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New Strategies for Single Crystal Plasmonic Nanostructures and Plasmon-based Solar Energy Harvesting

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Plasmon-based solar energy conversion relies on absorption and charge separation at rectifying, metal/dielectric interfaces. Hot electrons produced through plasmon decay can undergo internal photoemission (IPE) and injection into an adjacent dielectric material, generating useful photo-current and -voltage determined by the metal/dielectric material pair. Here, we describe our work to optimize plasmonic photovoltaic devices on smooth and nanostructured Ag/ZnO interfaces and identify the requirements for high quantum efficiency structures. We have (i) modelled the capture of solar radiation by plasmonic metal/dielectric structures using finite difference time domain (FDTD) simulation methods, (ii) fabricated test devices, (iii) evaluated their optical, rectifying, and photovoltaic response, and (iv) characterized their materials properties using electron microscopy, spectroscopy and x-ray diffraction methods. We describe the challenges and opportunities of this and related technologies and introduce a new bottom-up approach to deposit single crystal epitaxial metal films and nanostructures from solution. While this chemistry allows for the subtractive manufacture of nanostructure through ion beam milling, it also enables additive crystalline nanostructure using lithographic methods such as electron beam lithography to enable novel, large area, metamaterial arrays and high aspect ratio crystalline nanostructure. We anticipate that this new approach will have significant impact on this and other new plasmon-based nanotechnologies.

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