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Structural Performance of Micro- and Nanostructured Ceria for Solar Thermochemical Fuel Production[1]

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ASTRI AUSTRALIAN SOLAR THERMAL RESEARCH INITIATIVE

Syngas production via thermochemical redox cycles driven by high-flux solar irradiation is a promising emerging technology for chemical storage of solar energy. Here we investigate the performance of syngas production via nanostructured ceria with high surface area and porosity against commercial powders in two-step thermochemical redox cycles.

Introduction

- Methane partial oxidation (MPO) significantly alleviates the reduction temperature requirement.
- Ceria is a state-of-the-art redox material for stable two-step water splitting (WS) or carbon dioxide splitting (CDS) to produce syngas[2].
- Nanostructuring may improve reaction kinetics of ceria.
- Flame synthesis provides scalable production of ceria nanoparticles[3].

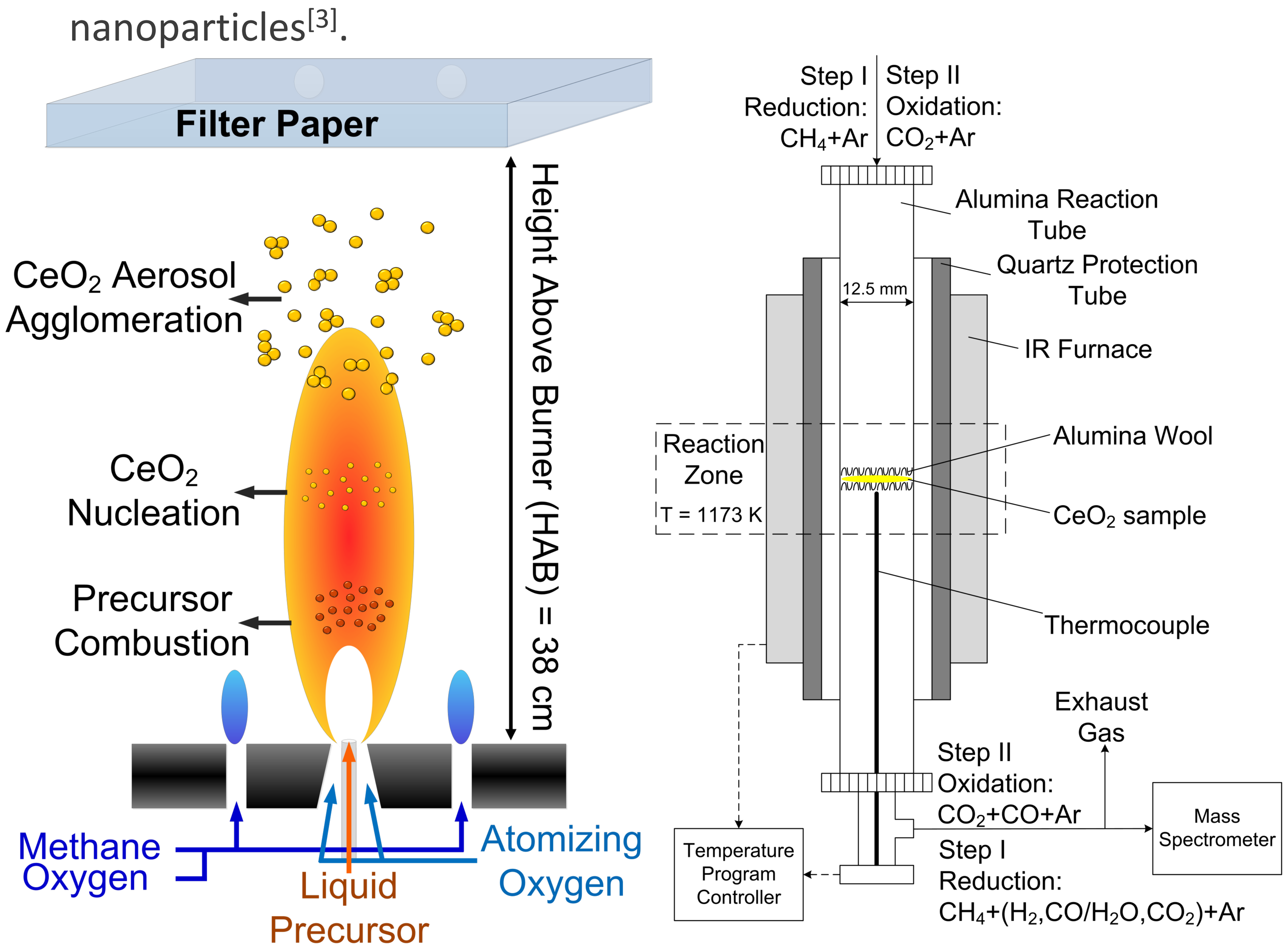

Figure 1: Schematics of the flame spray pyrolysis process[3] (left) and the IR furnace setup for the two-step MPO-CDS 10-cycle tests (right). The tests are performed at 1173 K isothermal condition.

