Development of High-efficiency and Cost-effective Forged Ingot Niobium Technology for Science Frontiers and Accelerator Applications

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G. Myneni[1,2], G. Ciovati[3,5], P. Dhakal[3], Hani E. Elsayed-Ali[1], A. Fajardo[4], Md Obidul Islam[1], B. Khanal[5], N. Lannoy[4], F. Marhauser[3], P. O'Larey[4], R. A. Rimmer[3], T. Saeki[6], M. Yamanaka[6], T. Dohmae[6], K. Umemori[6], A. Yamamoto[6,7]

[1]Electrical and Computer Engineering, Old Dominion University, Norfolk, VA 23529
[2]BSCE Systems Inc., Yorktown, VA 23693
[3]Acclerator R&D, Jefferson Lab, Newport News, VA 23606
[4]ATI Specialty Alloys & Components, Albany, OR 97321
[5]Physics, Old Dominion University, Norfolk, VA 23529
[6]High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki, Japan 305-0801
[7]European Organization for Nuclear Research (CERN), Geneva, Switzerland, CH-1211

Email: gmyneni@odu.edu

Development of Forged Ingot Niobium Technology:

Worlds science frontier programs and SRF accelerator applications demand high performance and cost-effective SRF accelerator technology [1-8]. **Fine-grain (FG)** and **Large-grain (LG) ingot** niobium technologies have been very well developed and implemented in all the present-day accelerator projects. However, **forged ingot** niobium technology which is the focus of this development proposal will be much more cost-effective and expected to have several technical advantages.

FG niobium sheet production is very complex involving more than ten processing steps making them prone to contamination. As a result, they are very expensive to produce and require stringent QA procedure to be ready for SRF cavity production. The accelerating cavity process steps are also numerous and require strict procedures in order to achieve high accelerating gradients and quality factors needed for science frontier programs.

LG niobium disc production, directly sliced from the ingot, is relatively simple and straight forward to keep surface cleanness. The disc production cost is significantly low compared to FG niobium sheet production. However, there are (some) draw backs due to non-homogeneity of the grain boundary distribution, resulting in non-uniform mechanical properties and complex cavity fabrication, although the LG cavities achieve the expected high-gradient performance goals with lower cost.

Medium-grain (MG) niobium disk production may be realized with a new approach/process, the disc directly sliced from the forged ingot, involves a simpler process steps contributing major production cost reduction [9]. These discs are expected to be superior as they tend to be homogenous with uniform sub millimeter grains and mechanical properties. We are eagerly looking forward to developing the forged ingot niobium SRF accelerator technology for the benefit of the world-wide science frontier programs, green energy subcritical nuclear energy systems and a wide variety of industrial applications including the production of radio isotopes and nuclear transmutation applications.

Measurement of thermal characteristics of the forged ingot niobium:

Measurement of the thermal diffusivity, *D,* of superconducting MG niobium is important to be understood in comparison with FG sheet and LG disc, as well as that of advanced composite material of Nb_3Sn film sputtered on forged ingot Nb, which will be determined using transient pump-probe thermo-modulation [10,11]. Transient thermo-modulation is based on using an ultrafast laser pulse to heat the superconducting materials by a few K, then a synchronized laser pulse probes the reflectance of the heated material. For thin films on a substrate (e.g, 100-nm Nb_3Sn on Nb), it takes <100 ps for the heat to reach the substrate by diffusion. Therefore, an ultrafast method is needed to probe *D* of the studied material. D will be measured from room temperature to liquid helium temperatures.

Fundamental Research:

The increase of rf loss in SRF cavities is related to trapping of residual magnetic field during the cavity cool-down. The study suggested that the micro structure plays the role in flux trapping sensitivity. The research includes the flux trapping and expulsion study as forged ingot niobium goes through several mechanical deformations, crystallization leading to the optimal SRF cavity performance. Furthermore, the cavity made from FG, MG, and LG sheet/disc will be compared to understand the optimal re-crystallization temperature that cavity needed to be heat treated which minimize the flux trapping and increase SRF cavity performance.

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