ThermoElectric Additive Manufacturing Using Reactive Sintering Algorithm (TEAM URSA)

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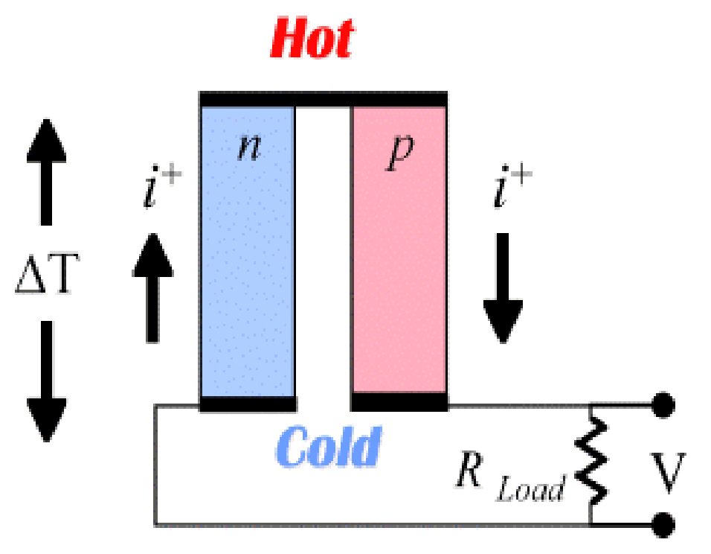
Program: Innovative Spontaneous Concepts

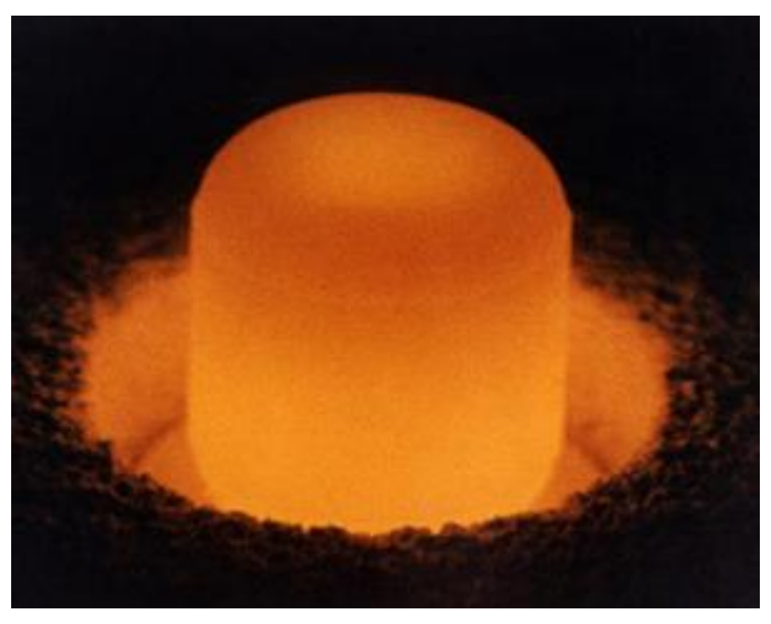
Project Objective:

Demonstrate reactive additive manufacturing (AM) of advanced thermoelectric (TE) materials and elements in order to improve production yield, decrease device fabrication and assembly time, decrease materials waste, and investigate novel device geometries.

