## EMERGING RESEARCH FRONTS - 2009

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**Ümit Özgür talks with *ScienceWatch.com* and answers a few questions about this month's Emerging Research Front Paper in the field of Materials Science.**

**Article: A comprehensive review of ZnO materials and devices**
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**SW: Why do you think your paper is highly cited?**

This review article represents a cohesive treatment of all aspects of zinc oxide (ZnO), a semiconductor material which is widely investigated for applications in photonics, transparent electronics, acoustics, and sensing. Even though first investigations of this material date back to the 1930s, availability of high-quality substrates in the last couple of decades and reports of p-type conduction and ferromagnetic behavior, both of which, however, still remain controversial, have fuelled the renewed interest in ZnO.

Especially if reliable and reproducible p-type conductivity in ZnO is achieved, this material system can provide optical emitters superior to today's devices. Our paper received such a high level of citation due to the fact that it is a well-organized and comprehensive review of this highly attractive field.

**SW: Does it describe a new discovery, methodology, or synthesis of knowledge?**

Our paper provides a complete synthesis of all the recent progress made by many of the leading experts in the field and a critical review of the published results. It is not only fair but also gratifying to state that so much is owed to our coworkers, colleagues, and those who contributed to the field of ZnO, in particular in our efforts to bring this paper to the service of all researchers, including graduate and undergraduate students.

*"Successful commercialization of ZnO-based devices will have a direct impact on our daily lives."*

**SW: Would you summarize the significance of your paper in layman's terms?**

My colleagues and I reviewed all physical properties and the applications of the ZnO semiconductor material system, which is attractive for a variety of applications in optoelectronics and electronics. Despite the progress made in the research phase, there are still a number of important issues that need to be investigated further before this material can be transitioned to commercial use.

However, there are some niche applications of ZnO, which are not addressed by other semiconductor systems of today. These include transparent thin-film transistors used in liquid crystal displays, transparent contacts applicable to all types of optical devices, including solar cells, gas, and bio-sensors based on nanostructures, and, ideally, thresholdless laser structures exploiting the large exciton-binding energy of ZnO, which makes it the best photon emitter among all semiconductors. This review paper discusses all these prospects and addresses present problems.

**SW: How did you become involved in this research and were any particular problems encountered along the way?**

I first became involved with the ZnO material during my graduate studies. In 1999, we had measured absorption coefficients and refractive indices, which are essential for designing optical devices, especially lasers, of ZnO and MgZnO thin films.

For over 10 years, I have been doing research on optoelectronic devices based on Gallium nitride (GaN), another semiconductor whose applications overlap considerably with ZnO. However, GaN device technology is much more mature as GaN-based very high performance electronic and optical devices, including power field effect devices, light-emitting diodes, and blue laser diodes (those in game consoles and blu-ray players), have already been commercialized.

The highly ionic nature of ZnO with large electron–phonon coupling and low thermal conductivity does not bode well for electronic devices. Additionally, and more importantly, a lack of credible p-type doping hampers the thought of widespread optical emitters based on ZnO, especially when there is such a stiff competition from GaN.

Until p-type conductivity is realized for ZnO, applications of this interesting material system in devices will be limited. I should also mention that, even though nanostructures seem a little easier to produce with ZnO, it remains to be seen whether nanostructures, in general, would really make inroads in the area of devices.

**SW: Where do you see your research leading in the future?**

Our current efforts are focused on understanding fundamental obstacles to obtaining reliable p-type conductivity in ZnO. Future work related to this material system also involves microcavities, which are quite promising for very low-threshold lasers operating in the UV and blue regions of the optical spectrum. If reliable p-type ZnO is obtained, we may see ZnO-based optical emitters revolutionize the optoelectronics industry.

**SW: Do you foresee any social or political implications for your research?**

Successful commercialization of ZnO-based devices will have a direct impact on our daily lives. As an example, if the p-type conductivity problem is resolved, ZnO's relatively low production cost and superior optical properties, when compared to other competing semiconductors, mainly GaN, may lead to a more efficient solid-state lighting technology based on ZnO. The expected economic and social impacts are tremendous, since such a development would reduce energy needs, and therefore, environmental pollution significantly, while improving the quality of life.

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