Universität Münster

Aktuelle Fragen der Nanophysik

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Interaction of surface acoustic waves and organic-inorganic semiconductor systems

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Often referred to as "nanoscale earthquakes", surface acoustic waves (SAWs) are elastic waves propagating on the surface of a solid that transfer energy into its vicinity and control fundamental excitations in surrounding material. Typically SAWs are generated on piezoelectric substrate by applying a sinusoidal voltage signal to comb-like metal electrodes, called as interdigital transducers (IDTs), and while interacting with a semiconductor in its acoustic path the SAW fields modulate the band-gap. Strain-induced field imposes an acoustoelectric (AE) drag on the charges in the direction of SAW propagation, and in a photoconductive semiconductor, excitons get ionized by piezoelectric field into separate electrons and holes, then captured and transported by SAW [1]. Interaction of SAWs with multitude of conventional inorganic semiconductor systems has been studied over the years for AE-driven devices and signal processing components [1, 2]. While the majority of these conventional III-V and 2D semiconductors require high-end cleanroom nanofabrication, emerging new materials, such as organic semiconductors and perovskites, are of low cost, involve spin coated/drop cast deposition and low annealing temperatures to form high-quality thin films.

In this talk, I will discuss how these emerging materials are different from the traditional inorganic semiconductors. I will highlight how the influence of SAW unfolds in these semiconductors, emphasizing on organic polymer, poly(3-hexylthiophene) (P3HT) and poly[2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylenvinylen] (MEH-PPV) based charge transport devices [3-4], excitonic transistor [5] and convolver unit [2]. Next, I will demonstrate the results from our latest investigation of SAW-induced charge transport in hybrid organic-inorganic semiconductor system of P3HT and halide perovskite ($CsPbBr_3$ and $CsPb(I_xBr_{1-x})_3$) nanowires (NWs) [6], and accentuate on how this study reveals the signature of electron and hole mobilities in these systems. Finally, I will present SAW tomography of the NWs using the so-called tapered IDTs, wherein the periodicity is tuned along the aperture of the transducers encoding the spatial coordinates in the frequency of the SAW, hence, uniquely probing the presence of a photoactive nano-material completely contact-free detecting only on the change in SAW transmission. Remarkably, the data also establishes that absorption edge spectrum of any photoconductive material can be evidently figured out with the change in SAW transmission.

References:
[1] P. Bhattacharjee et al., J. Phys. D: Appl. Phys. 57, 423001 (2024).
[2] P. Bhattacharjee et al., IEEE Trans. Instrum. Meas., 72, 1-7 (2023).
[3] H. Mishra, et al., J. Phys. D: Appl. Phys., 56, 015102 (2022).
[4] P. Bhattacharjee, et al., J. Appl. Phys., 133, 195501 (2023).
[5] P. Bhattacharjee, et al., ACS Appl. Electron. Mater., 5, 3650–3656 (2023).
[6] Y. Tong et al., Angew. Chem. Int. Ed., 56, 13887 (2017).

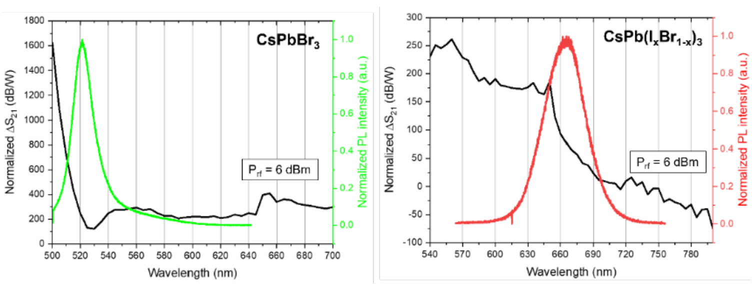

Fig. Estimated absorption edge of halide perovskite NWs via measured ΔS_{21} at $P_{rf} = 6$ dBm with a white light laser source at 60% power focused on the surface of a uniform IDT based SAW device with resonance frequency of 130 MHz, normalized to the laser power recorded for the entire wavelength