Study of a hybrid organic-inorganic system for X-ray detection

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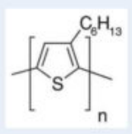
The development of X-ray radiation detectors is an active field of modern research due to their wide range of possible applications in modern medicine, security control and scientific research. Currently used semiconductor crystal X-ray detectors have several negative properties such as a limited size, high operating voltages, poor X-ray absorption capacity and no plasticity and flexibility. These problems can be solved by developing new types of hybrid X-ray detectors consisting of high-Z nanoparticles arranged in an organic matrix.

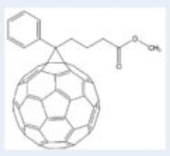
Materials

Organic matrix:

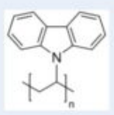
Poly(3-hexylthiophene-2,5-diyl) ***P3HT***



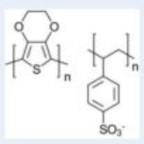
Phenyl-C61-butyric acid methylester ***PCBM***



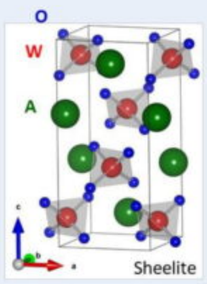
Poly(9-vinylcarbazole) ***PVK***

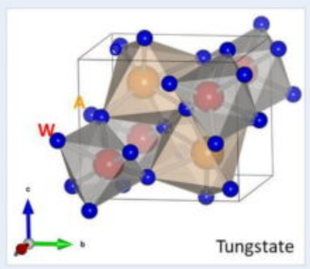


Poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate)
PEDOT:PSS



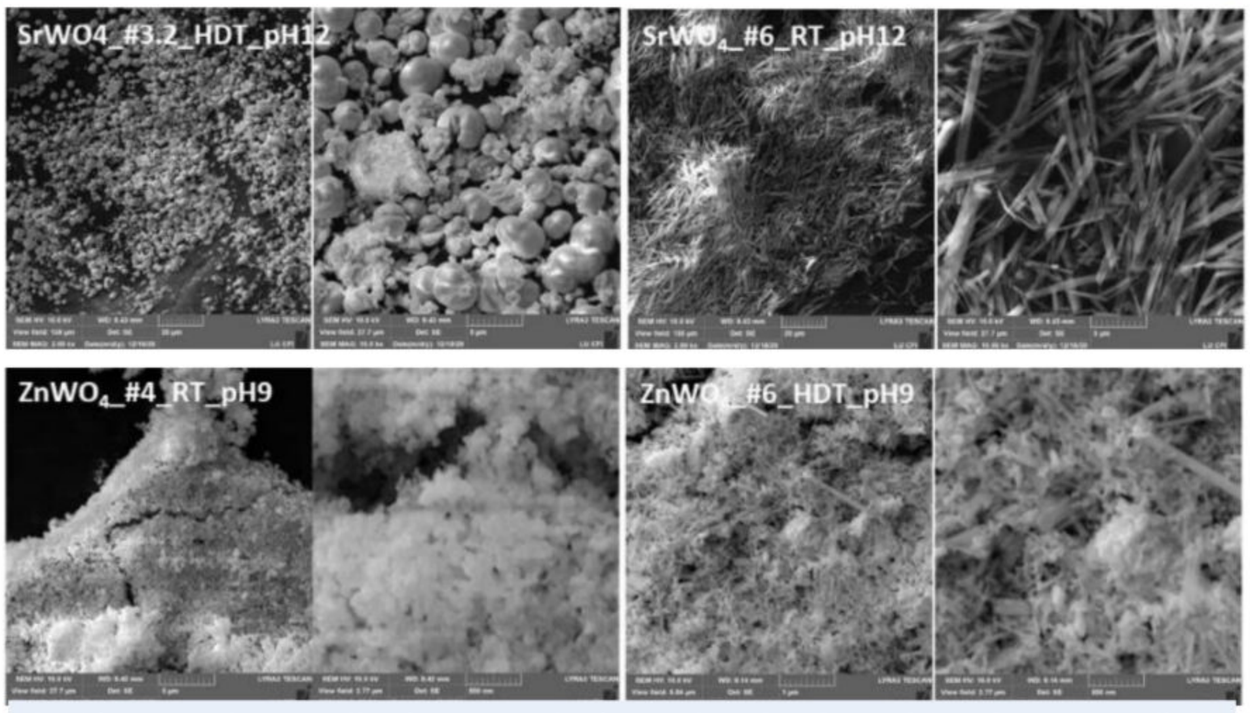
Tungstate's nanoparticles