Radioisotope Thermoelectric Generators (RTGs)

- Solid-state energy conversion of heat to electricity
- Applied temperature gradient (ΔT) results in voltage
- Convert heat from decaying radioisotope in to electrical power using thermoelectric materials

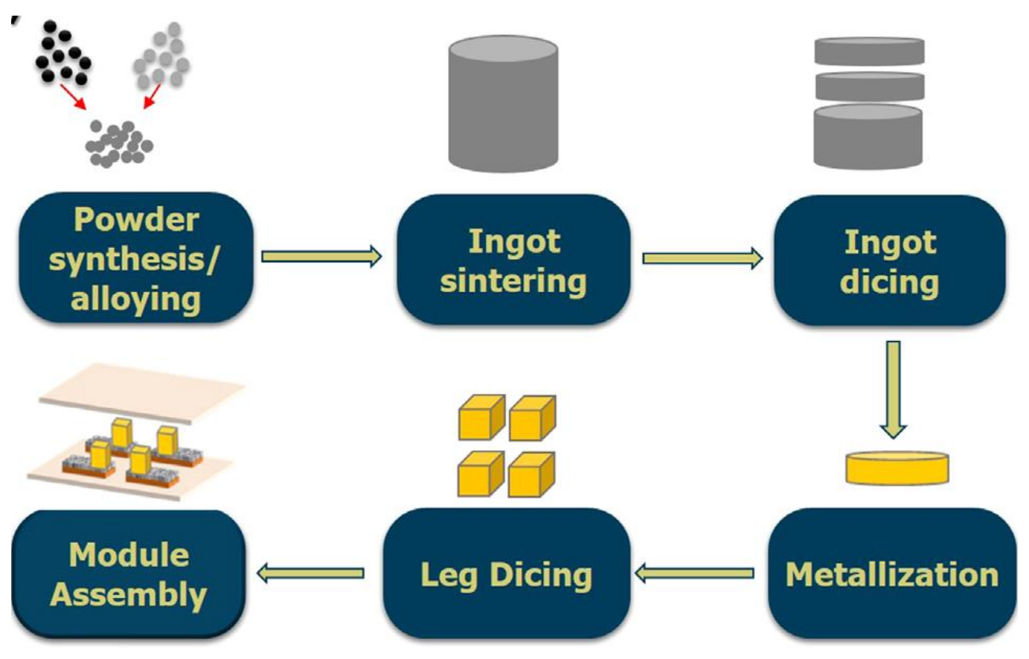




(Left) Radioisotope heat source used in RTGs. (Right) Image of *Curiosity*'s Multi-Mission Radioisotope Thermoelectric Generator (MMRTG).[1]

SOA Thermoelectric Materials Fabrication

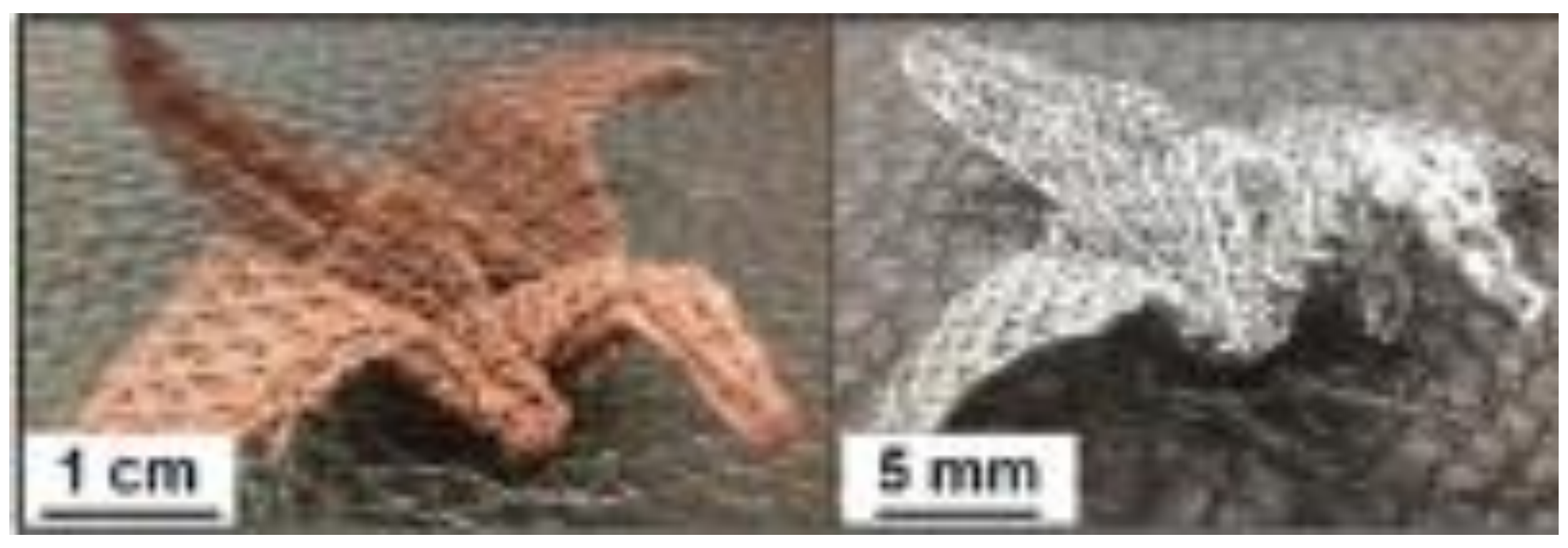
- •Time-consuming, multi-step process.
- •Brittle nature of TE materials leads to low production yield
- •Traditional AM methods (SLM/binder jetting) not well suited for TE materials



