SUPPLEMENT TO
Long-lived charge traps in functionalized pentacene and anthradithiophene studied by time-resolved electric force microscopy

Michael J. Jaquith,[1] John E. Anthony,[2] and John A. Marohn[1, *]
[1]*Department of Chemistry and Chemical Biology, Cornell University, Ithaca, New York 14853-1301*
[2]*Department of Chemistry, University of Kentucky, Lexington, Kentucky 40506-0055*

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Topography

For topographic imaging, the cantilever was excited by a resonance frequency sine wave having an amplitude of approximately 50 $\mathrm{mV_{rms}}$ delivered by the RHK PLLPRO. This sine wave was applied to a piezoelectric element mounted beneath the cantilever,[1] resulting in a cantilever amplitude of 328 $\mathrm{nm_{pp}}$ (a full interferometric fringe).

The output of the RHK PLLPRO that is proportional to the cantilever amplitude was input into a commercial proportional-integral-derivative (PID) feedback controller (Stanford Research Systems, Model no. SIM960). This PID controller was used to adjust the height of the cantilever above the sample by applying a potential to a custom-fabricated slip-stick nanopositioner[1,2] onto which the cantilever was affixed, as follows. The output of the PID controller was amplified by a commercial high-voltage amplifier (ThorLabs 3-Axis Piezo Controller, model no. MDT693; gain $G = 15$) before being sent to drive the piezo element of the nanopositioner. The extension constant of nanopositioner was 30 nm/V, resulting in a total extension constant, as viewed from the output of the PID, of 450 nm/V.

Images of topography were obtained as follows. The cantilever was advanced towards the surface until its amplitude dropped to a setpoint of 0.82 of the full amplitude. This corresponds to an amplitude of $268\ \mathrm{nm_{pp}} = 0.82 \times 328\ \mathrm{nm_{pp}}$. The sample was scanned laterally, and during the scan the PID compared the instantaneous amplitude to a set value (stored internally in the PIS) and supplied a voltage to the nanopositioner in order to keep the cantilever amplitude at the setpoint. To achieve this, the PID was programmed as follows: P=-0.1 OFF, I=500 $\mathrm{s^{-1}}$ ON, D=5×10^{-4} s ON, Internal Setpoint = 4.5 V. These constants were determined, by trial and error, to give stable feedback with rapid time response. The output of the PID was recorded by a commercial A/D converter (National Instruments DAQ board, model no. NI PCI-6259) controlled by Labview running in Windows XP. The sample height is computed from the PID output voltage by multiplying by 450 nm/V.

The root-mean-square surface roughness (R_{rms}) was determined using

$$R_{\mathrm{rms}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(z_i - \overline{z})^2} \tag{1}$$

where z_i are the height points, $\overline{z}$ is the average height of the image, and n, equal to 128×128 typically, is the total number of height points. Before applying Eq. 1, a plane correction was applied to the height points to account for sample tilt.

Imaging the Distribution of Trapped Charge

The gate bias was applied with a Keithley 6430 sub-femptoamp remote sourcemeter. The images in Figs. 2(b-d), 3(b), 4(b), and 5(b) have 128×128 points and take 5 minutes to acquire.

Trap Formation Rate

The protocol for measuring the rate of charge trap formation was essentially the same as described in Ref.3. By replacing a slow commercial frequency counter with the RHK PLLPRO frequency demodulator, however, we have been able to reduce the time required to quantify the local electrostatic potential from 5 minutes to 2 seconds, a 150-fold improvement.

In fitting the trap density to Eq. 3 in the manuscript, the best fit parameters and their relative error were determined using the Matlab Fit function.

References

[*] Email:jam99@cornell.edu
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