Plasma Facing Component Innovations by Advanced Manufacturing and Design
(project #2288-1509)

GAMOW Kickoff Meeting
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Team members and roles

Project GAP – GAMOW on AM for PFCs

PI: Yutai Katoh (ORNL)
Deputy PI: Morris Wang (UCLA)

Advisory Team
Chair: Steve Zinkle (UTK)

Task 1-1: W Laser AM (LLNL/UCLA)
Lead: Jianchao Ye
Morris Wang
Maria Strantza

Develop L-PBF technology for AM of W

Task 1-2: W EBM (ORNL)
Lead: Michael Kirka
Betsy Ellis
Chris Ledford

Develop EBM technology for AM of W

Task 2-1: Alloy Design (ORNL)
Lead: Ying Yang
Tim Graening
Yutai Katoh

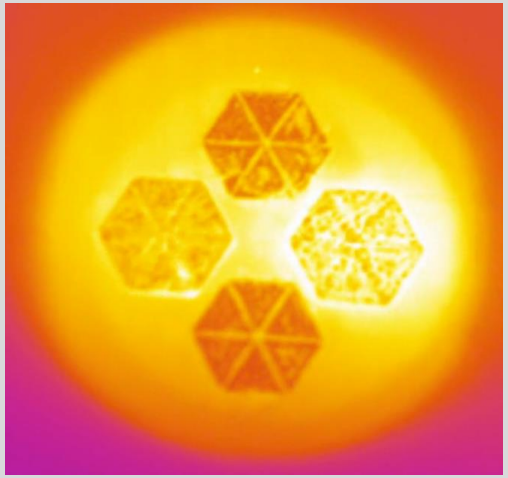
Develop compositionally graded alloy systems for W–RAFMS integration

Task 2-2: FGAM Integration (TAMU)
Lead: Ibrahim Karaman
Raymundo Arroyave
Raiyan Seede
Ryan Saucier

Develop LENS/DED technology for FGAM of W–RAFMS integration

Commercially viable fusion energy needs affordable, robust, and durable solutions for plasma-facing materials and components

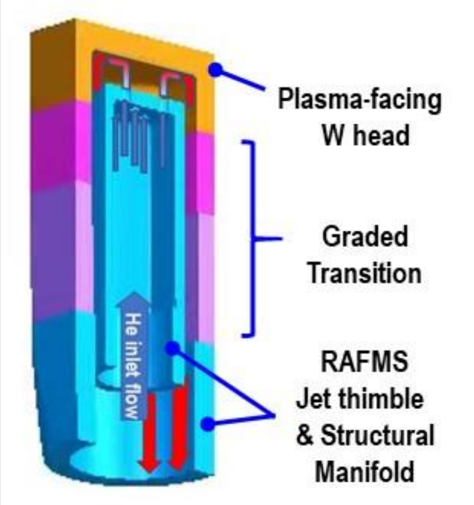
- Motivation
  - Plasma-facing components (PFCs) are among the most critical gaps for fusion energy to establish technical and economic feasibility.
  - To date no credible PFC engineering solution has been demonstrated to meet requirements for fusion power plants.
- Innovation
  - The project develops disruptive materials and manufacturing technologies that innovate how fusion PFCs are designed and made.
  - The developed technologies will have the potentials to 3D-print fusion divertors that are made with functionally graded structure and survive lifetime heat cycles of future power plants.
- Goal
  - Achieve transformative innovation for tungsten (W)-armored PFCs by adopting advanced materials and component technologies enabled by additive manufacturing (AM) with two specific objectives:
    - W AM – 3D-print W metal and alloys that perform equally or superior to materials from conventional manufacturing.
    - AM-enabled integration – seamlessly integrate structures of W armor and reduced-activation steel manifold by functionally graded AM.



Advanced AM technologies to build high quality materials and integration for next generation of plasma facing components (PFCs)

Ellis et al. (ORNL)

Courtesy – Nygren (SNL)



AM-built/integrated unibody He-cooled modular jet (HEMJ) divertor enabled by proposed technology development

Major tasks, milestones, risks, and desired project outcomes

WBS		Title	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
M1	M1.1	G/N: Refine tasks and milestones												
M2 W AM	M2.1	G/N: High quality W coupon by AM												
	M2.2	W AM by L-PBF												
	M2.3	W AM by EBM												
M3 Materials Integration	M3.1	Transition design and development												
	M3.2	Transition AM												
	M3.2.3.a	G/N: DED improved L1 build demonstration												
M4 Deliverables	M4.1	Tech-2-market plan												
	M4.2	Presentations												
	M4.3	Publications												

- Quantitative target for AM W

Property or attribute	Method of evaluation	Value for ITER-grade W	Project Target	G/N acceptance at Q5
Density	Apparent density	100%	>98%	>95%
Cracking	Microscopy	No macrocrack	No macrocrack	<1 mm projected length
Cracking	Elastic modulus	100% bulk modulus	>90% bulk modulus	>70% modulus
Cracking (optional)	RUS	No peak shift	<10% peak shift	N/A
Crack network (optional)	Helium permeation at RT	No leak	No leak	N/A
UTS (800°C)	Uniaxial tensile test	~300 MPa	300 MPa	150 MPa
Elongation (800°C)	Uniaxial tensile test	~10%	10%	5%
Modulus of toughness (800°C)	Uniaxial tensile test	~20 MJ/m^3	20 MJ/m^3	5 MJ/m^3

T2M and aspirational follow-on plans

- Techno-economic metrics
  - Three metric categories (robustness, affordability, durability) below contribute to cost of qualification, manufacturing, and operation, respectively, of fusion power plants

Metric	State of the Art	Proposed	Anticipated Cost Benefit
Robustness: Design stress margin vs. UTS in W pressure boundary	~0%	~25%	> *x2*
Affordability: Areal ratio of complex joining to divertor surface	~4 m^2/m^2	0	> x5
Durability: Anticipated thermal cycle life (operating temp. – RT)	1 cycle	>1,000 cycles	> x10

- Test & deployment plans/aspirations
  - Commercial fusion concepts adopting solid armors require techno-economically feasible PFC materials and component solutions
  - Pathways to testing on fusion-scale experiment are identified for:
    - Neutron irradiation
    - High transfer and HHF testing
    - Hydrogen isotope interactions
  - Potential partnerships with private sector
    - Private sector represented in Advisory Team