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Effects of Claw Geometry in MEMS Silicon Cooling Arms on Stress Distribution and Temperature Uniformity for Inertial Confinement Fusion

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Controlled nuclear fusion is a promising solution to the global energy crisis. Inertial confinement fusion (ICF) is one of the key approaches toward achieving practical fusion energy[1]. Within the ICF system, MEMS silicon cooling arms play a vital role in cryogenic fuel layer formation for DT fusion targets by thermal conduction and target supporting. The claw geometry directly affects stress distribution and temperature uniformity, which decides the formation of the DT ice layer [2].

In this study, finite element simulations were utilized to investigate how jaw number and length variations affect the stress distribution, displacement magnitude, and temperature field at the clamping end of the cooling arm under identical mechanical and thermal conditions. Simulated results indicate that, under the same radial external force, increasing the number of jaws reduces deformation, thereby improving the cooling arm's clamping stability and alignment accuracy. However, under identical thermal conditions, more jaws lead to elevated temperatures at the clamping end due to the enlarged heat dissipation area. Moreover, with the same radial load, longer jaws exhibit greater deformation and higher maximum stress at the root, attributable to decreased structural stiffness. Regarding thermal behavior, increasing jaw length enlarges the hollowed area at the clamping end, reducing the effective heat dissipation area and thereby lowering the average jaw-end temperature. However, the extended length also increases the thermal conduction path between different jaws, reducing temperature uniformity.

In a word, it was found that: For colling arm with a claw diameter of 11.538 mm with three-stage heat bifurcation structure, when the number of claws is 11 and the length is 4.74mm, the displacement amplitude can reach 1.73 μ m, and the temperature uniformity is controlled within 0.4mK near 18.3K, which can meet the technical requirements of DCI DT capsules freezing.

References

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