Ir-HfO_2 selective emitters for thermophotovoltaic application

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Introduction

Thermophotovoltaics (TPV)

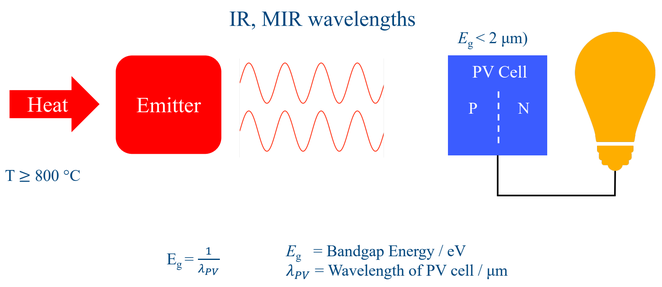
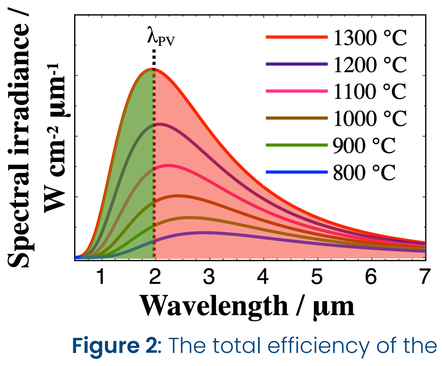


Figure 1 : The basic working principle of a TPV system. Heat from a source is absorbed by a emitter to emit tailored radiation in the infrared regime to a photovoltaic cell that generates electricity

- An emitter allows to transfer heat into electricity

Blackbody Spectrum



Selective Emitter

Figure 2: The total efficiency of the TPV system can be improved by using selective emitters which absorbs long-wavelength radiation highlighted in red. On the right is the STEM cross section of an as-prepared multilayered metamaterial selective emitter

- Challenges of TPV application: Thermal stability is required at high temperatures

Thin-film preparation

Figure 3: Sputtering facility with load lock ø 60 cm

- Multilayered selective emitters are fabricated using magnetron sputtering. (Metal - DC source & dielectric - RF source)

Experimental Results : in-situ XRD and STEM-EDX

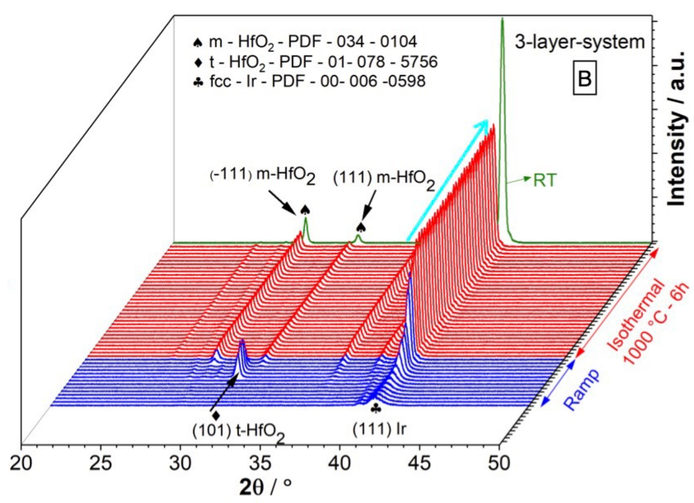


Figure 4: Isothermal annealing of a 3-layer-syste, at 1000 °C for 6 h at 2 × 10^{-6} mbar [1]

- As-prepared : two phase in HfO_2 layer
- Phase transformation in HfO_2 layers (Amorphous → tetragonal → monoclinic)
- Intensity of (111) FCC Ir remains stable during isothermal annealing

