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Solar Thermal Dissociation of Zinc Oxide

L. Schunk[a], R. Müller[a], P. Häberling[a], D. Wuillemin[a], A. Meier[a], R. Palumbo[a,b], A. Steinfeld[a,c]

[a] Solar Technology Laboratory, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland
[b] Mechanical Engineering Department, Valparaiso University, Valparaiso IN 46383, USA
[c] Department of Mechanical and Process Engineering, ETH Zurich, CH-8092 Zurich, Switzerland

Solar reactor technology

Thermal dissociation of zinc oxide: $ZnO \rightarrow Zn + ½\ O_2$

Direct heating **rotary reactor** *:

- **Cavity wall** – covered with layer of ZnO(s) of desired thickness –is capable of functioning at ZnO(s) decomposition temperature (> 2000 K) in corrosive environment.
- **Cyclic feeding** of fresh ZnO(s) through water-cooled screw feeder allows semi-continuous operation of the reactor.
- Novel **mechanical concept** ensures rotation at >100 rpm at goal temperatures of 2000 K.
- **Inert gas** – preheated above Zn condensation temperature (~1200 K) – is swept across the window and carries products to the quench zone.

* *European Patent Appl., EP 04 026 418.6, Nov. 17, 2004.*

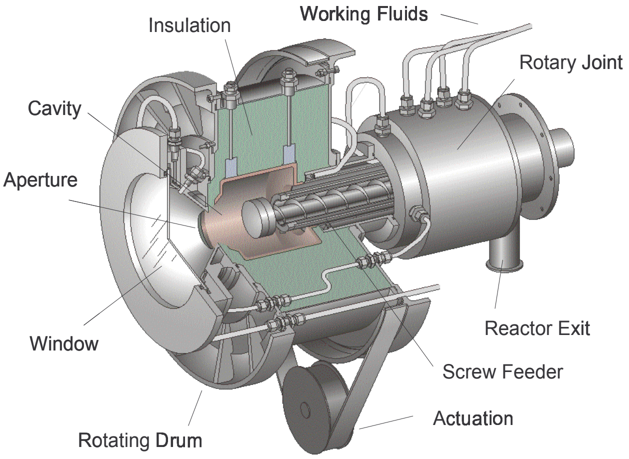
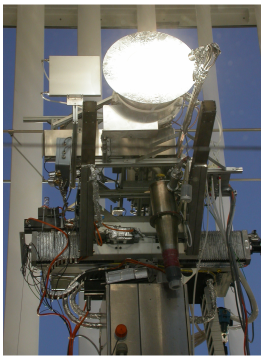


Fig. 1: Schematic of direct heating 10-kW solar reactor prototype.

Solar experimental results



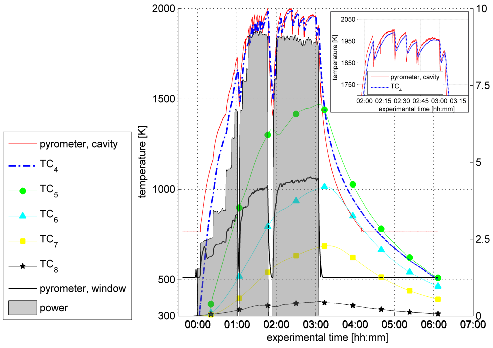


Fig. 2: Test of 10-kW solar rotary reactor at PSI's solar furnace (left); typical experimental run (right): Peak temperatures of 2000 K and input power near 9 kW; temperatures measured with pyrometer (window, cavity) and thermocouples from cavity (TC_4) to outer reactor wall (TC_8). Temperature variations during feeding cycles (inset upper right).

Solar reactor features:

- **Reliable operation** for more than 100 h.
- **Carbothermic reaction:** $ZnO + C \rightarrow Zn + CO$
  SiC cavity
  Optimum temperature: 1700 K
  Efficiency: $\eta_{reactor}$=14±2%; $\eta_{process}$=12 ±2%
- **Thermal dissociation:** $ZnO \rightarrow Zn + ½\ O_2$
  Al_2O_3 / ZnO cavity
  Maximum temperature: 2100 K
  Recombination of gaseous products

ZIRRUS reactor	$ZnO + C \rightarrow Zn + CO$	$ZnO \rightarrow Zn + ½\ O_2$
Temperature range	1400-1800 K	1750-1950 K
ZnO reduction rate	25 g/min	11 g/min
Product recovery	80-95%	50-83%
Zn purity	93-100%	0-80%

Fluid dynamics simulation

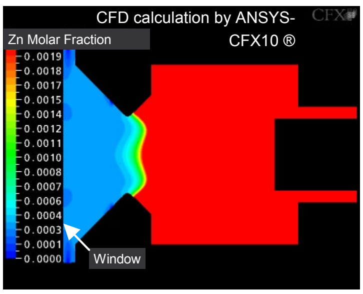


Fig. 3: Zinc gas concentration inside the rotating solar reactor. CFD simulations help optimizing the purge gas injection for keeping the reactor's window clean.

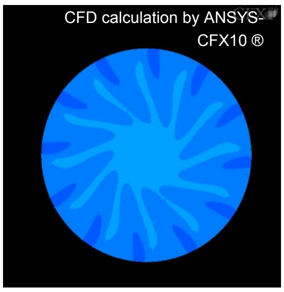


Fig. 4: Zinc gas concentration at the window (see Fig. 3) protected from condensable products by sophisticated purge gas system.

Final steps toward scale-up to 0.5 MW:

- Evaluate ultra-high temperature and thermal shock resistant **cavity and insulation materials**.
- Implement **quench** unit for Zn/O_2 separation.
- Develop reliable **window protection** system.
- Complete performance map of reactor and **validate transient heat transfer model**.
- Operate prototype reactor similar to **industrial solar power plant** (reactor on top of a tower and utilization of a secondary concentrator – CPC).

Information: http://www.pre.ethz.ch
http://solar.web.psi.ch
Contact: anton.meier@psi.ch

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