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Development and Testing of an Additively Manufactured Lattice for Demo Limiters

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ABSTRACT

A new limiter concept has been proposed using lattice structures [1] fabricated with tungsten and tantalum powders by Additive Manufacturing (AM) techniques. Here, the results of the first investigations into the production, characterisation, and high heat flux testing of the lattices to assess their suitability for DEMO limiters is presented.

BACKGROUND

In the conceptual design of EU-DEMO, damage to plasma facing components under disruption events is planned to be mitigated by specific sacrificial limiter components.

A new limiter concept has been proposed using lattice structures fabricated using AM. These structures were produced using pure tungsten (W) and tungsten with 6 wt.% tantalum (W-6Ta) as pre-mixed powder.

The major potential benefits of using a lattice structure for limiters are the possibility to customise the thermal conductivity and structural compliance of the component in order to manage temperatures and stress within material limits and lower the sensitivity to crack propagation.

CHALLENGES / METHODS / IMPLEMENTATION

PRODUCTION

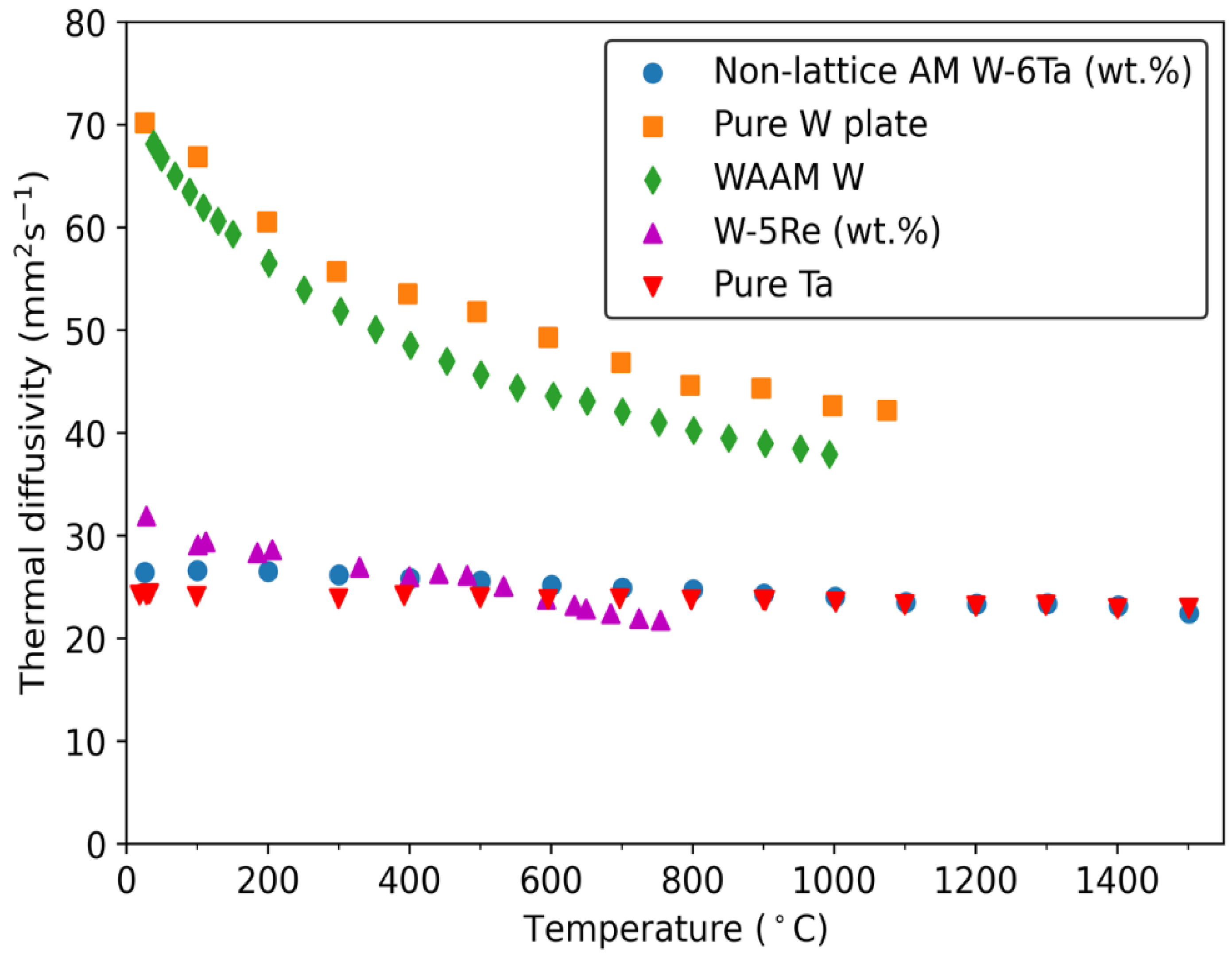
To achieve high dimensional accuracy and density of built lattice structures, a parametric build study varying the hatch distance, the laser point diameter, exposure time and energy density was carried out.

