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Innovative Solutions for Data Center Thermal Management: Oxide-Free Femtosecond Laser Processed Copper Surfaces

Abstract.

Rapid advances in the power density of processors used in data centers have led to a growing need for innovative thermal management solutions. Agencies like the Advanced Research Projects Agency–Energy (ARPA-E) are supporting ongoing research efforts to more efficiently manage large heat fluxes produced by high-performance computers to reduce power consumption associated with cooling. With the advent of widespread artificial intelligence (AI) based computing, the annual worldwide power consumption of AI data centers has been predicted to be as high as 134 TWh by 2027 [2]. The proposed work will focus on enhancing the two-phase heat transfer performance of copper (Cu) surfaces functionalized using femtosecond laser surface processing (FLSP) for mitigating large heat fluxes more efficiently than air-cooled solutions currently implemented in data centers. FLSP is a technology that can be utilized to produce finely-tuned, highly-permanent, micro- and nano-scale surface features that increase the boiling performance of surfaces. The two-phase heat transfer enhancements observed when applying FLSP to materials like aluminum and stainless steel are not observed for Cu processed by FLSP due to a laser-induced oxide layer. However, due to its superior thermal properties, Cu is a key material used in thermal management of electronics. Recently, the PI, working in the Center for Electro-optics and Functionalized Surfaces (CEFS), developed a novel technique to reduce the oxide state of surface and subsurface Cu atoms while maintaining the important micro- and nano-scale porosity of the laser processed surfaces. In preliminary studies, Cu FLSP surfaces fabricated with this post-laser-processing technique exhibited breakthrough improvement in two-phase heat transfer performance when compared to as-FLSP-processed and unprocessed Cu. The proposed research will take advantage of the flexibility and fine control of features achievable by FLSP and the environmental conditions of the post-laser process to improve the performance of Cu surfaces for two-phase heat transfer.