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Review of Latest Advances in Thermoelectric Generation Materials, Devices, and Technologies

Abstract: The last decade created tremendous advances in new and unique thermoelectric generation materials, devices, fabrication techniques, and technologies via various global research and development. This presentation will elucidate and highlight some of these advances to lay foundations for future research work and advances. New advanced methods and demonstrations in TE device and material measurement, materials fabrication and composition advances, and device design and fabrication will be discussed. This presentation will also discuss additional new research into materials fabrication and composition advances, including multi-dimensional additive manufacturing and advanced silicon germanium technologies. Further advancements in properties and module developments of relatively established champion materials such as skutterudites will be presented, and several high performance ($ZT \geq 2$) new material systems such as GeTe, $Mg_3(Sb,Bi)_2$ have also been relatively recently unearthed and module applications will be discussed. This presentation will discuss the most recent results and findings in thermoelectric system economics, including highlighting and quantifying the interrelationships between thermoelectric (TE) material costs, TE manufacturing costs and most importantly, often times dominating, the heat exchanger costs in overall TE system costs. We now have a comprehensive methodology for quantifying the competing TE system cost-performance effects and impacts. Recent findings show that heat exchanger costs usually dominate overall TE system cost-performance tradeoffs, and it is extremely difficult to escape this condition in TE system design. Novel or improved enhancement principles in TE device and material performance eminating from this cost-performance work will be presented, such as more stringent requirements from electrical and contact resistance effects and commonalities with solar cell design.

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Biography: Dr. Hendricks has recently re-retired from Blue Origin LLC (2024), where he served as the Director - Thermal Control Systems and Technical Program Director in the Advanced Development Program and Space Systems Development business unit. He briefly retired from NASA–Jet Propulsion Laboratory (JPL) / California Institute of Technology in 2021. He has over 40 years of professional expertise in thermal & fluid systems, nano-scale and micro-scale heat transfer, energy recovery, energy conversion and storage systems, terrestrial & spacecraft power systems, micro electro-mechanical systems, and project management. While at JPL, he was responsible for designing spacecraft thermal and propulsion systems, solar power systems, radioisotope power systems, thermal management and thermal energy storage systems critical to NASA missions. Prior to JPL, he was the Energy Recovery Program Director at Battelle Memorial Institute and Senior Program Manager at U.S. Department of Energy (DOE) Pacific Northwest National Laboratory, where he guided and managed U.S. DOE and Army projects in hybrid power system development, automotive & industrial waste energy recovery, military energy recovery, and advanced nano-scale heat transfer.

He received his Ph.D. and Master of Science in Engineering from the University of Texas @ Austin and Bachelor of Science (Summa Cum Laude) in Physics from the University of Massachusetts @ Lowell. His extensive expertise is embodied in 3 book chapters published by Taylor and Francis and Elsevier; and over 100 reports, conference papers, and journal articles in the Journals of Electronic Materials; Energy; Materials Research; Heat Transfer; Thermophysics and Heat Transfer; and International Heat & Mass Transfer. Among his numerous ASME, IEEE, and NASA recognition awards, he was inducted into the University of Texas at Austin Mechanical Engineering Academy of Distinguished Alumni in 2019.

Dr. Hendricks holds 9 patents and is a Registered Professional Engineer in California and Texas.