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Zr 광이온화 구도의 최적화

Optimal Excitation Pathway for Selective Photoionization of Zirconium

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The primary goal of atomic vapor laser isotope separation (AVLIS) is to develop a process that can enrich the target isotope at less than the costs of on-line technologies. Costs of AVLIS can be considered for two categories: capital and operating costs. There are the number of differences in capital and operating philosophies unique to AVLIS process. Most distinguishable factor that differentiates AVLIS from the other isotope separation methods based on the mass difference is high separation factor.[1,2] In AVLIS process, the number of separation stages can be reduced to one or two because of its high separation factor. This allows two contradistinctive processes: the enrichment and the depletion of target isotope. The usual formulation in terms of "separative work" are not in appropriate in AVLIS, since the electric power expanded in each stage is dependent only on the target isotope abundance and not on the total feed flow.[3] For AVLIS process, cascade inventory should be much lower than other processes and thus the capital costs will show the inherent benefits of small sizes and few states.

Usually in AVLIS, the isotopic component with small natural abundance is photoionized because the number of photons required for photoionization becomes small. In this sense, the best ionization scheme of zirconium would be the depletion of ^{91}Zr based on polarization selection rule from economical point of view. Because the natural abundance of ^{91}Zr is merely 11.2% of feed, the small number of photons in the depletion of ^{91}Zr process are required. However, all of the measured spectra of zirconium showed that hyperfine structure of ^{91}Zr overlapped with the transition lines of all non-target even isotopes. In AVLIS process based on the polarization selection rule with J=2-2-1-0 transitions, not only odd isotope, but also the even isotope is excited to the magnetic sublevel of the 2nd excitation step with m=1. Overlapping the absorption spectrum between target odd isotope and non-target even isotope causes the absorption of the considerable number of photons during the excitation process of AVLIS, which would degrades the photon efficiency. In AVLIS of zirconium, the laser with the bandwidth of 3~5 GHz is necessary and the laser energies in the 1st and 2nd excitations are absorbed by all isotope components.[4,5] Therefore, the photon efficiency of AVLIS of zirconium becomes much lower than that of AVLIS of gadolinium.

The other characteristic of absorption spectra of zirconium is that isotope shifts of even isotopes

are quite small: the isotope shifts of the first transition lines are comparable to 500 MHz and those of the second transition lines are less than 200 MHz. There exists only one or two hyperfine lines in the spread of even isotopes. The spread of even isotopes of the first and second transition lines are much less than hyperfine structure of ^{91}Zr and the Doppler width of atomic beam. By tuning the narrow band dye lasers to the clumps of even isotopes, even isotopes can be selectively ionized from ^{91}Zr.

In this work, the possible ionization schemes for AVLIS of zirconium were discussed to optimize the ionization scheme based on the cost performance of each process. Two ionization schemes were compared from a view of operating cost of AVLIS plant, which are 1) the 91Zr depletion process based on the polarization selection rule through the transition a^3F_2-$z^3D^o_1$-e^5F_1-53840 cm^{-1} (J=2-1-1-0), and 2) the even isotopes enrichment process by using the small even isotope spread through the transition of a^3F_2-$z^3D^o_3$-36341.77 cm^{-1}-53710 cm^{-1} (J=2-3-4-3). In the ^{91}Zr depletion process, it was found that two or more stages are required because ^{91}Zr atoms are populated also in the low-lying metastable states by thermal excitation during the evaporation process which are not photoionized and the depletion of ^{91}Zr is not sufficient in the tail product in one three-step photoionization process by linearly polarized lasers. In the even isotopes enrichment process, the depletion of ^{91}Zr is enough large in head products because the hyperfine spread of ^{91}Zr is very large compared with the even isotope spread. Operating cost of the even isotope enrichment process to deplete ^{91}Zr less than 2%. was estimated cheaper than that of the ^{91}Zr depletion process because two or more stages of plant will be required in the ^{91}Zr depletion process.

References

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