Typical thermoelectric device manufacturing process.[2]

Reactive Additive Manufacturing

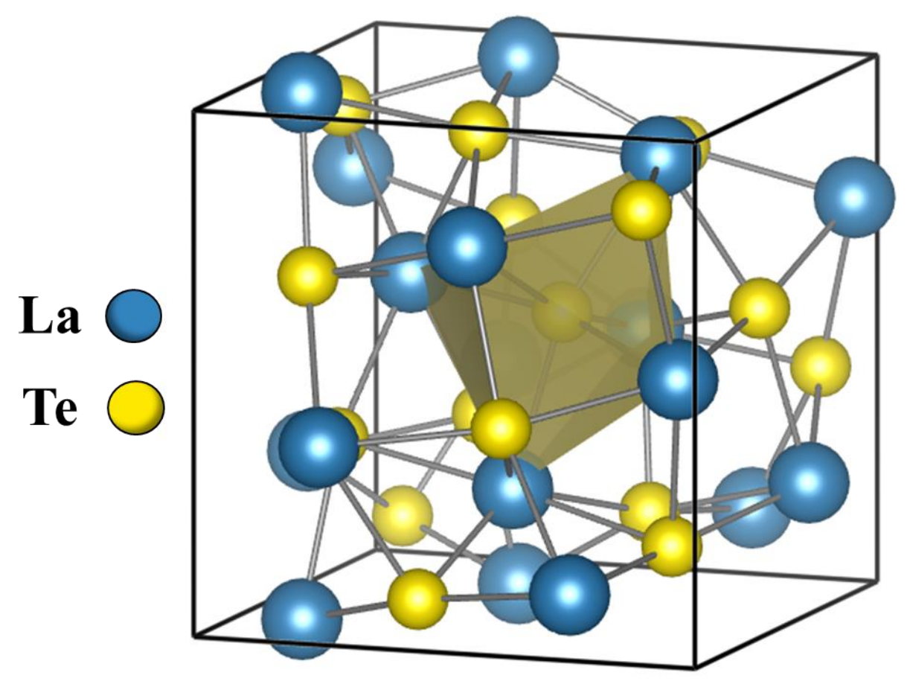
•Uses precursor materials dispersed in high vapor pressure solvents to create inks that can then be reacted using heat treatment



