Treatment of reentrant niobium cavities via Plasma Immersion Ion Implantation and HiPIMS

Michel Felipe Lima de Araújo, Lilian Hoshida, Odylio Denys de Aguiar, Carina Barros Mello, Graziela da Silva Savonov, Elvis Camilo Ferreira, Vincenzo Liccardo, Rogério de Moraes de Oliveira
[1]National Institute for Space Research (INPE)

1. Introduction

Reentrant niobium cavities are used in the Mario Schenberg gravitational wave detector, operating in DAS / INPE, playing the role of parametric transducers. They are part of a system designed to convert mechanical vibrations from a solid Al-Cu sphere of the detector into electrical signals. Nitrogen plasma immersion ion implantation (PIII) and High Power Impulse Magnetron Sputtering (HiPIMS) have been evaluated to treat these cavities in order to increase its respective quality factors (Q).

The first method is devoted to implant nitrogen ions into the near surface of niobium, since it was reported recently [1] that the presence of interstitial nitrogen into the crystal lattice of Nb has the effect of increasing such Q-values. The second method is devoted to deposit stoichiometric niobium nitride (NbN), another successful method reported in the literature [2,3] to attain this goal.

There is a vast investigation [4,5,6,7] being carried out by the international community in order to increase the quality factor of niobium superconducting resonant cavities, which also have application in High Energy Physics, specifically in particle accelerators [8,9].

One of the most promising studies regarding the improvement of Q, makes use of thermal treatment for the insertion of nitrogen on the surface of niobium [10,11]. These results present good convergence with recent experimental data attained by the PIII / LAP group at INPE [1].

A set of characterization results will be presented for samples treated by both methods, including profilometry, X-ray diffraction, scanning electron microscopy (field emission gun), X-ray photoelectron spectroscopy and atomic force microscopy.

2. Description of Techniques

A variation of conventional PIII has been used herein in order to heat the substrate during nitrogen ion implantation. In the current experiments it has been performed High Temperature PIII (HTPIII). The heating of the substrates facilitates the diffusion of the nitrogen ions implanted into niobium and it is an efficient tool to control de depth of the implantation and respective atomic concentration.

This controlled process can lead to the formation of nitrides and also the implantation of nitrogen in interstitial spaces of the crystal lattice of niobium. Concerning HiPIMS, in the process, a niobium target of high purity is sputtered in reactive glow discharge, mixing argon and nitrogen. The aim is to partially ionize Nb particles due to the high peak power density applied to the targed; thus it is expected the implantation and deposition of niobium and nitrogen into/onto the surfaces of Nb samples.

3. Expected Results

After evaluating the set of characterization methods for Nb samples treated by HTPIII and HiPIMS, some experimental conditions previously used will be repeated for the treatment of the cavities in order to search for a correlation between the respective operation parameters of these processes and the Q-factors.

4. References

[1] Liccardo, V. ; França, E. K. ; Aguiar, O. D. ; Oliveira, R.M. ; Ribeiro, K. L. ; Silva, M. M. N. F. “Study of the effect of NbN on microwave Niobium cavities for gravitational wave detectors”. Journal of Instrumentation, v. 11, p. P07004-P07004, (2016).

[2] LUO, Quanshun; YANG, S.; COOKE, K. E. Hybrid HIPIMS and DC magnetron sputtering deposition of TiN coatings: Deposition rate, structure and tribological properties. Surface and Coatings Technology, v. 236, p. 13-21, 2013.

[3] HELMERSSON, Ulf et al. Ionized physical vapor deposition (IPVD): A review of technology and applications. Thin Solid Films, v. 513, n. 1, p. 1-24, 2006.

michellfisico@gmail.com

[4] FURTADO, Sérgio Ricardo. Desenvolvimento de transdutores paramétricos de alta sensibilidade para o detector de ondas gravitacionais Mario Schenberg. **Doctor Thesis, Inst. Nacional de Pesquisas Espaciais**, 2009.
[5] BARISH, Barry C. The detection of Gravitational Waves with LIGO. arXiv preprint gr-qc/9905026, 1999.
[6] GENG, R. L. et al. Testing the first 1300 MHz reentrant cavity. In: **Proceedings of the Workshop of Pushing the Limits of RF Superconductivity, Argonne National Laboratory**. 2004.
[7] KELLY, Michael. Superconducting radio-frequency cavities for low-beta particle accelerators. **Reviews of Accelerator Science and Technology**, v. 5, p. 185-203, 2012.
[8] WEINGARTEN, Wolfgang. Field-dependent surface resistance for superconducting niobium accelerating cavities. **Physical Review Special Topics-Accelerators and Beams**, v. 14, n. 10, p. 101002, 2011.
[9] CIOVATI, Gianluigi; DHAKAL, Pashupati; GUREVICH, A. Decrease of the surface resistance in superconducting niobium resonator cavities by the microwave field. **Applied Physics Letters**, v. 104, n. 9, p. 092601, 2014.
[10] GRASSELLINO, A. et al. Nitrogen and argon doping of niobium for superconducting radio frequency cavities: a pathway to highly efficient accelerating structures. **Superconductor Science and Technology**, v. 26, n. 10, p. 102001, 2013.
[11] ROMANENKO, A. et al. Proximity breakdown of hydrides in superconducting niobium cavities. Superconductor Science and Technology, v. 26, n. 3, p. 035003, 2013.

michellfisico@gmail.com