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Preface

The High Average Power Laser (HAPL) Program is a multi-institutional program to develop the basic science and technology needed to design a practical electrical power plant based on inertial fusion energy (IFE) with lasers. The HAPL program is developing a chamber concept based on a solid first wall. This approach was chosen based on its simplicity, its flexibility, and the ability to address many key issues on a smaller scale. This reduces the uncertainty and costs associated with the concept development. This special issue of the Journal of Nuclear Materials describes the program's research to develop a credible first wall for an IFE reactor.

The target implosions produced in a commercial reactor will likely produce hundreds of MJ of energy, carried to the wall in the form of X-rays, ions, and neutrons. These will impinge on the chamber wall over the first few microseconds following the implosion, with the X-rays arriving first, followed by the neutrons and, finally, the ions. In all designs analyzed to date, the ions are the prime contributor to the peak surface temperature. The neutrons are sufficiently penetrating, so they contribute almost nothing to the surface temperature and their primary effect is radiation damage and the associated property changes in the wall materials. The X-rays cause a significant surface temperature increase, but the surface cools before the ions arrive, so the ion and X-ray temperature increases can be considered separately. Hence, each implosion leads to two significant temperature increases (likely well over 1000 °C) and a burst of neutrons causing significant displacement damage. It is believed that a commercial reactor will require targets to be imploded at 5–10 Hz in order to be economical.

The challenge is to design a first wall for a laser IFE chamber using materials that can withstand nearly a billion temperature cycles of well over 1000 °C while producing sufficiently high coolant outlet temperatures for high energy conversion efficiency. In addition, the material properties will be evolving as a result of both neutron damage and displacement damage from the ions. These may introduce additional damage mechanisms, such as blistering and sputtering. Our current research is concentrating on a tungsten-coated ferritic steel first wall. This choice was based on the vast experience with these materials in a nuclear environment and the ability to address most of the key remaining issues with existing facilities. The tungsten must be thick enough to protect the steel from the temperature transients, but thin enough to provide good adhesion.

The first paper in this issue provides an overview of the HAPL program, summarizing the progress made in other areas in the development of Laser Fusion Energy. These areas include the lasers, the optics used to guide the lasers into the chamber, target fabrication (and associated cryogenics), target injection and target engagement. The overview paper is meant to be a broad brush of the progress to date, and owing to publication schedules, is not up to date. Further, more timely details can be found at the HAPL web site (http://aries.ucsd.edu/HAPL/), in particular in the meetings archive (http://aries.ucsd.edu/HAPL/MEETINGS/). The overview paper is followed by several modeling papers, which provide a framework for the design of the first wall. These are followed by several experimental papers, which discuss the effects of ion implantation, X-ray deposition, and rapid surface heating on the candidate materials. There is also a series of papers associated with fabrication of the coated structures and another addressing the issues associated with helium ion effects.

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The results presented here are promising, but show additional research is needed to fully understand and evaluate the outstanding issues. Some of these will not be resolved until a fusion test facility is fully operational. That facility is designed to be both a test bed to fully optimize the target physics, and a vehicle to perform the needed R&D on materials and chamber components.

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