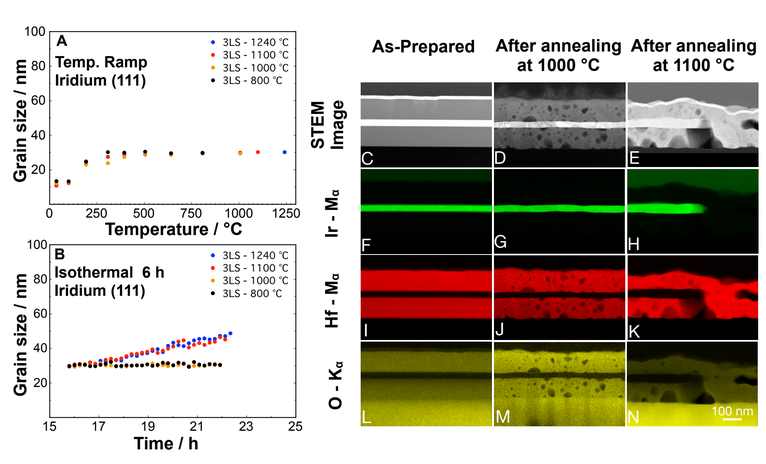


Figure 5 : Grain size Ir as a function of temperature and time during in-situ annealing. Cross sectional STEM-EDX images of 3-layer system before and after annealing [1]

- Grain size of Ir calculated from (111) FCC peak using Scherrer's formula
- Grain size reaches value of 30 nm up to 1000 °C
- After annealing at 1100 °C, grain grown up to 50 nm greater than the layer thickness

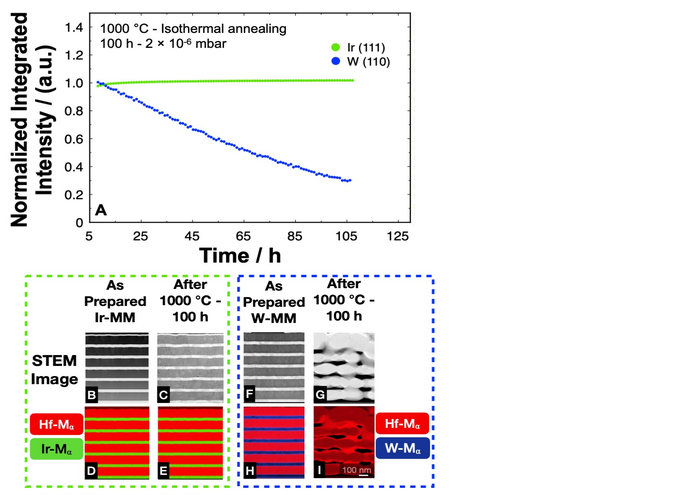


Figure 6: The integrated intensity of (110) BCC W and (111) FCC Ir at 1000 °C for 100 h at 2 × 10^{-6} mbar. Cross section STEM-EDX images of Ir and W metamaterial before and after annealing. [1]

- Time dependent changes in volume fraction of W due to oxidation / sublimation
- Ir remain stable in the multilayer over 100 h at 1000 °C and 2 × 10^{-6} mbar demonstrating excellent thermal stability