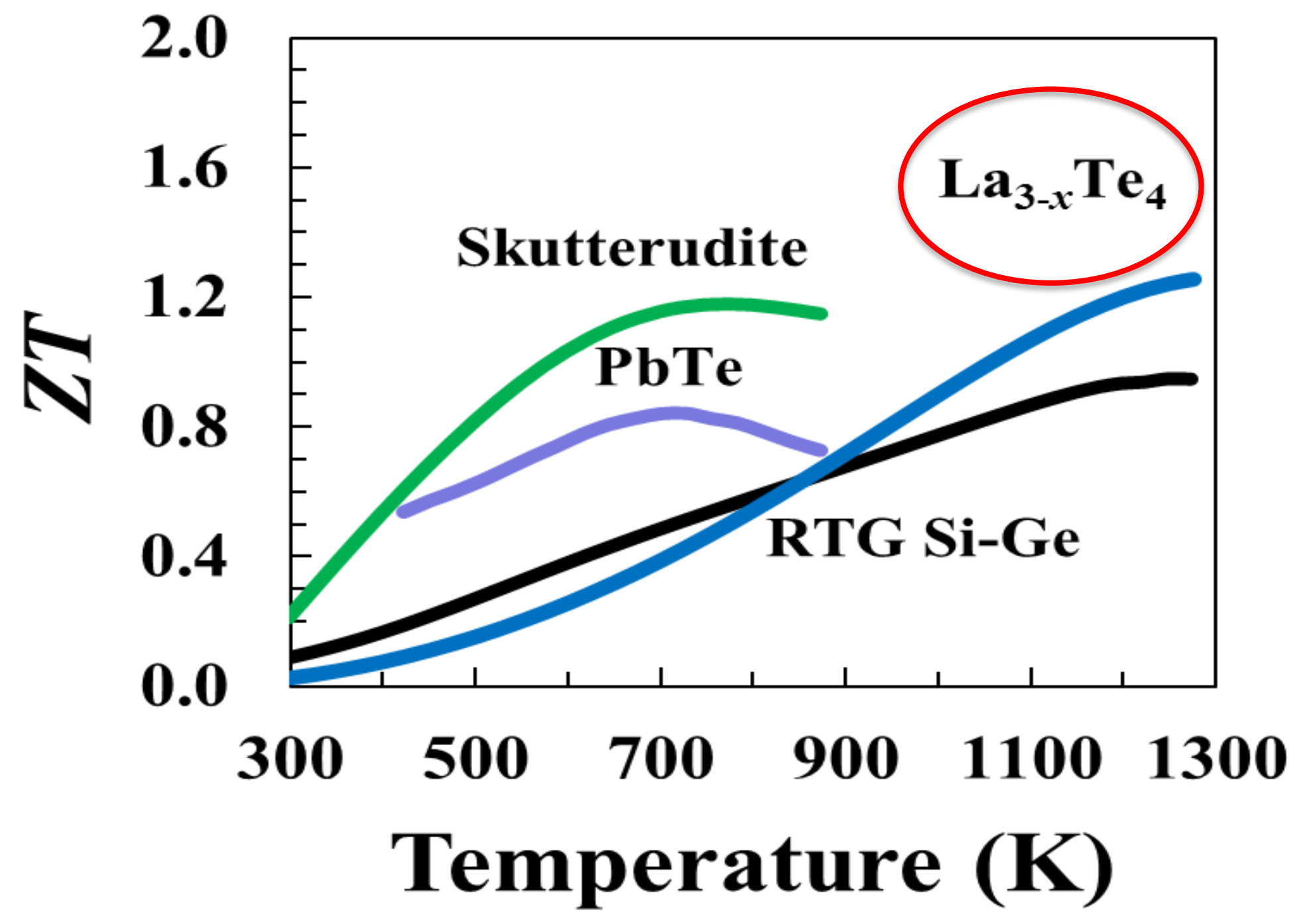
Conversion of printed Fe_2O_3 structure in to metallic Fe.[3]

FY19 Results:

- Investigated reaction schemes to produce state-of-the-art $La_{3-x}Te_4$ from air-stable precursor materials



