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Growth Studies at Northwestern University of Vapor Diffusion Samples from Fermilab

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There has been significant progress in Nb3Sn SRF cavities during the last decade and the current maximum accelerating electric field of Nb3Sn cavities exceeds ~24 MV/m for a single-cell. Collaborative research on Nb3Sn film growth studies between Fermilab and Northwestern University have been performed during the last three years. We explored effects of growth parameters such as Sn supply (amount of Sn, size of crucible etc) and furnace temperature, and tried to understand how they affect growth kinetics and imperfections in the final microstructures of Nb3Sn coatings. It has been found that the following microstructural imperfections in Nb3Sn coatings play important roles in the performance of Nb3Sn cavities: (i) patchy regions with thin-grains; (ii) Sn segregation at GBs; and (iii) surface roughness. Firstly, we found that the patchy regions with thin-grains are formed in the case of a low Sn-flux, which leads to texturing of Nb3Sn coatings on Nb, due to the orientation relationships at Nb/Nb3Sn heterophase interfaces. Secondly, a possible correlation between Sn-segregation at GBs and cavity performance is observed. We find that the chemical composition of GBs in Nb3Sn is controlled by Sn and Nb diffusion during annealing with or without a Sn-flux. And Nb3Sn SRF cavities without significant Sn or Nb segregation are achieved by a carefully designed coating procedure, which also yields a high-cavity performance without a significant Q-slope untill ~17 MV/m. Lastly, a possible correlation between surface roughness and the cavity performance is also observed: Nb3Sn SRF cavities with an extremely smooth surface are fabricated and it has a value of surface roughness (arithmetic average height, Ra) less than ~100 nm. Then, the maximum accelerating electric field of the cavities exceeds ~24 MV/m. The significantly reduced surface roughness is attributed to the smaller average grain diameter of Nb3Sn coatings (~700 nm) with thinner thicknesses (~1 μm), and further investigations on this subject are ongoing. We demonstrated that the performance of Nb3Sn SRF cavities can be significantly improved by controlling microstructural imperfections and the current study provides a pathway for fabricating high-performance Nb3Sn SRF cavities.

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