Summary

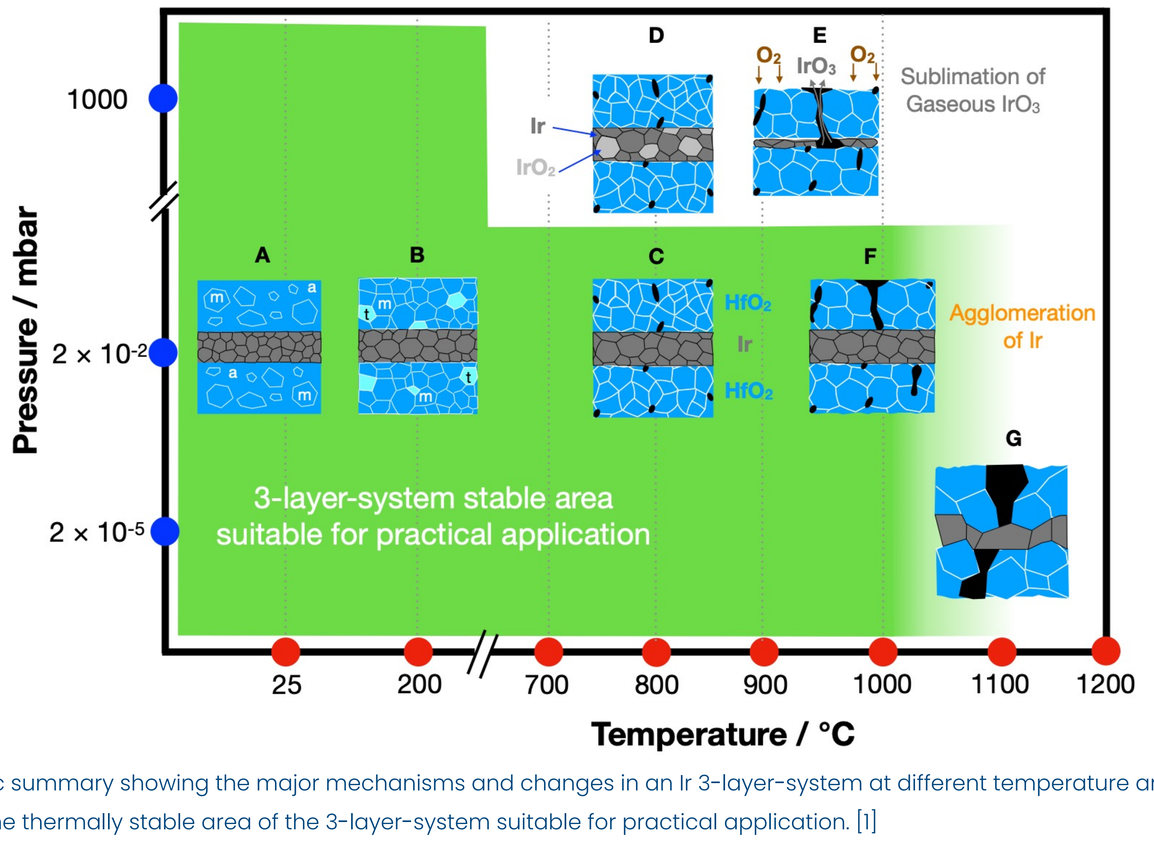
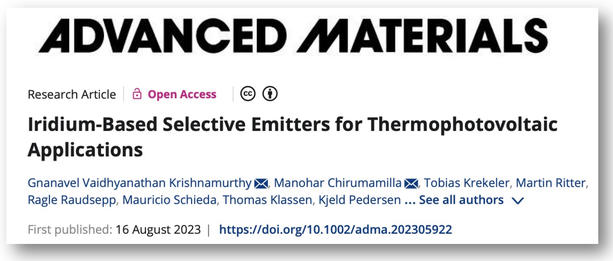


Figure 7: Schematic summary showing the major mechanisms and changes in an Ir 3-layer-system at different temperature and pressure ranges. The green area show the thermally stable area of the 3-layer-system suitable for practical application. [1]

Future Work

- Stabilizing the phase in the HfO_2
- Alloying Ir with a second metal like Ce to prevent grain growth

Publications

1. 
ADVANCED MATERIALS
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Iridium-Based Selective Emitters for Thermophotovoltaic Applications
Gnanavel Vaidhyanathan Krishnamurthy, Manohar Chirumamilla, Tobias Krekeler, Martin Ritter, Ragle Raudsepp, Mauricio Schieda, Thomas Klassen, Kjeld Pedersen ... See all authors
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2. Krishnamurthy, G.V., Chirumamilla, M., Rout, S.S. et al.
Structural degradation of tungsten sandwiched in hafnia layers determined by in-situ XRD up to 1520 °C.
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