Crystal structure of $La_{3-x}Te_4$



ZT as a function of temperature for bulk *n*-type materials characterized at JPL.[4]

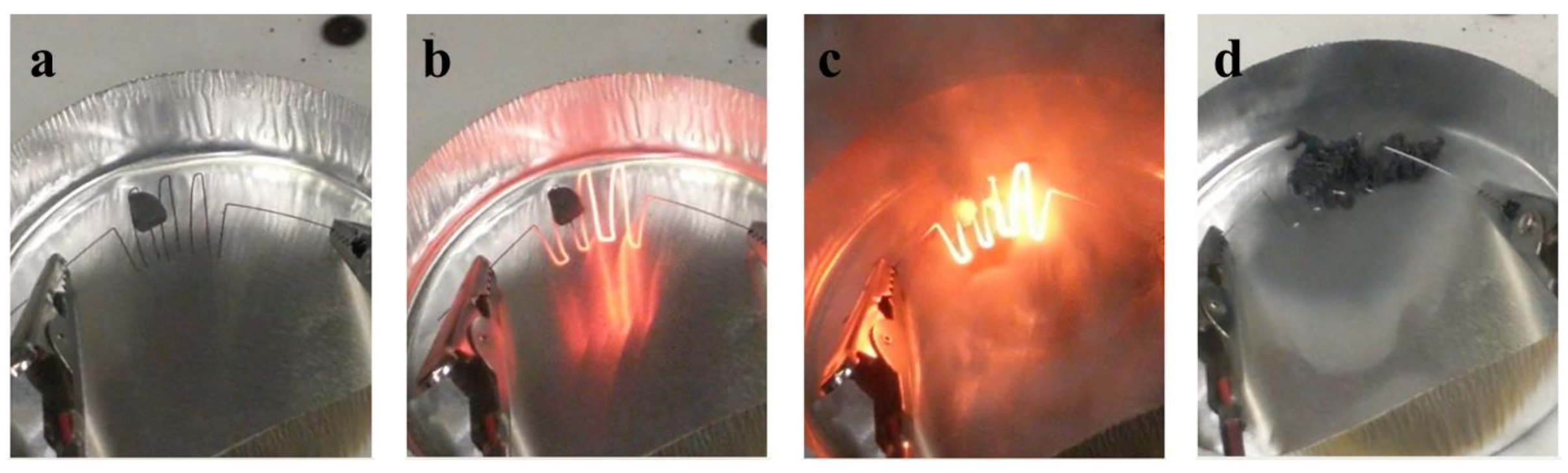
Reaction Schemes

