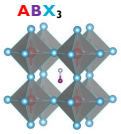
Sandia National Laboratories

PACT

Environmental and Health Safety Risk Assessment for Perovskite Solar Cells and Modules

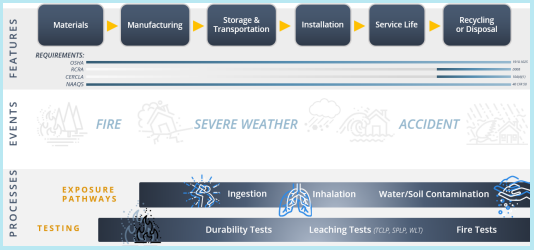
Christa Torrence[1,2], Cara Libby[3], **Joshua S. Stein**[1]

[1] Sandia National Laboratories
[2] Los Alamos National Laboratories
[3] Electric Power Research Institute



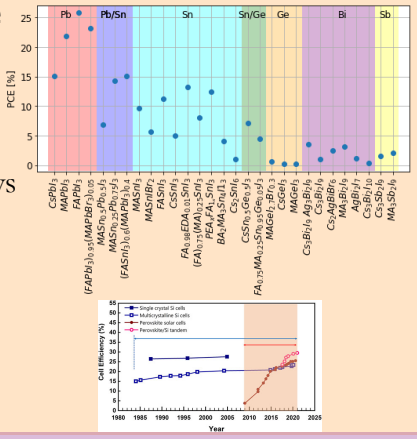
A= Pb, Sn, Ge, Bi, Sb, ...
X=halides (Cl, Br, I)
B= Organics or metal (Cs)

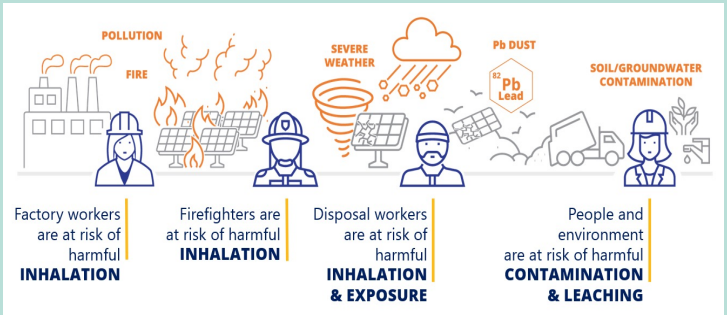
- Perovskite solar cells have demonstrated PCE of >25% for single junctions and ~30% for tandems.
- Low-cost solution process manufacturing
- Absorber usually contains lead in a soluble form
- If this technology is to succeed commercially any environmental and health risks need to be quantified and managed from cradle to grave.



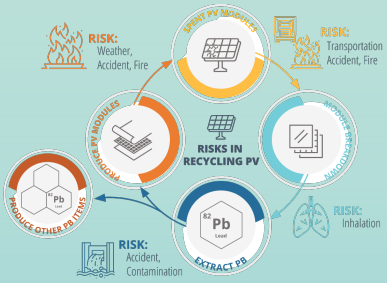
Mitigation Strategy 1: Replace Lead with Something Else?

- Summary of published results utilizing different metals occupying the A site in the ABX_3 formula shows Pb-based perovskites have highest PCEs.
- Tin based perovskites suffer from poor stability (Tin oxidation)





- Exposure pathways include:
  - Inhalation / fire
  - Ingestion / bioaccumulation
  - Skin contact
  - Water / Soil contamination
- Recycling can reduce disposal of toxic chemicals but also involves risks.
- Perovskite recycling has already been demonstrated by several groups (Chen et al., 2021 & Liu et al., 2021)



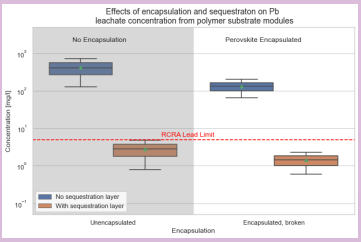
Mitigation Strategy 2: Add Materials to Bind Lead

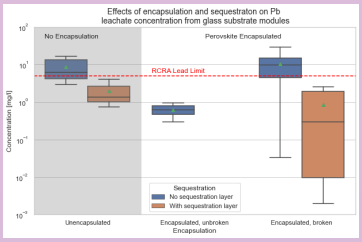
- Toxicity Characteristic Leaching Procedure (TCLP) is used to quantify leaching risks.

RCRA heavy metals concentration limits

Analyte	Limit (mg/L)
Arsenic	5
Barium	100
Cadmium	1
Chromium	5
Lead	5
Mercury	0.2
Selenium	1
Silver	5

- Limited tests on perovskite PV shows that **polymer sequestration layers** can help to reduce risks from leaching.
  - Cation-exchange resin layered on the glass surface
  - Phosphonic acids + polymer film blended with lead chelating agents





Next Steps:

- Fire risks for perovskites needs more study.
- Explore use of nontoxic solvents.
- Explore need for perovskite-specific testing standards.
- Technoeconomic studies of recycling perovskites and circular economy implications.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND No. _____ SAND2022-12422 C

References

Liu, F.-W, Biesold, G., Zhang, M., Lawless, R., Correa-Baena, J.-P., Chueh, Y.-L., and Lin, Z. (2021). Recycling and recovery of perovskite solar cells. Materials Today *43*, 185-197.
Chen, B., Fei, C., Chen, S., Gu, H., Xiao, X., and Huang, J. (2021). Recycling lead and transparent conductors from perovskite solar modules. Nature communications *12*, 1-10.
Zhang, P.; Li, M.; Chan, W-C, (2022) A Perspective on Perovskite Solar Cells: Emergence, Progress, and Commercialization. Frontiers in Chemistry 11, doi: 10.3389/fchem.2022.802890.

Sandia National Laboratories