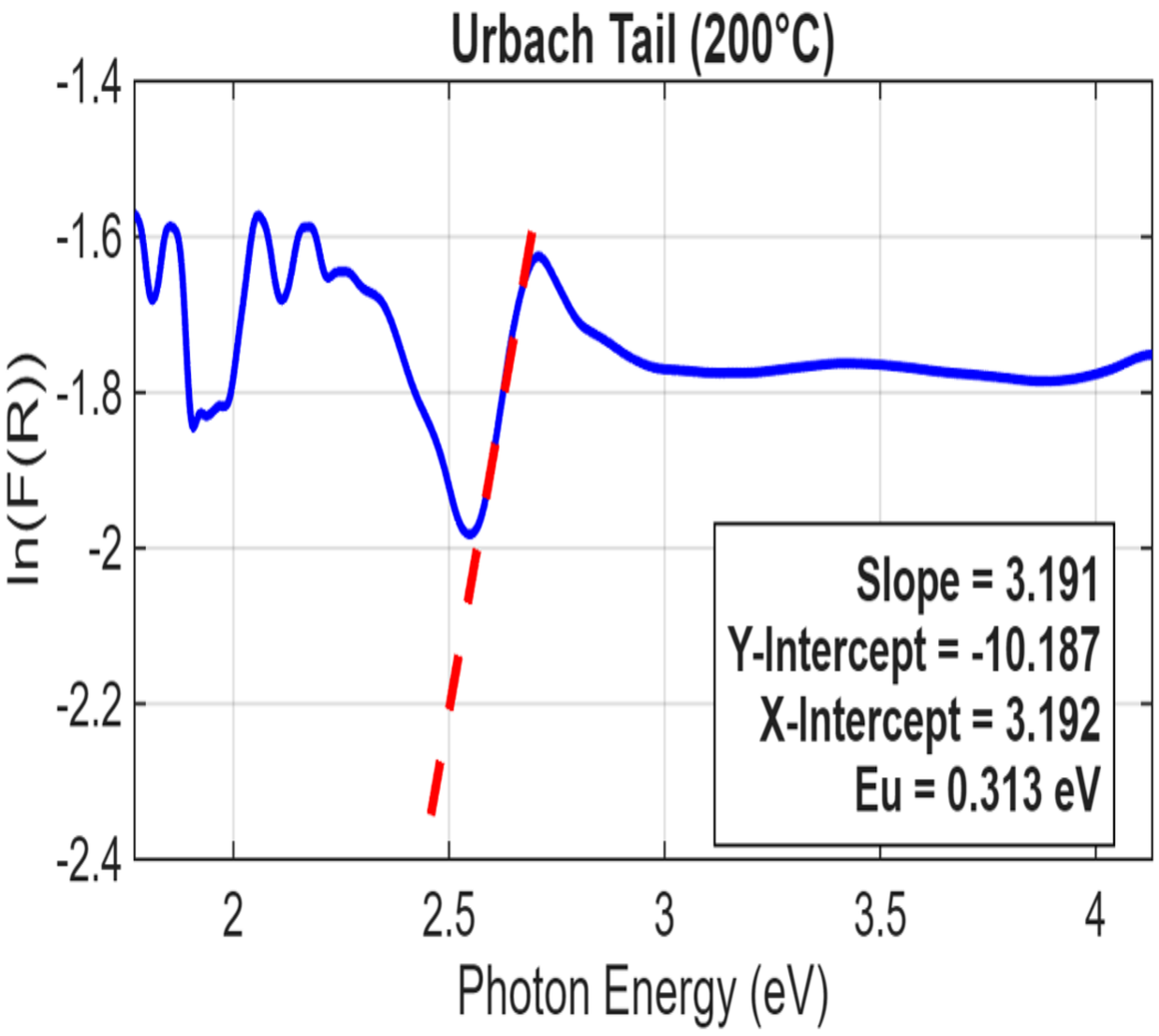
https://doi.org/10.1007/s00289-025-05725-3

Figures


Tauc Plot (100°C)
$(F(R)h\nu)^{1/2}$
Photon Energy (eV)
Slope = 0.564
Y-Intercept = -2.074
X-Intercept = 3.678 eV


Tauc Plot (200°C)
$(F(R)h\nu)^{1/2}$
Photon Energy (eV)
Slope = 1.327
Y-Intercept = -2.825
X-Intercept = 2.129 eV


Urbach Tail (100°C)
ln(F(R))
Photon Energy (eV)
Slope = 8.281
Y-Intercept = -37.935
X-Intercept = 4.581
Eu = 0.121 eV


Urbach Tail (200°C)
ln(F(R))
Photon Energy (eV)
Slope = 3.191
Y-Intercept = -10.187
X-Intercept = 3.192
Eu = 0.313 eV