Sandia paper on flat-panel displays is one of Applied Physics Letters' 50 greatest hits

May 7 2012

A paper by Sandia National Laboratories researchers with implications for early flat panel televisions is one of the 50 most cited papers from the prestigious journal *Applied Physics Letters* in the last 50 years, according to a listing made public by that journal.

The 1996 paper shows that zinc oxide (ZnO) will luminesce in the green (visible) range instead of the invisible ultraviolet range if its oxygen level is reduced. The finding initially proved important in attempts by developers of flat panel technology to use low voltages to create luminescent display panels. The paper, titled “Correlation between photoluminescence and oxygen vacancies in ZnO phosphors,” was authored by former Sandians K. Vanheusden, Carl H. Seager, W. L. Warren, David R. Tallant and J. A. Voigt.

Interestingly, a second, longer paper on the subject by the same authors five months later was cited more than twice as often as the first piece — 1,902, compared with 887, according to the Web of Science, an online academic citation index. The second paper, “Mechanisms behind green photoluminescence in ZnO phosphor powders,” was published in the *Journal of Applied Physics,* where it is listed as one of the 20 most cited papers.

And the hits keep coming: There have been 33 new citations so far this year.

Because even 33 citations are more than most physical science papers ever get — even those with significant impact in their area — the questions arise: Why was this paper so popular, and why is it still being cited?

Tallant, a Sandia retiree who has returned to work a few hours a week, explained that at the time, researchers worldwide were trying to move from high-voltage to low-voltage excitation of phosphors for phones and display panels. Low-voltage excitation seemed promising, but the only materials that would work were organic and didn't survive long. "You wanted something rugged," he said.

The big questions were, "Why does the zinc oxide phosphor work, and what do you have to do to get it to work better?"

As it happens, in a lattice filled by zinc oxide molecules, the negatively charged oxide ions exactly balance the charge of positive zinc ions. But reducing the number of oxide ions creates vacancies (holes) in the lattice that attract electrons to maintain charge balance. This rearrangement creates the lower energy levels that emit green light. "So these were good candidates for green panel displays, hot at that time," Tallant said.

Using Sandia's unusually wide array of instrumentation to narrow possibilities, the researchers observed a strong correlation between green-light emission and oxygen vacancies in commercial ZnO phosphor powders.

As to why two papers were written rather than one, Carl Seager wrote in an email, "The work was of sufficient interest to the community studying phosphors that we felt quick publication was important. This was only possible for papers submitted to journals that rapidly publish letters, like *Applied Physics Letters*. Unfortunately, the totality of the work could not be compressed to fit in the space dictated by the restricted letter format, so a later publication was also warranted where all the details of the research could be presented. Thus a follow-up, longer paper was prepared for the *Journal of Applied Physics*. So it wasn't really the interest in the first paper that stimulated the second paper, it was the interest in the topic that dictated putting part of the work in the earlier, shorter*APL*."

The seminal nature of the finding may be the reason that the paper continues to be cited, though present technology has left the old advance far behind.

Provided by Sandia National Laboratories