

Table 2. Overall Figures of Merit (Defined as Efficiency Times Power Output of System Based on Ref. [10]) for 1-4 Layer Tungsten–Silica Cermet Selective Emitter Structures

Selective Emitter Structure	FOM
Optimized 1 Layer Cermet	16.18
Optimized 2 Layer Cermet	16.96
Optimized 3 Layer Cermet	17.01
Optimized 4 Layer Cermet	17.00

provides the optimized parameters producing the figures of merit in its last column. Figure 8(a) graphs the emissivity spectrum for optimized structures consisting of AR coatings plus 1-4 layer cermets (illustrated in Fig. 2); Fig. 8(b) shows the metal volume fraction as a function of position for optimized cermet structures. The best FOM for selective emitters found was 17.01, which is substantially better than previous FOMs found for 1D photonic crystal structures of 9.79, and platinum structures coated with silica of 10.35 [10]. This corresponds to a projected experimental efficiency of 10.66%, greater than the efficiency of many thermoelectric systems [3]. Thus, tungsten-silica cermets appear to be a good choice for selective emitters as well as selective absorbers.

4. Conclusions

In this paper, we examined the basic physical mechanism for the operation of selective absorbers and emitters based on cermets. We explored a wide range of metals and dielectric materials that could be employed in fabricating a high-performance design, and suggested a combination of tungsten and silica is optimal. It was found that subdividing the cermet layer into multiple layers with varying metal volume fractions and globally optimizing using the software package NLOpt yields gradually increasing performance, although there appears to be a law of diminishing returns when adding more layers. To the best of our knowledge, the overall performance of the optimized 4-layer selective solar absorber exceeds anything else found in the literature, even compared to a 9-layer design in Ref. [14], with a thermal transfer efficiency of 84.3% for 400 K and unconcentrated sunlight, and an efficiency of 75.59% for 1000 K at 100 suns concentration. Furthermore, it was found that a separately optimized but similar 3-layer selective emitter design could yield an energy conversion efficiency of 10.66% for a TPV system as a whole, exceeding other 1D designs of equal or greater complexity. In future work, the role of angular dependence will be explored, and additional optical elements will be introduced to yield higher and even more realistic performance predictions.

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Table 3. Parameters for 1-4 Layer Tungsten–Silica Cermet Structures at 400 K and 1000 K for (a) 1-Layer Cermets, (b) 2-Layer Cermets, (c) 3-Layer Cermets, and (d) 4-Layer Cermets (All Thicknesses in nm)

(a)

1 Layer Parameters	Sel. Absorber (400 K)	Sel. Absorber (1000 K)	Sel. Emitter (1000 K)
AR refractive index	1.44	1.78	1.79
AR thickness	91.1	62.6	57.1
Cermet volume fraction	.2506	.4438	.1988
Cermet thickness	107.7	67.1	188.9

(b)

2 Layer Parameters	Sel. Absorber (400 K)	Sel. Absorber (1000 K)	Sel. Emitter (1000 K)
AR refractive index	1.24	1.24	1.46
AR thickness	114.3	96.3	20.0
Cermet 1 volume fraction	.0910	.1751	.1882
Cermet 1 thickness	80.1	68.3	123.5
Cermet 2 volume fraction	.2495	.4939	.1858
Cermet 2 thickness	124.5	54.4	45.2

(c)

3 Layer Parameters	Sel. Absorber (400 K)	Sel. Absorber (1000 K)	Sel. Emitter (1000 K)
AR refractive index	1.25	1.24	1.25
AR thickness	79.8	53.8	49.3
Cermet 1 volume fraction	.0487	.1622	.1874
Cermet 1 thickness	64.5	33.6	80.5
Cermet 2 volume fraction	.2277	.1874	.1885
Cermet 2 thickness	82.0	37.3	42.0
Cermet 3 volume fraction	.4356	.4918	.1816
Cermet 3 thickness	58.9	95.7	20.0

(d)

4 Layer Parameters	Sel. Absorber (400 K)	Sel. Absorber (1000 K)	Sel. Emitter (1000 K)
AR refractive index	1.24	1.24	1.50
AR thickness	109.6	95.0	11.0
Cermet 1 volume fraction	.0651	.1607	.1877
Cermet 1 thickness	74.3	27.4	85.4
Cermet 2 volume fraction	.2324	.1849	.1882
Cermet 2 thickness	83.9	41.6	42.9
Cermet 3 volume fraction	.4265	.4926	.1918
Cermet 3 thickness	27.8	45.7	10.0
Cermet 4 volume fraction	.4596	.5717	.1684
Cermet 4 thickness	28.5	9.5	30.2