Modeling and Measuring Cathodoluminescence of Eu in AlN and Er in Glass

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Abstract

Electroluminescence of Rare Earth Ion (REI) doped materials may one day be used as a light source for displays or lasers. To understand this phenomenon, we study the Cathodoluminescence (CL, light produced by electron bombardment) of those materials. Previous work showed that the intensity of REI emission from CL was much less than from photoluminescence – reducing its usefulness as a light source, and that saturation quickly occurred – increasing current did not increase intensity. A possible explanation is that the REIs are not directly excited by the electron beam, nor do the electron-hole pairs it creates move directly to the REIs. Instead, there might be an intermediate trap. This would limit the active REIs to ions near a trap, and the process would take longer than direct excitation. We took CL measurements of two more materials – Eu doped AlN and Er doped glass – and observed the same saturation phenomenon. We modeled this as a two energy level system, with N total ions, N_e excited ions, and N_g ions in the ground state. When the beam bombards a region, $\frac{d}{dt}N_e = pN_g - kN_e = -pN_e - kN_e + kN$ and when it was not, $\frac{d}{dt}N_e = -kN_e$ (p is a pump rate proportional to beam current, and k is the decay rate). By sweeping the electron beam back and forth, in a line, at varying frequency, regions of the sample are alternatively bombarded and left alone for different amounts of time. While the equations for N_e have simple exact solutions, the steady state – where N_e is the same at the beginning and end of one sweep – does not. We found two useful approximations for the time average of N_e – which is proportion to the observed intensity, but we decided to solve it numerically. We wrote a computer program to fit the model to the data, and we were able to determine $\tau = \frac{1}{k}$. This value was close to the lifetime of the $^5D_0$ state of Eu (which we were observing as its emission is the most intense), so that did not provide evidence for a trap. However, the reduced intensity indicates that something is limiting the number of active REIs – possibly a trap that is faster than the decay of the EU state, thus avoiding easy detection by this method.

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