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Three-dimensional metallo-dielectric selective thermal emitters with high-temperature stability for thermophotovoltaic applications

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Thermophotovoltaic (TPV) systems convert heat into electricity via intermediate photons without any moving part. In a nutshell, photons thermally generated by a hot emitter are converted into electricity by a standard photovoltaic (PV) cell. As opposed to the Sun's radiation, which is a fixed parameter, in a TPV system the spectrum of radiation becomes a parameter that can be engineered so as to maximize the overall system efficiency. One way to achieve this is by using selective thermal emitters, which can thermally radiate in a spectrum much narrower than that of the blackbody. They are, thus, key elements of TPV systems defining its maximum power throughput and efficiency.

Selective emitters can be engineered by using photonic structures with feature sizes in the order of the wavelength. In addition, the emitter must also be designed to withstand high temperatures for long operation times. Structures based on refractory metals, such as tungsten and tantalum, are typically preferred due to their high melting point and natural low emissivity at long wavelengths. Unfortunately, micro and nanostructures fabricated on such materials become unstable at temperatures much below the expected values due to recrystallization and surface diffusion effects.

Here we present a three-dimensional metallo-dielectric selective emitter with good thermal stability. The structure is based on a macroporous silicon 3D scaffold, pitch of 2µm, conformaly covered with a thin Pt layer. Macroporous silicon allows the fabrication of 3D photonic crystals on large surfaces (full wafer surface) with great finesse. The fabricated structures are monocrystalline, as the original wafer, and can be thermally stable at temperatures close to the melting point of silicon under the appropriate ambients. This structure is further protected with a thin high-quality thermal SiO_2 layer and conformally covered with a Pt layer by ALD. In this way the final structure benefits from both the high thermal stability of the scaffold and the good emission selectivity of metallic-like structures. The fabricated structures have proved to be thermally stable at temperatures up to 1100K in N_2 ambient. Detailed emissivity characterization at high temperatures show that these structures are best in combination with III-V semiconductors in the range E_g=0.4—0.55 eV such as InGaAsSb (E_g=0.5–0.6 eV) and InAsSbP (E_g=0.3-0.55 eV).

Keywords: