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Electrical-thermal-structural coupled-field finite element modeling and experimental testing of high-temperature ion sources for the production of radioactive ion beams

Mattia Manzolaro[1], A. Andrighetto[1], G. Meneghetti[2], G. Vivian[1], F. D'Agostini[2]

[1]INFN, Laboratori Nazionali di Legnaro, Viale dell'Universita' 2 - 35020 Legnaro, Padova (Italy)
[2]Department of Industrial Engineering, University of Padova, Via Venezia 1 - 35131 Padova (Italy)

Corresponding Author: Mattia Manzolaro, e-mail address: mattia.manzolaro@lnl.infn.it

In the specific field of isotope separation on line (ISOL) facilities, two of the most widely used ion source types are the hot-cavity ion source[1] (used for both surface and laser ionization) and the forced electron beam induced arc discharge (FEBIAD) ion source[2]. In both cases a specific high temperature field is required, mainly to maximize the ionization efficiency, and to obtain short confinement times (with a consequent reduction of particle decay losses). High temperatures are reliably obtained making use of tantalum components, that can be easily resistively heated, showing in the same time a high ductility during operation, and a good machinability in the production phase. In this work the electrical-thermal behavior of both the aforementioned ion sources is studied in detail by means of dedicated coupled field finite element models[3], and taking as a reference the specific ion source versions adopted for the selective production of exotic species (SPES) facility[4]. Since thermal expansions can affect significantly the functioning of FEBIAD ion sources (especially at the cathode-anode interface), a detailed thermal-structural study is also presented for this specific ion source type. Then, numerical results are compared with electric potential difference, temperature, and displacement measurements, allowing for validation of both the electrical-thermal and the thermal-structural models. Finally, ionizing electron current values for the SPES FEBIAD ion source are estimated combining calculated temperatures with the well-known Richardson formula and Child-Langmuir relation, showing a good agreement with the corresponding experimental values. The approach presented in this work can be taken as a reference for the electrical-thermal-structural design of new hot-cavity and FEBIAD ion sources, including the high temperature targets and ovens often related to their functioning. In the specific case of FEBIAD ion sources, the ionizing electron current can also be predicted with a high level of accuracy.

References

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