Supplementary Information

Imaging Surface Acoustic Waves on Semiconducting Polymers by Scanning Ultrafast Electron Microscopy

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Multi-pulse Accumulation Effect

Here we argue that the propagation velocity of the surface acoustic wave can be calculated by simply dividing the spatial shift of the waveform by the corresponding delay time used in the experiment as long as the system under study is linear and time-invariant, despite the fact that the observed waveforms contain contributions from multiple excitation pulses. For simplicity, but without loss of generality, we assume the response of the system to a single pulse is a 1-dimensional wave $f(x-ct)$, where x and t are space and time coordinates, and c is the wave velocity. Therefore, at delay time t_1, the observed waveform is

$$F_{t_1}(x)=\sum_{n=0}^{+\infty} f\left[x-v\left(t_1+nT\right)\right], \tag{1}$$

where T is the period of the input pulse train, and the summation takes into account the contribution from multiple input pulses. Similarly, at delay time t_2, the observed waveform is

$$\begin{aligned} F_{t_2}(x) &= \sum_{n=0}^{+\infty} f\left[x-v\left(t_2+nT\right)\right] \\ &= \sum_{n=0}^{+\infty} f\left[x+v\left(t_1-t_2\right)-v\left(t_1+nT\right)\right] \\ &= F_{t_1}\left[x+v\left(t_1-t_2\right)\right]. \end{aligned} \tag{2}$$

Therefore, the spatial shift of the observed waveform is equal to the product of the wave velocity and the different of the delay times, even with responses from multiple pulses. Intuitively, this conclusion is based on the simple fact that each term in the summation of Eq. (1) propagates the same amount in space given the same amount of time, if we assume the wave velocity is invariant with time. A similar argument can justify measuring the damping coefficient from observed waveforms, as long as we assume a time-invariant damping coefficient throughout the measurement.