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Li^+ alumino-silicate ion source development for the Neutralized Drift Compression Experiment (NDCX-II)*

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To heat targets to electron-volt temperatures for the study of warm dense matter [1] with intense ion beams, low mass ions, such as lithium, have an energy loss peak (dE/dx) at a suitable kinetic energy [2]. The Heavy Ion Fusion Sciences (HIFS) program at Lawrence Berkeley National Laboratory will carry out warm dense matter experiments using Li^+ ion beam with energy 1.2 - 4 MeV in order to achieve uniform heating up to 0.1-1 eV. The accelerator physics design [3] of Neutralized Drift Compression Experiment (NDCX-II) has a pulse length at the ion source of about 0.5 μs. Thus for producing 50 nC of beam charge, the required beam current is about 100 mA. Focusability requires a normalized (edge) emittance $\approx$2 π-mm-mrad. Here, lithium aluminosilicate ion sources, of β-eucryptite, are being studied within the scope of NDCX-II construction [4].

Several small (0.64 cm diameter) lithium aluminosilicate ion sources, on 70 %-80 % porous tungsten substrate, were operated in a pulsed mode. The distance between the source surface and the mid-plane of the extraction electrode (1 cm diameter aperture) was 1.48 cm. The source surface temperature was at 1220^0 C to 1300^0 C. A 5-6 μs long beam pulsed was recorded by a Faraday cup (+300 V on the collector plate and -300 V on the suppressor ring). Figure 1 shows measured beam current density (J) vs. $V^{3/2}$. A space-charge limited beam density of $\approx$1 mA/cm^2 was measured at 1275^0 C temperature, after allowing a conditioning time of about $\approx$ 12 hours. Maximum emission limited beam current density of $\geq$ 1.8mA/cm^2 was recorded at 1300^0 C with 10-kV extractions.

Figure 2 shows the lifetime of two typical sources with space-charge limited beam current emission at a lower extraction voltage (1.75 kV) and at temperature of 1265$\pm$ 7^0 C. These data demonstrate a constant, space-charge limited beam current for 20-50 hours.

The lifetime of a source is determined by the loss of lithium from the alumino-silicate material either as ions or as neutral atoms. Our measurements suggest that for the low duty factor ($\sim$$10^{-8}$) required for NDCX-II, the lifetime of an emitter depends mostly on the duration that the emitter spends at elevated temperature, that is, at $\geq$$1250^0$ C. At this temperature, lithium loss is due mostly to neutral loss (not charged ion extraction). Extension of the lifetime of the source may be possible by lowering the temperature between beam pulses, when the idling time is sufficiently long between shots.

The NDCX-II design seeks to operate the ion source at the maximum current density without running into heat management and lifetime problems. In preparation to fabricate a large (10.9 cm in diameter) source for the NDCX-II experiment, recently a 7.6 cm diameter source has been fabricated. The method of fabrication of this larger source is similar to that of fabrication of a 6.3 mm diameter source, except a longer furnace heating time was used due to mass differences. NDCX-II construction is in progress [4]. Progress of lithium source study for NDCX-II is available in literature [5].

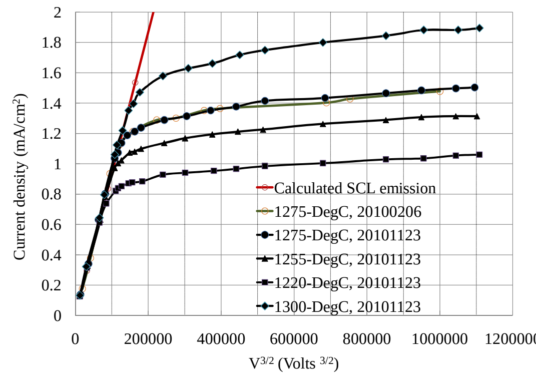

Figure 1: Measured Li^+ beam current density vs. $V^{3/2}$.

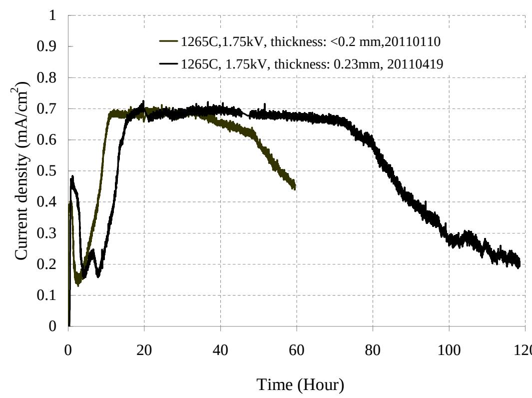

Figure 2: Lifetime of sources when operated at 0.033 Hz.

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