(1) $6LaH_3 + 8TeI_4 \Rightarrow 2La_3Te_4 + 18HI + 7I_2$ ΔH = -109 kJ/mol

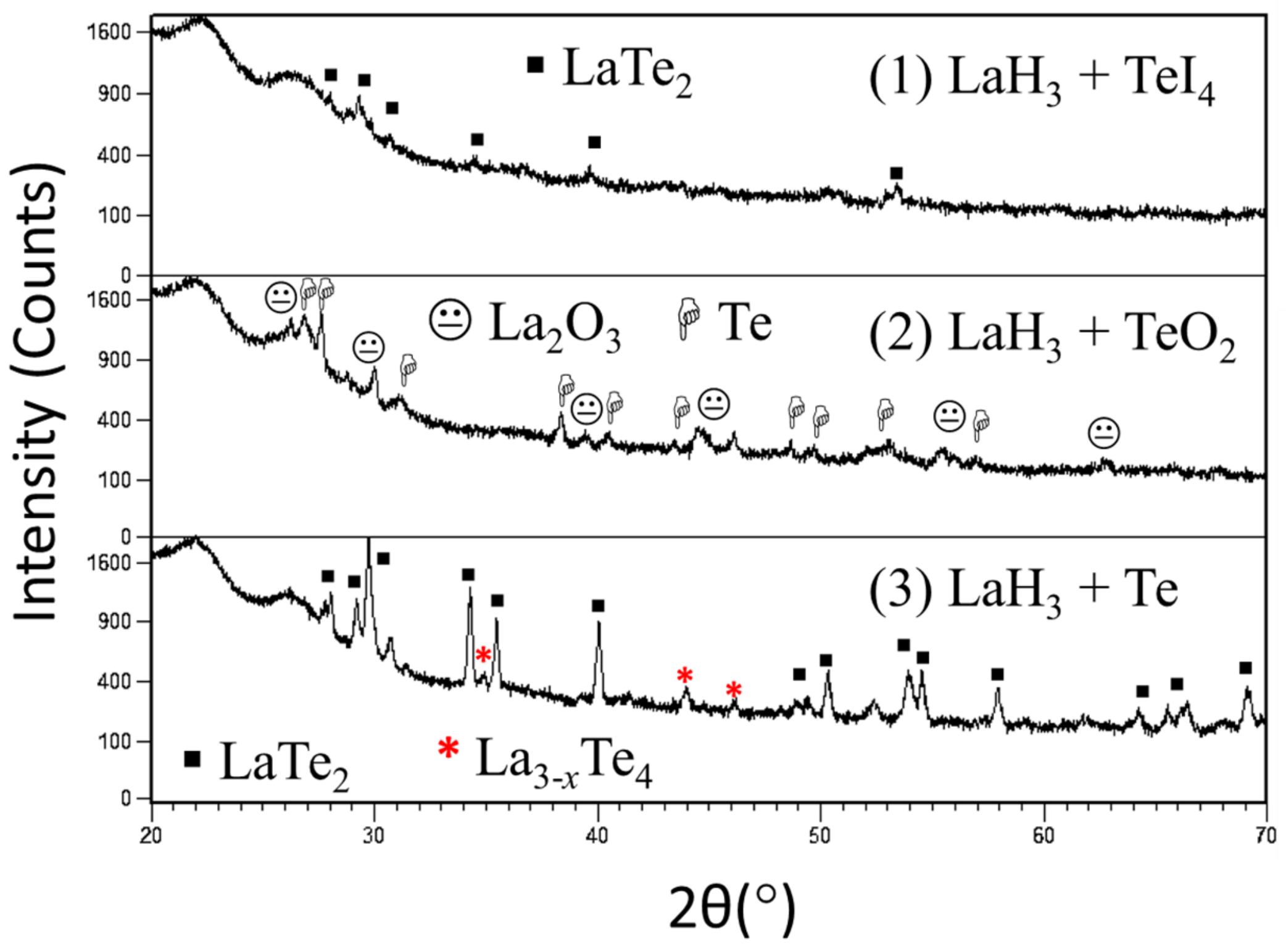
(2) $6LaH_3 + 8TeO_2 \Rightarrow 2La_3Te_4 + 9H_2O + 7O$ ΔH = 2905 kJ/mol