- ***W (Z=74)***
- ***Solid solutions:***
  $A_xA'_{1-x}WO_4$ & $AW_xMo_{1-x}O_4$
- ***0D, 1D, 2D:***
  - *nanocrystals*
  - *nanowires*
  - *thin films*

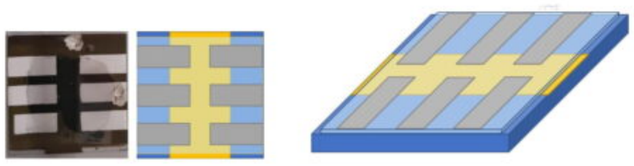
A = Ca, Sr, Ba, Pb & Mg, Mn, Fe, Co, Ni, Cu, Zn, Cd



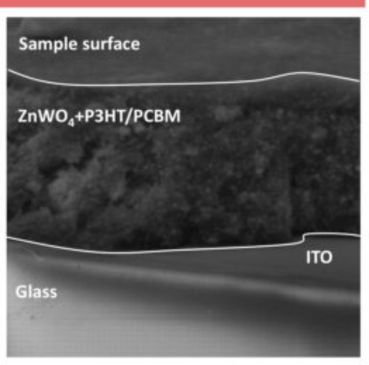
SEM images show synthesis parameter impact on $SrWO_4$ and $ZnWO_4$ nanoparticle powders morphology.

Samples

Nanoparticles are mixed with organic compounds in appropriate solvent. Thin film samples are made by spin-coating or blade-casting methods on glass/ITO substrates.



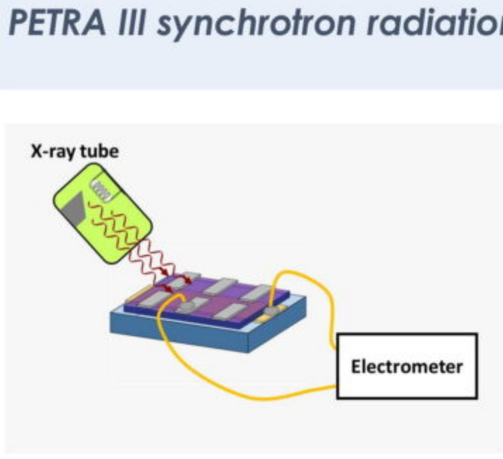
Shematic representation of samples.



SEM omage of sample crosss-section.

Experiments

The electrical properties of produced hybrid systems were studied under X-ray illumination using the W anode X-ray tube in the lab and PETRA III synchrotron radiation facility.



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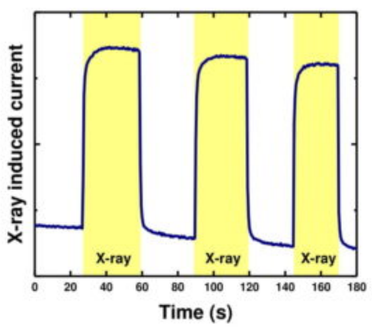
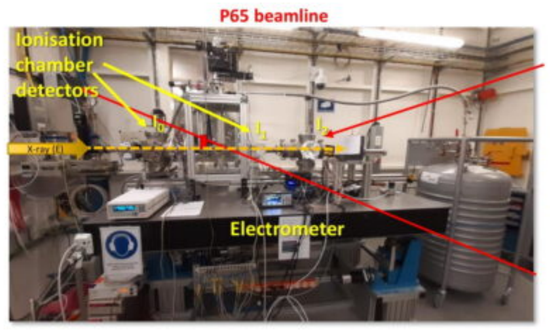
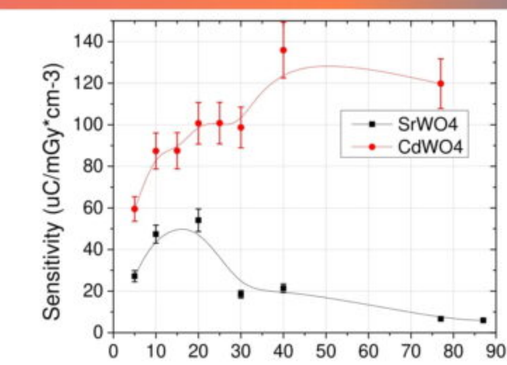
https://photon-science.desy.de/facilities/petra_iii/index_eng.html
C.G. Schroer et al., J.Synchrotron Rad. 25 (2018) 1277-1290.



