

Microwave Reactor Engineering for Catalyst Syntheses

Wm. Curtis Conner^{1a}, Geoffrey Tompsett^{1a}, Bernard Panzarella^{1a}, Bhruqesh J. Patel^{1a}, Michael Pratt^{1a}, Ryan Pavlica^{1a}, Murad Gharebeh^{1a}, Fan Lu^{2a}, Scott Auerbach^{1,3a} and K. Sigfrid Yngvesson^{2a}

Chemical & Electrical Eng., Univ. Massachusetts

Studies of the use of microwaves in chemistry have increased exponentially in the last score of years resulting in over two thousand publications in the last year. Reaction rates are often increased by over an order of magnitude while selectivities can also be enhanced. It is recognized as at the forefront of Green Chemistry¹. Continuous processes might even replace batch processes². Microwave enhanced reactions span from ceramics to pharmaceuticals to polymers to zeolites³⁻⁸. The reasons for microwave enhancement are not understood and results from different laboratories are not reproducible.

This paper will discuss and give examples of the microwave reactor engineering of zeolite syntheses, We will demonstrate how reactor geometry, temperature profile, power delivery and distribution influence the synthesis kinetics. Simulation of the distribution of electromagnetic energy within the microwave delivery systems (oven, open or tuned waveguides) for different reactor geometries helps to explain many of the differences^{9,10}. Molecular theory and kinetic theory and simulation in the presence of microwave exposure are recently beginning to unravel the reasons for microwave effects in interfacial reactions such as syntheses, sorption and catalysis¹¹⁻¹³. Both experiment and theory demonstrate that microwave exposure creates systems with multiple local temperatures at steady state.

Microwave enhancements of chemical reactions in a broad range of chemistries are experimental facts. The unique phenomena are due to the chemistries and distribution of microwave energies in time and space as well as their effects on the molecules and their reaction intermediates. The crucial component in understanding and taking advantage of microwave enhancement in chemistry is microwave reactor engineering a multidisciplinary field in its infancy.

References

- (1) Ryan, M. A.; Tinnesand, M. *Introduction to Green Chemistry*; ACS: Washington DC, 2002.
- (2) Kim, D. S.; Kim, J. M.; Chang, J.-S.; Park, S.-E. *Studies in Surface Science and Catalysis* **2001**, 135, 573.
- (3) Clark, D.; Folz, D. *Advances in Science and Technology (Faenza, Italy)* **2003**, 31, 367.
- (4) Ahmad, I.; Clark, D. E. *Ceramic Transactions* **1991**, 21, 605.
- (5) Kappe, C. O. *Current Opinion in Chemical Biology* **2002**, 6, 314.
- (6) Kappe, C. O. *Angewandte Chemie, International Edition* **2004**, 43, 6250.
- (7) Santagada, V.; Perissutti, E.; Caliendo, G. *Current Medicinal Chemistry* **2002**, 9, 1251.
- (8) de la Hoz, A.; Diaz-Ortiz, A.; Moreno, A. *Chemical Society Reviews* **2005**, 34, 164.
- (9) Conner, W. C.; Tompsett, G.; Lee, K.-H.; Yngvesson, K. S. *J. Phys. Chem. B* **2004**, 108, 13013.
- (10) Stenzel, C.; Brinkmann, M.; Müller, J.; Schertlen, R.; Venot, Y.; Wiesbeck, W. A. *Microwave Power & Electro. Energy* **2001**, 36., 155.
- (11) Blanco, C.; Auerbach, S. M. *Journal of the American Chemical Society* **2002**, 124, 6250.
- (12) Blanco, C.; Auerbach, S. M. *Journal of Physical Chemistry B* **2003**, 107, 2490.
- (13) Combariza, A. F.; Sullivan, E.; Auerbach, S. M.; Blanco, C. *Journal of Physical Chemistry B* **2005**, 109, 18439.