(3) $6LaH_3 + 8Te \Rightarrow 2La_3Te_4 + 9H_2$ ΔH = -590 kJ/mol

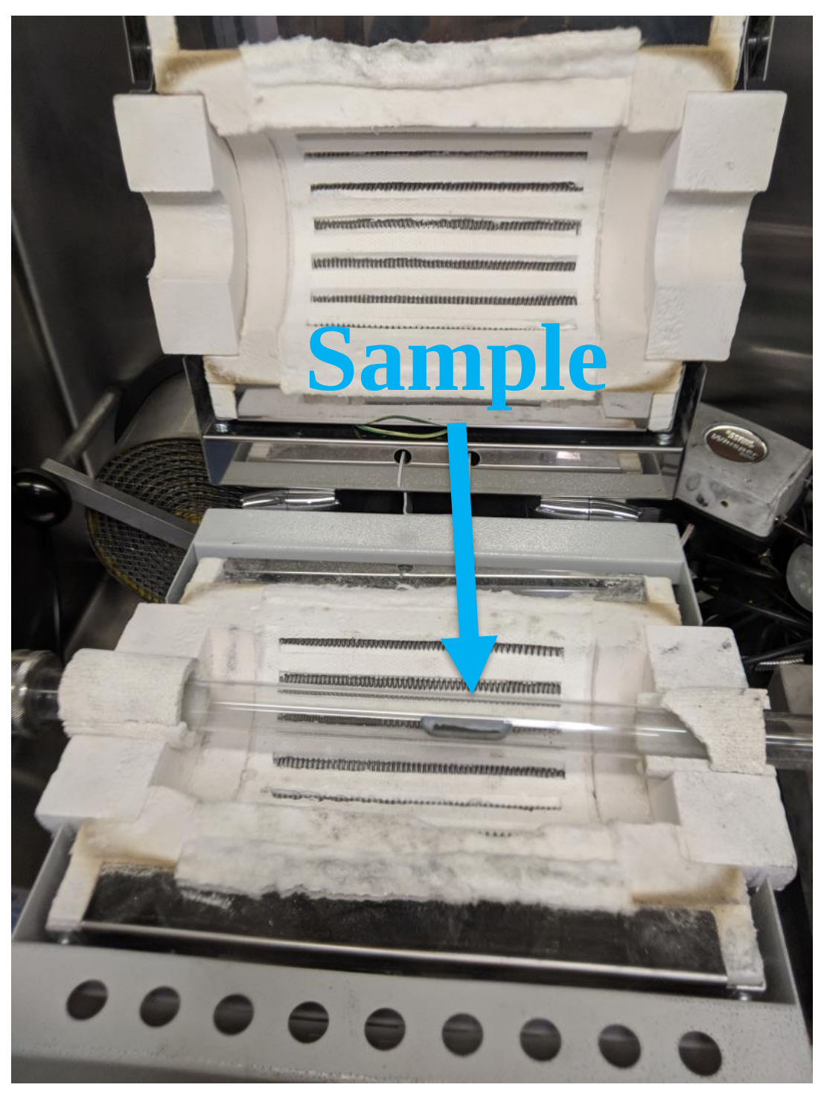
Resistive Heating

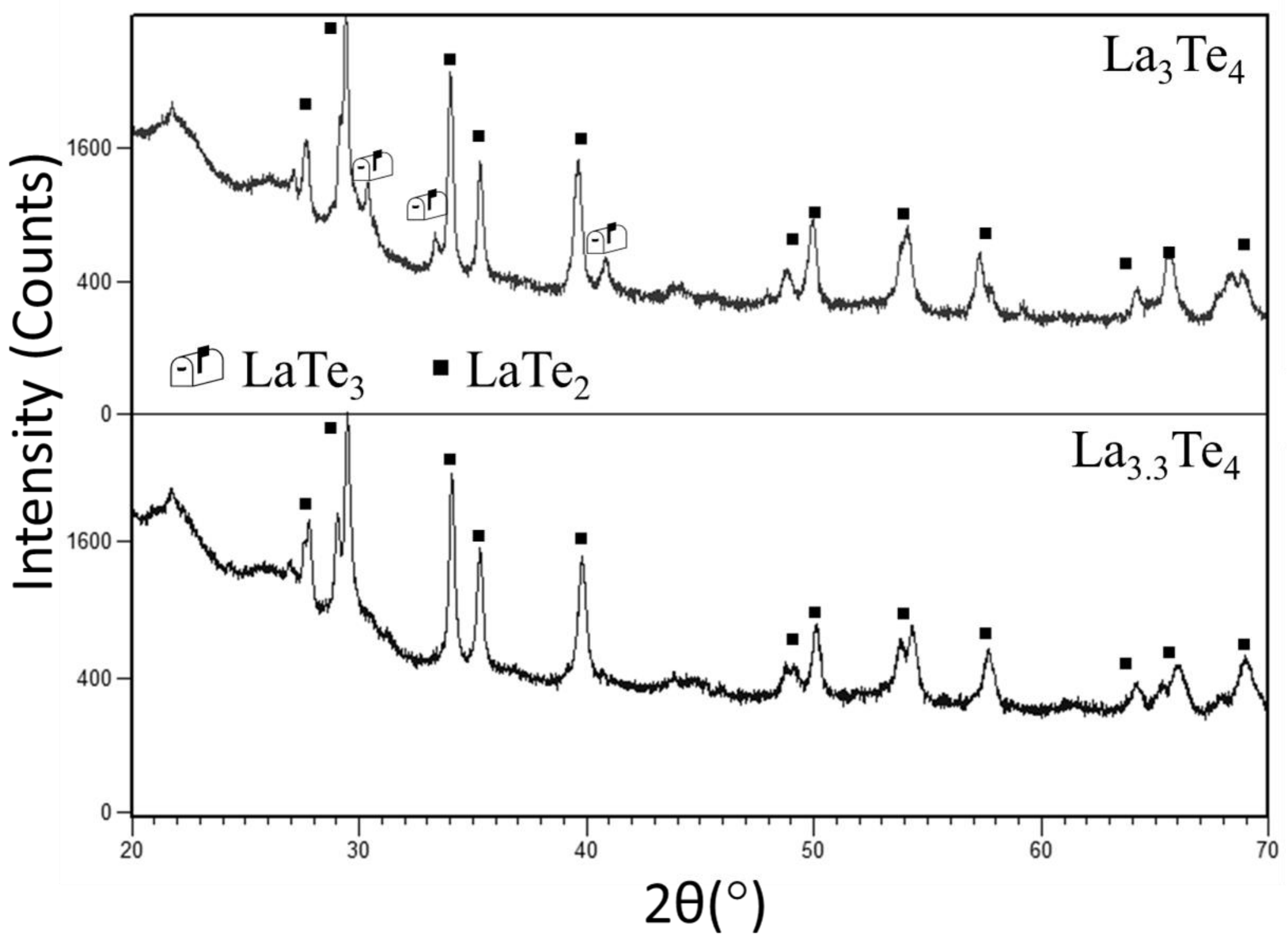


- Precursor materials were mixed and compacted in to pellets
- Reaction was initiated using resistively heated W filament
- **Mixed phase of $La_{3-x}Te_4$ and $LaTe_2$ produced using LaH_3 and Te metal**



LaH_3 + Te Tube Furnace Reaction





- LaH_3 + Te reaction was also investigated using furnace to initiate reaction
- Samples heated to 723 K for 1 hour
- Adding excess LaH_3 resulted in pure $LaTe_2$ phase

Conclusions

- Demonstrated state-of-the-art thermoelectric material ($La_{3-x}Te_4$) can be synthesized using reaction schemes compatible with reactive additive manufacturing
- New Technology Report (NTR) submitted

References

1. www.rps.nasa.gov
2. A. El-Desouky, M. Carter, M. A. Andre, P. M. Bardet, and S. LeBlanc, *Mat.* Lett. 185 (2016) 598–602
3. A. E. Jakus , S. L. Taylor , N. R. Geisendorfer , D. C. Dunand , and R. N. Shah, *Adv. Funct. Mater.* 25 (2015) 6985–6995
4. J.-P. Fleurial, *JOM*, vol. 61, 79–85, 2009

Benefits to NASA and JPL:

- ➢ Further development of this methodology would allow improve production yield, decrease device fabrication and assembly time, and decrease materials waste for TE manufacturing
- ➢ Enables unique TE device geometries that cannot be fabricated using current methods that could allow for novel RTG designs and improved performance
- ➢ Methodology can be applied to other TE materials or technical ceramics

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Poster No. RPC-168