Control of Point Defects and Space Charge in ZnS:Mn with KCl

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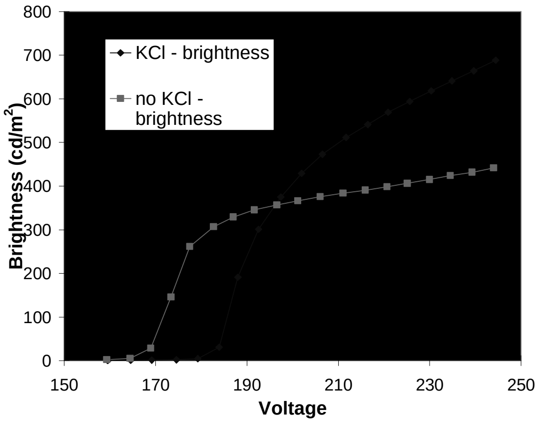
Alternating-current thin-film electroluminescent (ACTFEL) devices based on a ZnS:Mn emitting layer have been studied since the early 1960s, and have been the mainstay of the commercial ACTFEL market since the early 1980s. Historically, the brightest and most efficient devices are fabricated using either thermal evaporation or atomic layer chemical vapor deposition (ALCVD) to deposit the ZnS:Mn layer.[1] Efforts to produce comparable devices by sputter depositing the phosphor layer have resulted in more defective films and lower brightness and efficiency.[1]

Previously we have shown that ex-situ co-doping of the sputter deposited ZnS:Mn active layer with K and Cl results in 53% improvement in brightness, 62 % improvement in efficiency, and better 100-hour accelerated aging stability (see figure 1).[2] The mechanisms leading to improved brightness, efficiency, and stability of alternating-current thin-film electroluminescent (ACTFEL) ZnS:Mn phosphors have been studied. In this work, we demonstrate that these improvements result from a 75% increase in excitation efficiency for conduction electrons (see figure 2 and 3), combined with a small decrease in the efficiencies of both light outcoupling and non-radiative recombination. Electrical properties data were used to determine that there is a reduced amount of static space charge in the co-doped films, resulting in a larger average field, increased excitation efficiency, and increased charge multiplication.

The role and nature of point defects in ZnS and ZnS:Mn are reviewed. The reduced space charge is attributed to the addition of charge compensating zinc vacancy-chlorine complexes and isolated chlorine point defects, which are acceptor and donor defects, respectively, and the reduction of zinc vacancy deep hole traps. It is postulated that higher average fields results in sufficient electron multiplication or donor ionization such that current for EL excitation is limited by the phosphor resistance rather than the capacitance or density of states. The possibility of using these mechanisms to increase the efficiency of generic ACTFEL phosphors is discussed.

References
1. K.E. Waldrip, M.R. Davidson, J.H. Lee, B. Pathangey, M. Puga-Lambers, K.S. Jones, P.H. Holloway, S.-S. Sun and C. N. King, Display and Imaging, **8 suppl.**, 73 (1999).
2. K.E. Waldrip, J.S. Lewis, Q. Zhai, M. Puga-Lambers, M.R. Davidson and P.H. Holloway, J. Appl. Phys. **89**, 1664 (2001).



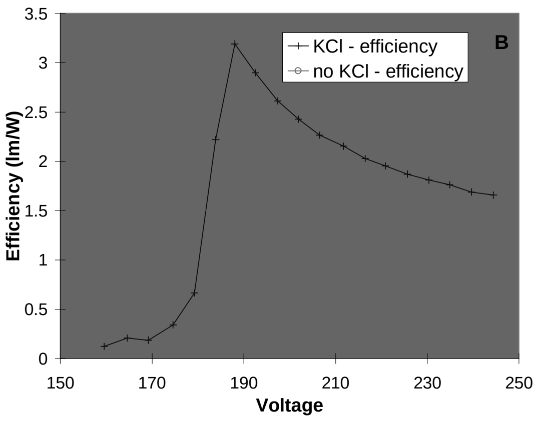


Figure 1. (a) Brightness and (b) efficiency vs. voltage for ZnS:Mn devices with and without KCl co-doping.

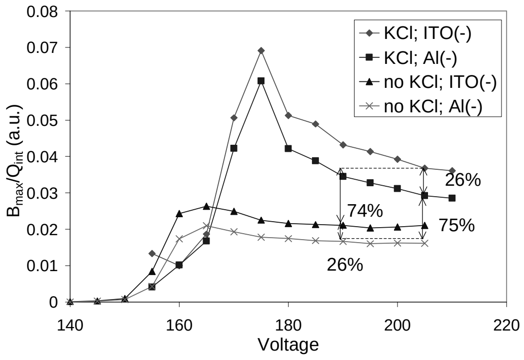


Figure 2. B_{max}/Q_{int} vs. applied voltage for both polarities of KCl codoped and undoped ZnS:Mn samples

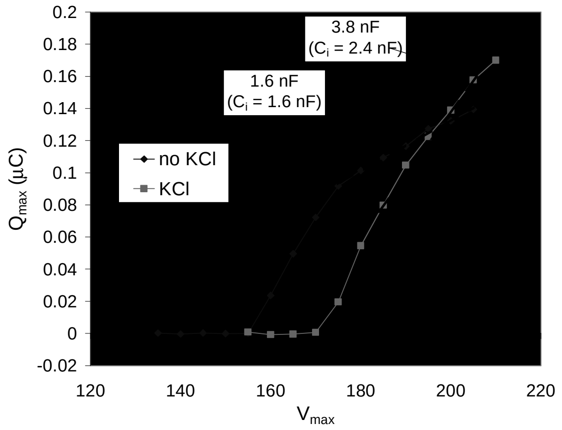


Figure 3. Q_{max} vs. V_{max} for KCl codoped and undoped ZnS:Mn samples.