Structural Properties

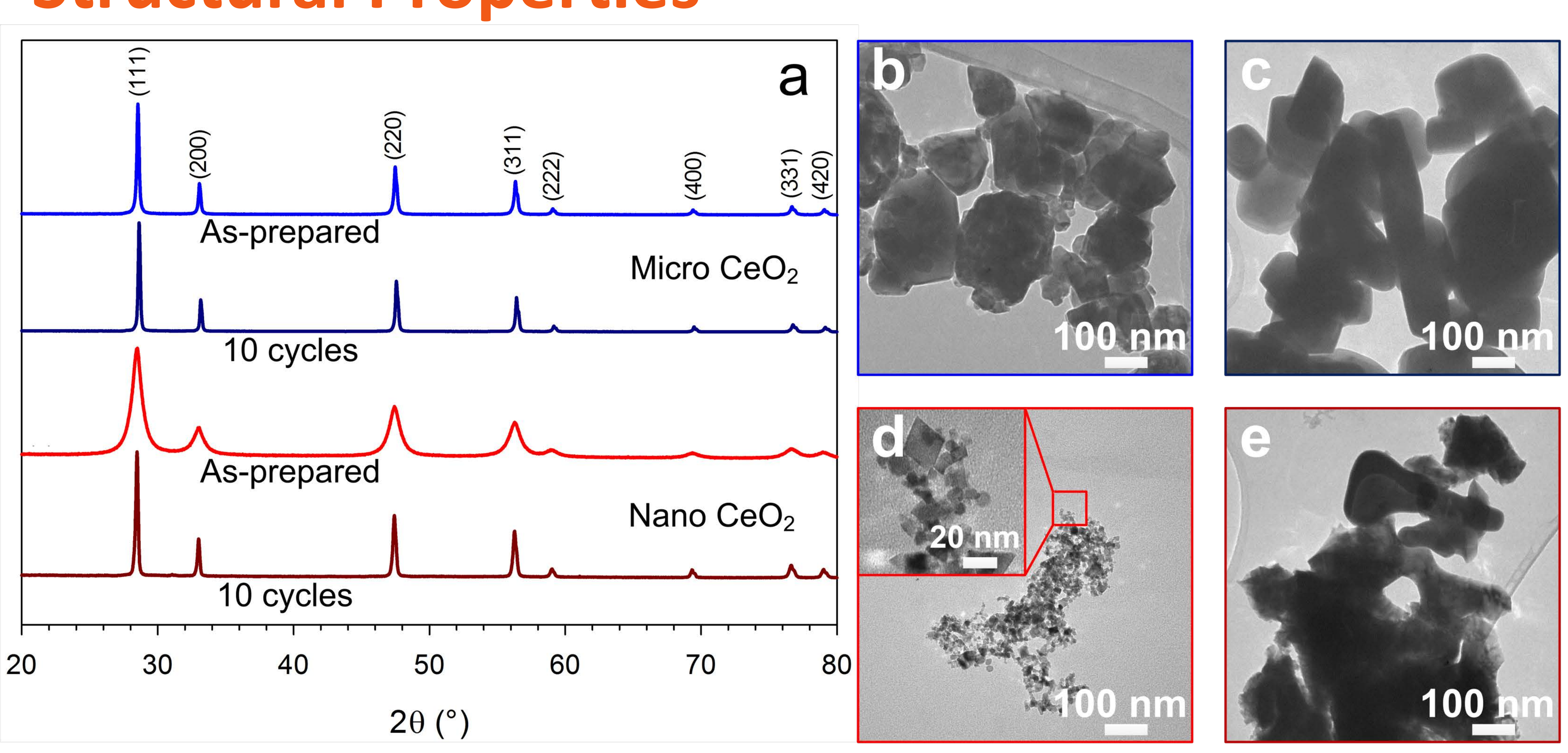

Figure 2: XRD patterns (a) and TEM micrographs of the micro- (b, c) and nanostructured (d, e) ceria before and after 10-cycle MPO-CDS isothermal tests.

Table 1: Specific surface area (SSA), particle sizes (d_{BET}), and crystal sizes (d_{XRD}) of the micro- and nanostructured ceria before and after 10-cycle MPO-CDS isothermal tests.

Material	SSA (m^2 g^{-1})		d_{BET} (nm)		d_{XRD} (nm)	
	As-Prepared	10 cycles	As-Prepared	10 cycles	As-Prepared	10 cycles
Micro- CeO_2	7.34	1.59	106.9	493.3	83.8	86.1
Nano- CeO_2	76.63	1.58	10.2	496.4	9.4	51.3

Fuel Production Performance

- The nano-structured ceria showed up to 167%, 144% and 97% increase of initial average production rates of H2 (MPO), CO (MPO) and CO (CDS), respectively, compared to those of micro-structured ceria.
- After 10 MPO-CDS cycles, despite of the deterioration of structural properties, the above production rates of nano-structured ceria were still 57%, 54% and 15% higher.

