High Sensitivity Mid-Infrared/Thermal Detectors

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Fast, high detectivity, and room temperature operable infrared detectors are needed to enable next generation hyperspectral arrays. While photoconductor (pc) detectors can achieve high detectivity and ~100 ps time constants, pc detectors suffer from a narrow spectral range and must be cooled to cryogenic temperatures for efficient detection beyond ~ 4 µm wavelength. Thermal detectors, meanwhile, exhibit a flat detectivity response with respect to wavelength and can, ideally, reach a detectivity of $1.98*10^{10}$ $cmHz^{1/2}W^{-1}$ at room temperature. In this work we focus on two sensitive novel thermal detector architectures: (1) a nanogap based thermomechanical bolometer and (2) a pyroelectric gated field effect transistor (FET) biased in the subthreshold regime.

The thermomechanical (thm) bolometer achieves high sensitivity by closing a ~1.3 nm gap as the surrounding materials expand due to infrared light absorption, resulting in an exponential increase in current. The suspended thm bolometer is made of two metal cantilever arms connected by a 5 nm thick platinum wire (see Figure 1). The nanogap detectors are mechanically stabilized via a self-assembled monolayer (SAM). Early experimental results show temperature coefficient of resistance (TCR) values as high as 0.16 K^{-1}, which is indeed higher than state of the art ~0.1 K^{-1}. Studies to characterize the noise of these devices, measure their response to laser illumination, and determine their detectivity are in progress.

We are also exploring an additional low power and sensitive bolometer design using subthreshold, pyroelectric gated thin film transistors. When infrared light is absorbed, dipole charges in the pyroelectric material align and gate the transistor channel. We estimate that these devices can achieve TCR values of $0.6275/I_0$ K^{-1}, where I_0 is the bias current. The proposed device structure can be found in Figure 2. We are currently exploring the design space of $Hf_{0.5}Zr_{0.5}O_2$ ferroelectric/pyroelectric FETs and optimizing them for 5 µm – 10 µm wavelength detection.

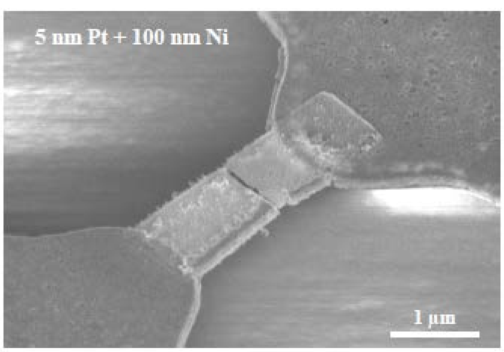

Figure 1: SEM image of suspended thm bolometer

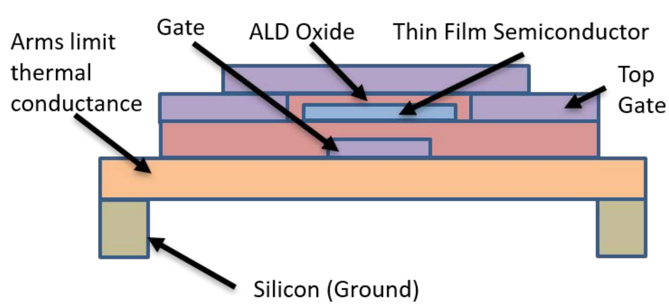

Figure 2: Cross section of proposed pyroelectric gated transistor

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Further Reading

[1] Lin, Y. Infrared Detectors Based on Two-Dimensional Materials and Heterostructures. Massachusetts Institute of Technology, Cambridge, MA, 2019.