Opportunities in Materials Science and Engineering Driven by ICF Hybrids – Materials for LIFE

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Hybrid reactor systems are once again being considered as a possible means of producing electrical power from natural or depleted uranium, uranium of various enrichments, plutonium, spent nuclear fuel, and thorium, without the need for isotopic enrichment. Ultimately, such technology might enable the more complete burning of spent nuclear fuel from light water reactors, without chemical separation into weapons-attractive actinide streams.

The National Ignition Facility (NIF) is complete and operational, and initial experiments that are expected to lead to ignition are well underway with rapid progress being made. The Department of Energy's NIF is now a reality, and ignition is visible on the horizon. Once ignition is achieved, the Nation's scientific and technical community will have a unique opportunity, the investigation of how to best leverage the ignition event to help solve our problems related to energy independence, global warming, and the eventual disposal of our inventory of spent nuclear fuel.

In the case of LIFE (Laser Inertial Fusion Energy), an ICF-type hybrid that will leverage ignition, a point-source of high-energy neutrons produced by laser-generated, thermonuclear fusion within a target will be used to achieve ultra-deep burn-up of the fertile or fissile fuel in a sub-critical fission blanket. Starting from as little as 300 to 500 MW of fusion power, this machine could conceivably generate 2000 to 3000 MW of thermal energy, and over 1000 MW of electrical energy. Of course, hydrogen could also be generated in a variety of ways.

Based upon preliminary design work, it is now believed that ICF-type hybrids could be developed to the point where they could help meet worldwide electricity need in a safe and sustainable manner, while shrinking the stockpile of spent nuclear fuel and excess weapons materials. Furthermore, it appears that such hybrid systems could reduce the energy-normalized load on any future geological repository for spent nuclear fuel and high-level waste by a ~20X.

The development of modularized ICF-type hybrids will serve as an important driver for advanced materials science and development in Silicon Valley, and throughout the Nation's research establishment. Materials for fusion-fission hybrid reactors fall into several broad categories, including: (1) lasers and optics, (2) fusion targets, (3) first wall, (4) structural material, (5) neutron multiplication blanket, (6) fission blanket, (7) reflector, (8) coolant, and (9) balance of plant. Issues related to lasers and optics, as well as fusion targets are discussed elsewhere. The first wall and structural materials in such a system must be able to withstand relatively high temperatures, intense neutron bombardment, and corrosive attack by molten fluoride salts. The high power density may require molten fluoride salt coolants, such as FLiBe (Li_2BeF_4) or FLiNaK (Li-Na-K-F), and perhaps liquid metals. Materials under consideration for these applications include refractory metals and alloys, oxide dispersion strengthened steels, and high-temperature composites. Materials and conditions for one hypothetical design are shown in Figure 1.

Fuels for the fission blanket must be able to contain a relatively large amount of fission gas, as well as stresses due to the volumetric changes that accompany transmutation. Several possible fuel forms have been identified for investigation for a wide range or promising applications, including but not limited to an enhanced TRI-structural-ISO-tropic (TRISO) fuel; solid hollow core (SHC) fuels; metallic and ceramic inert matrix fuels (IMFs); and molten salt fuels (MSFs). The neutron multiplier could be made of metallic beryllium, beryllides which may be more radiation resistant, or other appropriate materials. Materials and fuels will have to be selected, and developed as necessary to enable operation in these harsh conditions. While several possible fission fuels are being considered, published data indicates that reasonably high burn-ups may be possible with enriched uranium in TRISO particles. However, to achieve comparable burn-up with natural or depleted uranium, substantially more radiation damage will have to be tolerated.

In summary, once ignition is achieved, the Nation's scientific and technical community will have a unique opportunity, the investigation of how to best leverage the ignition event to help solve our problems related to energy independence, global warming, and the eventual disposal of our inventory of spent nuclear fuel. Most of the materials that will be developed in support of such hybrid systems will have multiple uses, spanning from optoelectronics to nuclear energy, aerospace and transportation.

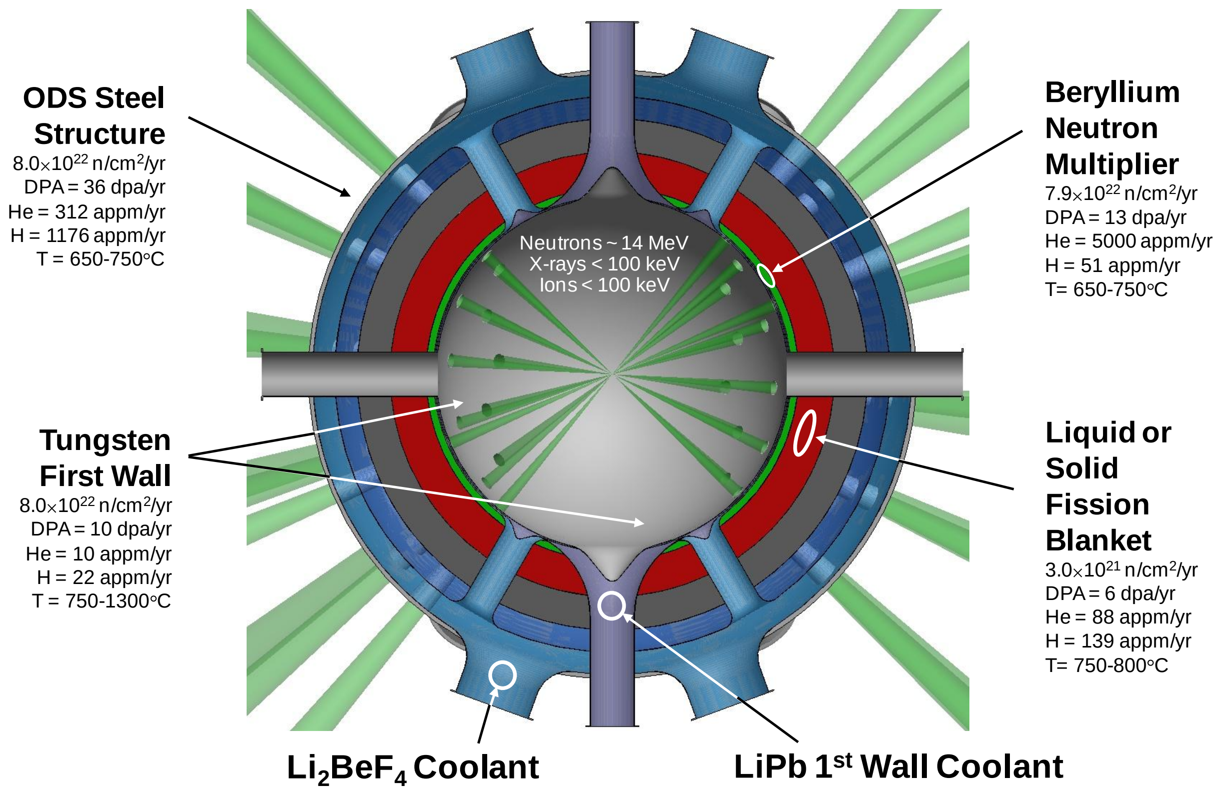

Figure 1 – Conditions challenging materials and fuels in hypothetical ICF-type hybrid system.

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