

Positron annihilation spectroscopy and the use of positron beams. Applications in Cultural Heritage

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This contribution outlines the principles and applications of Positron Annihilation Spectroscopy (PAS) as a robust, non-destructive probe for characterizing open-volume regions and atomic-scale chemical environments [1] within Cultural Heritage materials. The presentation introduces two primary techniques: Positron Annihilation Lifetime Spectroscopy (PALS), utilized for determining defect size and concentration via positron lifetimes [2], and Coincidence Doppler Broadening (CDB), which yields elemental specificity of the annihilation site [3]. A key focus is the application of variable energy positron beams; unlike conventional bulk methods, this approach enables depth-profiling of thin layers and surfaces, effectively linking bulk properties with surface phenomena.

Given that preserving object integrity is paramount in Cultural Heritage, PAS provides critical insights into microstructure, open-volume regions, and degradation states without the need for destructive sampling. The versatility of these methods is demonstrated through case studies on UV-photodegraded polymers in Modern Art [4] and ancient amber jewellery [5], highlighting how PAS complements traditional analytical techniques across a vast historical timeline.

Intended audience: This contribution is aimed at young professionals, undergraduate, graduate students, and academics working in physics, materials science, and cultural heritage conservation who are interested in advanced non-destructive characterization techniques and the specific application of antimatter probes for material analysis.

Learning outcomes: By the end of the lecture, participants will gain understanding of the physical mechanisms behind positron annihilation and the distinct capabilities of PALS and CDB techniques. They will appreciate the specific advantages of using positron beams for surface and depth-dependent studies. Furthermore, attendees will learn how to interpret basic PAS data in the context of Cultural Heritage, recognizing how microstructural evolution correlates with the aging and processing of cultural materials.

1. A. Dupasquier and A. P. Mills (Eds.) *Proceedings of the International School of Physics Enrico Fermi*, course CXXV: “Positron Spectroscopy of Solids” (IOS, Amsterdam, 1995).
2. J. Čížek. Positron Lifetime Spectroscopy to Study Defects in Solids, *Solid State Phenomena* **373**, 3-25 (2025), doi: [10.4028/p-3YSi87](https://doi.org/10.4028/p-3YSi87)
3. R. Ferragut. Coincidence Doppler Broadening to Study the Chemical Environment at Positron Annihilation Sites, *Solid State Phenomena* **373**, 27-38 (2025), doi: [10.4028/p-m789Yx](https://doi.org/10.4028/p-m789Yx)
4. D. Saviello. Preservation of plastic artefacts: multi-analytical assessment of materials degradation and development of conservation strategies. *PhD Thesis, Politecnico di Milano* (2015).
5. B.I. Łydźba-Kopczyńska, et al. Provenance investigations of amber jewelry excavated in Lower Silesia (Poland) and dated back to Early Iron Age. *J. Raman Spectrosc.* **43**, 1839–1844 (2012), doi: [10.1002/jrs.4187](https://doi.org/10.1002/jrs.4187)