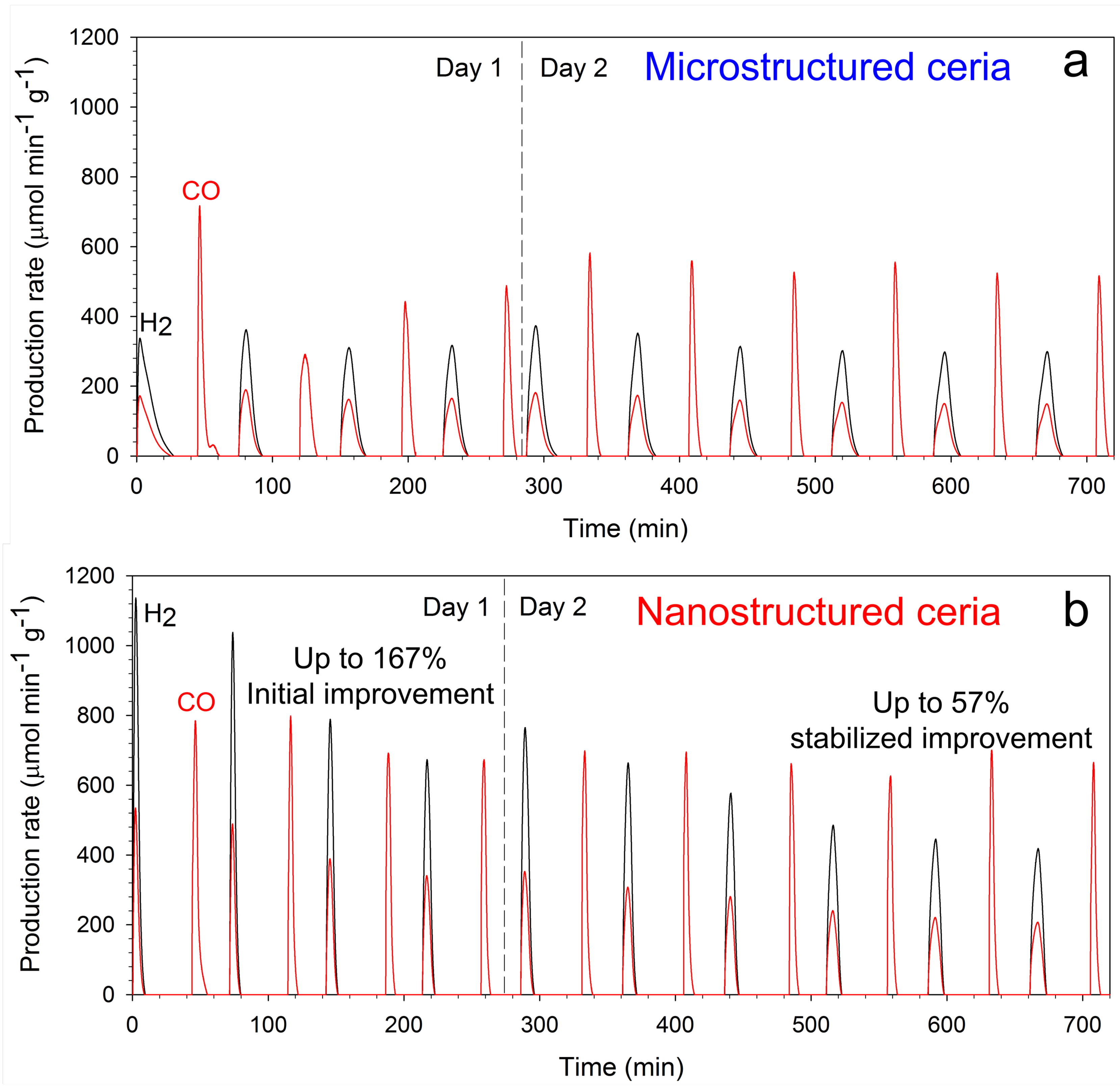

Figure 3: H_2 and CO production rates of the microstructured (a) and nanostructured (b) ceria during 10-cycle MPO-CDS tests. Each cycle includes a reduction step driven by methane partial oxidation (MPO) followed by an oxidation step driven by carbon dioxide splitting (CDS).

Conclusions

- A nanostructured ceria with fast reaction kinetics for two-step thermochemical MPO-CDS fuel production cycles was presented.
- Scalable production of nanostructured ceria with high SSA by flame synthesis was achieved.
- The fast kinetics was mainly attributed to high initial SSA.
- Grain boundary defects helped to increase the oxygen vacancy formation and improve the fuel production performance.
- Maintaining the nanoscale features is crucial for long-term solar thermochemical fuel production performance.

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