Enabling High Performance III-V Thin-Film Photodetectors on Unconventional Surfaces

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Chair: Professor Stephen Forrest

Abstract: High performance optoelectronic devices made of III-V compound semiconductors are preferred over elemental semiconductors due to their superior optical and electronic properties. With the development of semiconductor fabrication technology, thin-film optoelectronics on unconventional surfaces have drawn attention due to the benefits of enhanced absorption/reflection, reduced fabrication cost, superior mechanical flexibility, opportunities for integration with dissimilar materials, etc. In this thesis, we demonstrate novel fabrication techniques that transfer the III-V optoelectronic devices, especially high-performance photodetectors focal plane arrays, from their bulky and rigid crystalline substrates, to unconventional lightweight, flexible, conformal, and non-developable surfaces without performance degradation. The demonstrations include a cylindrical and bendable 8×100 thin-film In$_{0.53}$Ga$_{0.47}$As p-i-n photodiode array fabricated on a thin flexible plastic foil, and a hemispherical GaAs p-n junction focal plane array that mimics the size, form, and function of the human eye. In addition, we integrate an energy harvesting photodetector comprising an InGaAs-based thin-film thermophotovoltaic (TPV) cell with low index dielectrics and even air for enhanced out-of-band photon recycling. Specifically, an unconventional TPV cell is fabricated over an air cavity, showing 8% (absolute) power conversion efficiency improvement compared to conventional thin-film TPV cells, leading to a record-high TPV power conversion efficiency of > 30% at 1500K emitter temperature. The demonstrated high performance III-V thin-film photodetectors on unconventional surfaces unlock possibilities for future optoelectronics that are beyond current planar and lattice-matched substrates, and provide paths to their ubiquitous applications.