

## Amperometric Gas Sensors with Ionic Liquid Electrolytes

M. T. Carter, J. R. Stetter, M. W. Findlay and V. Patel

KWJ Engineering Inc.  
8430 Central Avenue  
Newark, CA 94560

Room temperature ionic liquids have been of interest among the analytical chemistry and chemical sensor communities in recent years, primarily because of their promise in designing new sensors and new analytical methods with improved capabilities, utilizing the unique and diverse chemistry possible with these materials [1-9].

We will discuss new amperometric gas sensors developed at KWJ Engineering, that utilize ionic liquid electrolytes, in both conventional and printed formats. The printed sensor approach exploits modern screen printing and printed electronics strategies to produce a high performance gas sensor at low cost [10,11]. The screen-printed electrochemical sensor (SPEC, Figure 1) shows great promise to provide a new avenue to miniaturized, high-performance, low-cost monitoring of toxic gases, i.e. to bridge the cost-performance gap in gas sensing technology, in addition to enabling battery free operation. The platform provides high sensitivity, high selectivity, low detection limit, long-life and durability for a wide variety of applications, with performance often surpassing what is possible with conventional amperometric gas sensors. Low power operation, a small, thin form factor and scalable manufacturing potential are key enabling features of the technology. We envision these key attributes to be augmented by selection of ionic liquid electrolytes that optimize sensor performance in specific applications.

This presentation will cover the fundamentals of amperometric gas sensing, the transition of this well-established approach to the printed device and specific illustrative examples of applications of conventional and printed gas sensor formats using ionic liquid components.

## References

1. C. D. Tran, "Ionic Liquids for and by Analytical Spectroscopy," *Anal. Lett.*, **40**:13, 2447-2464 (2007):
2. D. Wei, A. Ivaska, "Applications of ionic liquids in electrochemical sensors," *Anal. Chim. Acta*, **607**, 126-135 (2008).
3. P. Sun, D. W. Armstrong, "Ionic liquids in analytical chemistry," *Anal. Chim. Acta*, **661**, 1-16 (2010).
4. I. Goubaidouline, G. Vidrich and D. Johannsmann, "Organic Vapor Sensing with Ionic Liquids Entrapped in Alumina Nanopores on Quartz Crystal Resonators," *Anal. Chem.*, **77**, 615-619 (2005).
5. X.-J. Huang, L. Aldous, A. M. O'Mahony, F. J. del Campo, R. G. Compton, "Toward Membrane-Free Amperometric Gas Sensors: A Microelectrode Array Approach," *Anal. Chem.*, **82**, 5238-5245 (2010).
6. L. Chen, D. Huang, S. Ren, Y. Chi, G. Chen, "Carbon Dioxide Gas Sensor Based on Ionic Liquid-Induced Electrochemiluminescence," *Anal. Chem.*, **83**,

6862-6867 (2011).

7. M. Nádherná, F. Opekar, J. Reitera, "Ionic liquid-polymer electrolyte for amperometric solid-state NO<sub>2</sub> sensor," *Electrochimica Acta*, **56**, 5650-5655 (2011).

8. K. Murugappan, J. Lee, D. S. Silvester, "Comparative study of screen printed electrodes for ammonia gas sensing in ionic liquids," *Electrochem. Commun.*, **13**, 1435-1438 (2011).

9. A. Rehman, A. Hamilton, A. Chung, G. A. Baker, Z. Wang, X. Zeng\*, "Differential Solute Gas Response in Ionic-Liquid-Based QCM Arrays: Elucidating Design Factors Responsible for Discriminative Explosive Gas Sensing," *Anal. Chem.*, **83**, 7823-7833 (2011).

10. J. R. Stetter, E. F. Stetter, D. Ebeling, M. Findlay and V. Patel, "Printed Gas Sensor," Pub. No. US 2012/0125772 A1 (2012). Patent Pending.

11. M. T. Carter, J. R. Stetter, M. W. Findlay and V. Patel, "Printed Amperometric Gas Sensors," *ECS Transactions*, **50**(12), 211-220 (2012).

## Acknowledgements

This work is supported by the National Science Foundation, Award No. 1058563 (NSF SBIR Phase II and follow-on Phase III supplements) and the National Institutes of Health, Grant Nos. 1R43ES019385-01 and 1R43ES021676-01.



Figure 1. Conventional (top) and prototype printed (bottom) amperometric gas sensors.