CHARACTERISATION

The thermal diffusivity of the AM W-6Ta material of a fully filled cylindrical sample Ø3 x 12.5 mm was assessed using a Netzsch laser flash analyser (LFA). LFA measurements were taken at room temperature, followed by 100 ℃ increments henceforth to a maximum temperature of 1500 ℃.

HIGH HEAT FLUX TEST

To replicate the high heat load potentially applied to the limiter, additively manufactured W and W-6Ta were exposed for 0.25 ms to H plasma with an energy density of 1.8, 2.3 and 3 MJ/m^2 to compare with cold rolled W (CRW) armour material at KIPT on the QSPA Kh-50 [2].



Thermal diffusivity measurement of AM W-6Ta in non-lattice form, compared to pure W plate [3], WAAM W [4], W-5Re (wt.%) [5] and pure Ta [6].

OUTCOME

CHARACTERISATION

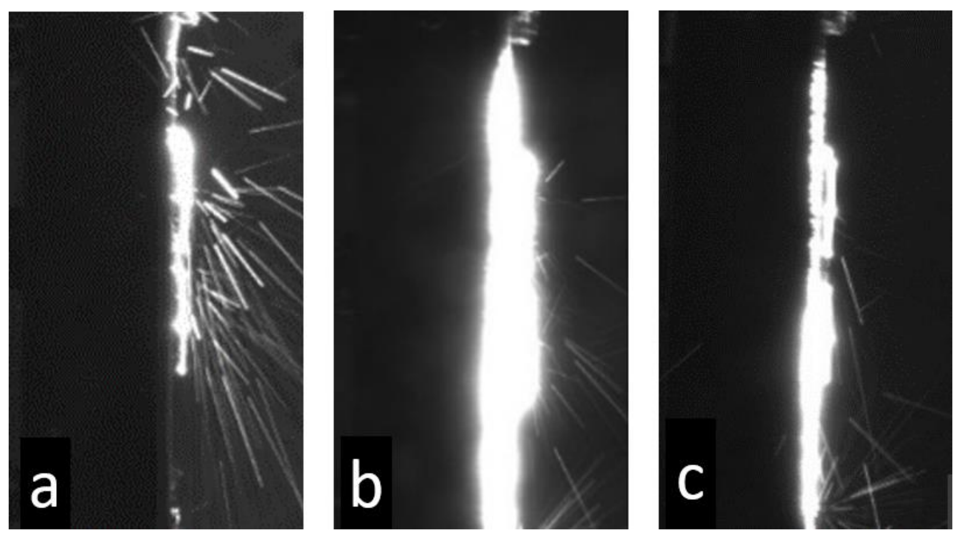
Compared to pure W [3], the thermal diffusivity of AM W-6Ta is reduced by 63% at ~25 ℃. At 1500 ℃, this is less pronounced at a 47% reduction. This indicates that the 6 wt.% Ta has a strong effect on the thermal diffusivity of the W-6Ta alloy, reducing it to a level similar to that of pure Ta.

