Microgram-order palladium isotope separation by odd-mass-selective photoionization

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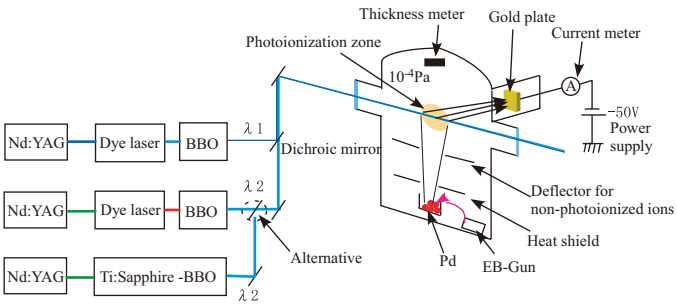
High-level radioactive wastes generated from nuclear power plants contain small percentages of platinum group metals such as palladium, rhodium, zirconium, and plutonium, which are valuable resources for industrial applications. A novel research project has been started by the Impulsing Paradigm Change through Disruptive Technologies Program (ImPACT, Project manager: R. Fujita), which includes (1) the separation of those valuable metals from fission waste, (2) the separation of long-lived and short-lived nuclei, and (3) the nuclear mutation from long-lived to short-lived nuclei. One of the key techniques in (2) was successfully advanced in the method using odd-mass-selective laser excitation.[1] The separation of even- and odd-mass-number isotopes of Pd using orthogonally polarized lasers was demonstrated with ionization that was 10,000 times more efficient[1] than the scheme used so far. From a practical perspective, the yields on the separation of even- and odd-mass-number isotopes must be comparable to Avogadro's number of atoms for a large amount of nuclear waste.

We demonstrated stable Pd isotope separation on a microgram order by photoionization using a high-power, high repetition rate pulsed laser system.[2] The experimental apparatus is shown in Fig. 1. The Pd vapor was produced by an electron beam that irradiated Pd samples in a crucible. Two linearly polarized beams with parallel polarization were applied for the selectively resonant ionization of odd-mass Pd isotopes among stable six isotopes (^{102,104,105,106,108,110}Pd). We succeeded in the dominant photoionization of the ^{105}Pd.

Two Frequency doubled Nd:YAG InnOSlab lasers (EdgeWave) individually pumped two dye lasers having a pulse width of 10 ns and repetition rate of 10 kHz.



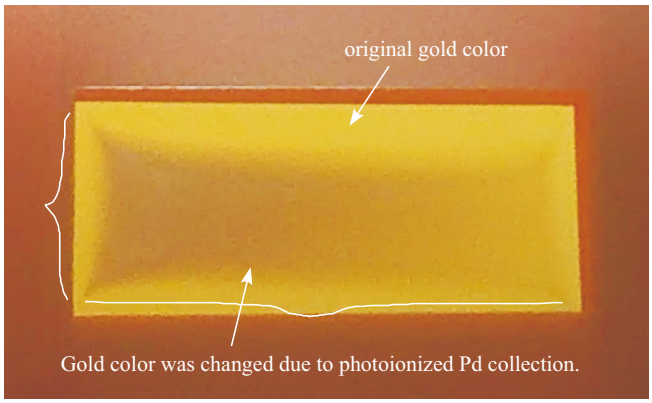


Fig. 2. The gold plate implanted by selectively ionized ^{105}Pd (total deposition time is 3 h 23 min).

Also, there is an intra-cavity SHG in a Ti:Sapphire laser system pumped by Nd:YAG, whose repetition rate and pulse width are 10 kHz and 35 ns, respectively. The first excitation wavelength (λ_1) of 244.9 nm was produced by the first dye laser after frequency doubling in a BBO crystal, which excites Pd atoms into the $4d^9(^2D_{3/2})5p[1/2]$ state. The typical power of λ_1 was 100 mW. The second dye laser or Ti:Sa laser produces the second excitation wavelength (λ_2) of 361.023 nm via frequency doubling in a BBO crystal placed at the external (dye) and internal (Ti:Sa) cavity configuration. The λ_2 excites Pd atoms to the Rydberg autoionizing state $4d^9(^2D_{3/2})9d[3/2]$. We used dye or Ti:Sa, depending on the situation. The typical power of λ_2 in the case of Ti:Sa was 2 W, while that in the case of dye was 1.5 W. Photoionized ^{105}Pd ions were collected on the gold plate on which a collection voltage of −50 V was applied. The distance between the gold plate and the ionization area was about 5 cm. We confirmed the yields of Pd ions and identified the Pd element from the off/on resonant frequency by monitoring with a current meter. The typical current level attributed to the photoionized Pd was 10 μA.

Figure 2 shows the gold plate after collecting photoionized ^{105}Pd ions for 3 h and 23 min. From the value of the total deposition current, we deduce the total number of ^{105}Pd to be 3.0×10^{17}, which corresponds to a weight of 50 μg. For the first time, we confirmed Pd isotope separation in microgram orders by using odd-mass-selective laser excitation.

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References

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