Positron-Induced Luminescence

E. V. Stenson,[1,2,3*] U. Hergenhahn[1,4] , M. R. Stoneking[1,5], and T. Sunn Pedersen[1,6]

[1]*Max Planck Institute for Plasma Physics, Greifswald & Garching, Germany*
[2]*Technische Universität München, Garching, Germany*
[3]*University of California San Diego, La Jolla, California, U.S.A.*
[4]*Fritz Haber Institute of the Max Planck Society, Berlin, Germany*
[5]*Lawrence University, Appleton, Wisconsin, U.S.A.*
[6]*University of Greifswald, Greifswald, Germany*

Cathodoluminescent materials, in addition to being widespread in consumer devices, are important scientific tools for diagnosing charged particle beams, short-wavelength photons, and non-neutral plasmas. Despite decades of use, however, some important aspects of the physics of phosphors remain topics of debate and investigation; depending on the material, this may include the structure of luminescence centers, the excitation and relaxation pathways, and/or the origin of the "dead voltage" [†]. Yet another question involving phosphors is a practical one; although they are routinely used for diagnosing both matter and antimatter systems, comparisons between the two are scarce.

Low-energy positrons incident on a phosphor screen have been found to produce significantly more luminescence than electrons do [1]. For two different wide-band-gap semiconductor phosphors (ZnS:Ag and ZnO:Zn), the luminescent response to a positron beam was compared with the response to an electron beam. For both phosphors, the positron response is significantly brighter than the electron response, by a factor that depends strongly on incident energy (0–5 keV). Positrons with just a few tens of eV of energy (for ZnS:Ag) or less (for ZnO:Zn) produce as much luminescence as is produced by electrons with several keV. We tentatively attribute this effect to valence band holes and excited electrons produced by positron annihilation and subsequent Auger processes.

These findings are expected to have significant utility for nonperturbatively diagnosing low-energy positron beams and plasmas (relevant to electron-positron pair plasma creation, antihydrogen experiments, slow positron scattering processes, and positronium ionization studies, among other applications). They potentially also represent a new approach for addressing longstanding questions about luminescent materials.

References

[1] E. V. Stenson, U. Hergenhahn, M. R. Stoneking, and T. Sunn Pedersen. *Phys. Rev. Lett.* **120**, 147401 (2018).

[*]Corresponding author, Email: evs@ipp.mpg.de

1 For most phosphors, no luminescence is observed when incident electrons' kinetic energy is below some threshold, which is usually orders of magnitude larger than the material's band gap. The transition to the linear regime, in which an increase in electron beam energy produces a proportional increase in the number of photons produced, may not occur until the energy exceeds several keV.