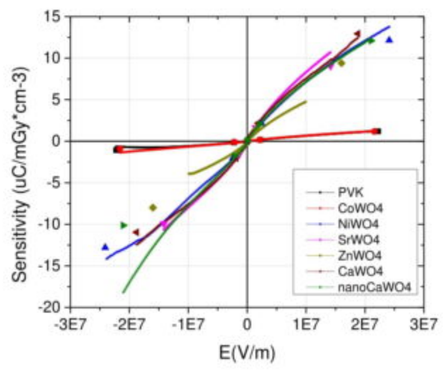


Results

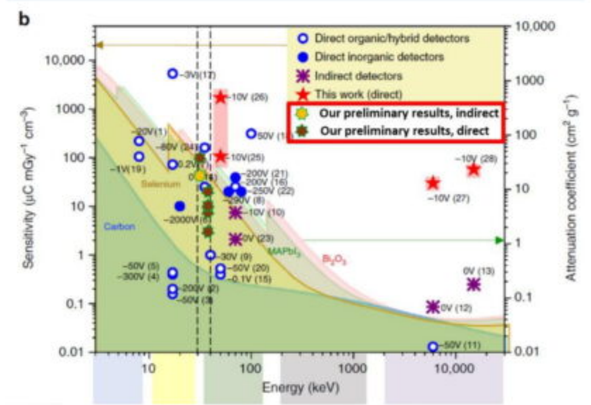
- *Several samples from metal tungstate nanoparticles in P3HT/PCBM, PVK and PEDOT:PSS matrix have been studied.*
- *The optimal concentration of nanoparticles in PEDOT: PSS matrix is 20-40%.*
- *Nanoparticles of different metal tungstates show very similar properties in the PVK matrix.*
- *Obtained results are comparable with state-of-the-art results.*
- *Potential applicacition of hybrid dectetor is demonstrated.*



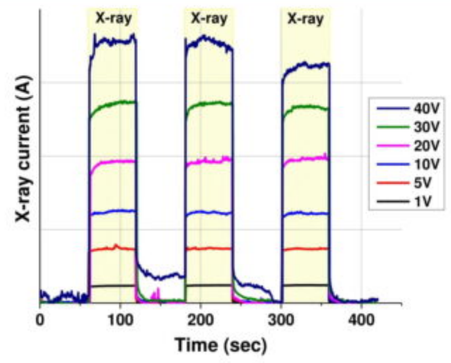
Sensitivity parameter dependence from nanoparticle concentration (wt%) in PEDOT:PSS matrix.



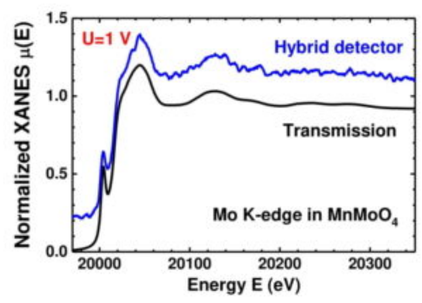
Sensitivity parameter dependence from applied electric field for AWO_4 + PVK hybrid systems (A=Co, Ni, Sr, Zn, Ca).



Comparison of performance for current solid state X-ray detectors (graph taken and modified from [1]) and our results.



X-ray generated photocurrent of hybrid $CaWO_4$+PVK system dependence on applied voltage. $CaWO_4$ concentration is 17 wt%.



XANES spectra obtained with ionisation chamber detector and hybrid detector at PETRA III P65 beamline.

[1] H.M. Thirimanne et al., High sensitivity organic inorganic hybrid X-ray detectors with direct transduction and broadband response, Nature Commun. 9 (2018) 2926.

Acknowledgement

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