Morphology Considerations for Optimizing Metasurface Quantum Well Photodetector Performance

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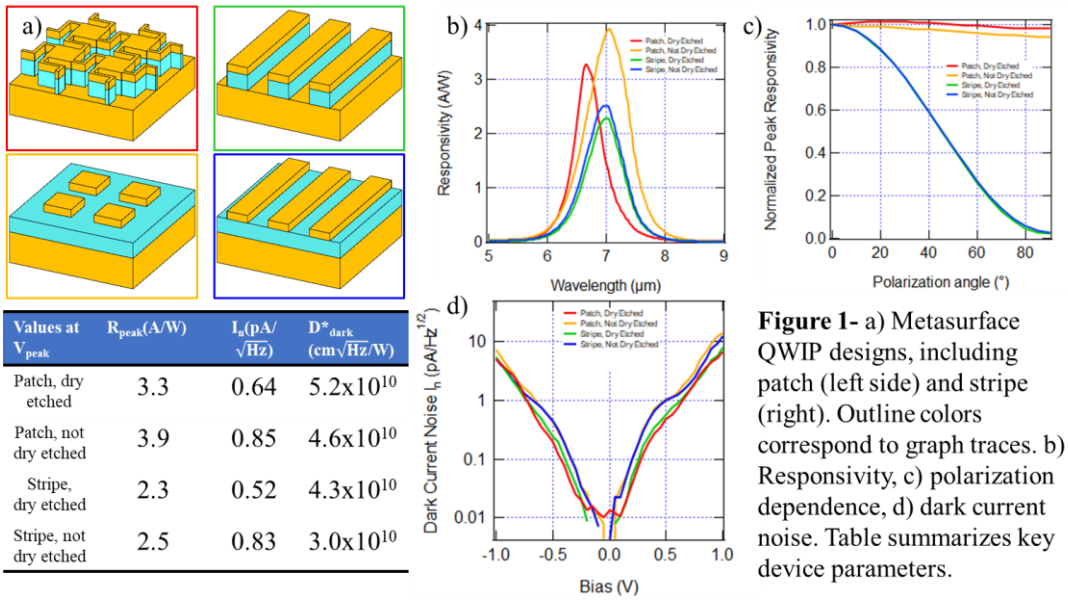
In recent years, metasurface quantum well infrared photodetectors combining metal plasmonic metasurfaces with GaAs quantum wells have demonstrated detectivities approaching the theoretical limit at industrially relevant mid-infrared wavelengths from 6-9μm[1,2]. These detectors have commonly taken on the design of a wired, patch antenna, where larger, micron-scale patches are connected by thinner, nanometer-scale wires and the surrounding semiconductor material is etched away.

However, many other morphologies are possible, such as stripe or patch arrays that do not remove the underlying semiconductor material, as well as dry-etched stripe arrays. Here we discuss how different detector morphologies affect detector device characteristics and the ultimate detectivity of the device based on our experimental results. As seen in Figure 1, different detector morphologies show strong differences in responsivity. While responsivity is higher for both stripe and patch detectors with continuous semiconductor layers than the dry-etched versions, the reduction in dark current that occurs due to dry etching is such that the dark-current-limited detectivity of the detector with the lowest peak responsivity (dry etched stripe) is nearly the same as that of the detector with the highest peak responsivity (not dry etched patch). By combining an optimized antenna structure and dry etching process, an optimum antenna design can be realized.



Values at V_{peak}	R_{peak}(A/W)	I_n(pA/√Hz)	D^*_{dark} (cm√Hz/W)
Patch, dry etched	3.3	0.64	$5.2x10^{10}$
Patch, not dry etched	3.9	0.85	$4.6x10^{10}$
Stripe, dry etched	2.3	0.52	$4.3x10^{10}$
Stripe, not dry etched	2.5	0.83	$3.0x10^{10}$

Figure 1- a) Metasurface QWIP designs, including patch (left side) and stripe (right). Outline colors correspond to graph traces. b) Responsivity, c) polarization dependence, d) dark current noise. Table summarizes key device parameters.

1. D. Palaferri *et al.*, *Nature* **556** (7699), 85-88 (2018).
2. H. T. Miyazaki *et al.*, *Nature Commun.*, in press (2020).