HIGH HEAT FLUX TEST

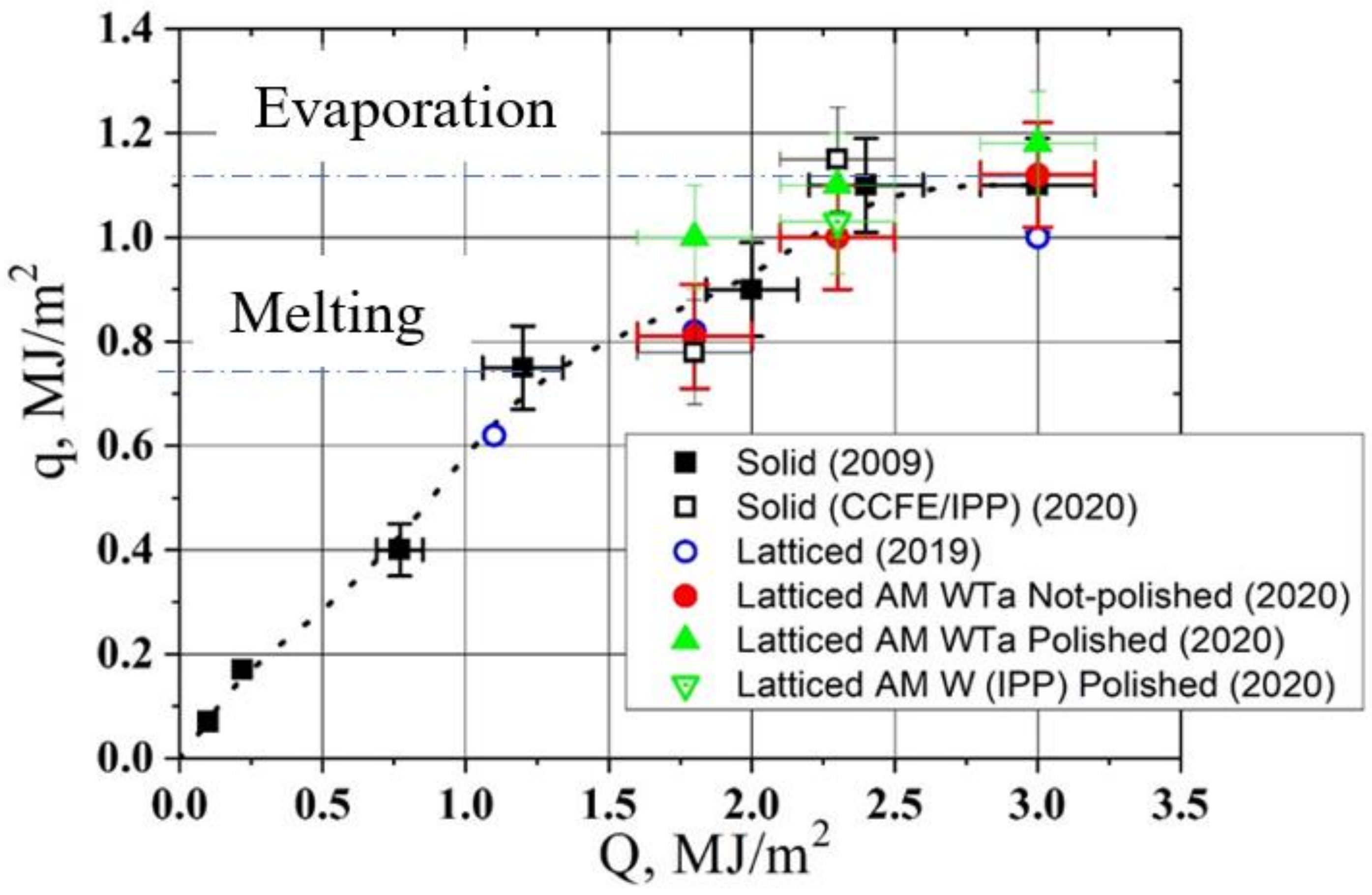
Large numbers of ejected particles are observed under plasma impact, with increasing energy density causing strong melting/pronounced evaporation.

Particle ejection decreased with an increasing number of plasma pulses.

The observed difference in absorbed heat load between results obtained for CRW and lattice targets is negligible.



Images of plasma surface interaction during plasma impact of polished latticed, W-6Ta (a) , W (b) and CRW samples (c) energy density of incoming plasma 2.3 MJ/m² corresponding to 1.2-2.4 ms after start of the plasma third pulse– (texposure=1.2 ms)



The energy density (q) absorbed by the target surface vs. the energy density (Q) of impacting plasma stream. Black squares – results for CRW targets [2]

CONCLUSION

AM materials behave similarly to CRW under HHF test suggesting that they may be used for limiter applications with the added advantage of the heat transfer performance adjustment by geometry design or tailoring material properties through alloying.

ACKNOWLEDGEMENTS / REFERENCES

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[1] https://doi.org/10.1016/j.fusengdes.2020.111721
[2] https://doi.org/10.1016/j.jnucmat.2009.01.215
[3] https://doi.org/10.1016/j.fusengdes.2018.04.117.
[4] https://doi.org/10.1016/j.jnucmat.2019.04.049
[5] https://doi.org/10.1016/S0022-3115(00)00170-7
[6] https://doi.org/10.1007/s11510-008-0017-z

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