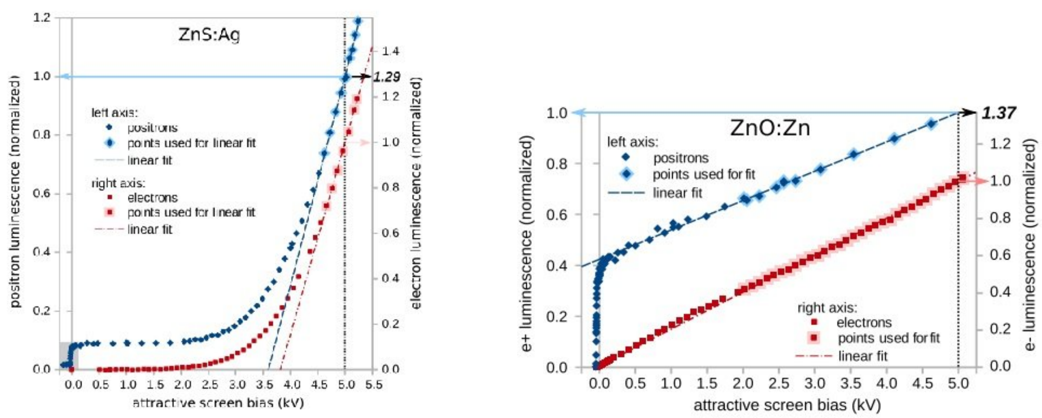
Positron luminescence outshines that of electrons

April 30 2018, by Lisa Zyga



Differences between electron luminescence and positron luminescence for two different phosphors, ZnS:Ag and ZnO:Zn. Credit: Stenson et al. ©2018 American Physical Society

In old cathode ray TVs, a picture is generated when an electron beam excites a phosphor screen, causing the phosphor to radiate light. Now in a new study, researchers have found that a beam of positrons (positively charged anti-electrons) incident on a phosphor screen produces significantly more luminescence than an electron beam does.

When the researchers began their research, they expected the applications to be primarily utilitarian: mainly, to understand the differences between using positrons and electrons when performing experiments with phosphor screens as positron diagnostics. However, the differences were much more interesting than they expected, which may extend the potential applications to areas such as designing new diagnostic systems as well as learning more about the properties of luminescent materials.

The scientists, E. V. Stenson, U. Hergenhahn, M. R. Stoneking, and T. Sunn Pedersen, at the Max Planck Institute for Plasma Physics, among other institutes, have published a paper on their comparison of positron and electron luminescence in a recent issue of *Physical Review Letters*.

In their experiments, the researchers compared the luminescence excited by a positron beam with that excited by an electron beam for two different phosphors (ZnS:Ag and ZnO:Zn). For both phosphors, the overall results were similar. As the beam energy increased from zero, the amount of positron-induced luminescence rose rapidly, while the amount of electron-induced luminescence increased much more gradually. Above a certain level of beam energy, both types of luminescence grew in a linear fashion at approximately the same rate. So at very high beam energy levels, the difference between positron- and electron-induced luminescence became negligible.

Instead, the most striking difference occurred at the lower beam energy levels. For example, in order to produce the same amount of luminescence that is produced by an electron beam with several thousand electron volts of energy, a positron beam required only a few tens of electron volts (eV) for ZnS:Ag, and for ZnO:Zn, even less than 10 eV. As the researchers explain, the huge difference arises from positron annihilation, which produces greater numbers of excited states in the phosphor materials.

As positrons can be used as a tool for learning about phosphors, and phosphors can be used as a tool for learning about positrons, the researchers expect that the results will be interesting for both areas.

"For researchers who look at positrons incident on materials, it's the positrons that are the object of interest," Stenson told *Phys.org*. "In this case, a phosphor screen is seen as just a tool for learning about the positrons—for example, something as simple how many of them you have available as ingredients for making anti-atoms or matter-antimatter plasmas.

"For other researchers, it is the other way around, where positrons are a tool for learning about some material. One can do this, for example, by looking at how long it takes positrons to annihilate with a particular solid or liquid or gas, at what angles positrons scatter off a material, or the energy spectrum of electrons that are emitted from a material in which a positron beam annihilates."

Because of the striking difference between electrons and positrons, the results also offer a new tool for understanding the properties of luminescent materials in general.

"Luminescent materials have a long history, having been used for decades in things like cathode ray tubes, and they are still being developed for a variety of new applications," Stenson said. "Luminescent materials have applications ranging from consumer goods (displays, afterglow materials) to specialized detectors (gas sensors, scintillators) to nanoparticles used for cancer treatment."

Stenson explained that, despite these materials having such a long history, there are still open questions about important aspects of the physics of luminescent materials. These questions include the structure of luminescence centers, the excitation and relaxation pathways for cathodoluminescence, and the origin of the 'dead voltage'—that is, why electrons with less than a keV or two of energy don't produce detectable luminescence in many phosphors.

"I expect that further studies of positron-induced luminescence (for example, comparing the spectrum of light produced by low-energy positrons vs. high-energy positrons vs. high-energy electrons) will be a valuable means of investigating these open questions, especially when combined with other approaches that are already in use for studying luminescent materials," Stenson said.

More information: E. V. Stenson, U. Hergenhahn, M. R. Stoneking, and T. Sunn Pedersen. "Positron-Induced Luminescence." *Physical Review Letters*. DOI: 10.1103/PhysRevLett.120.147401