Ps\(^{-}\) emission from Na coated W(100) surfaces

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Abstract. The emission of positronium negative ions from a Na coated W(100) surface has been studied. The emission efficiency was found to increase with time following Na deposition to a maximum of 1.4% after \(6 \times 10^4\) s. The efficiency then gradually decreased but was still higher than 0.5% after 3 days.

1. Introduction

Recently, we have observed that positronium negative ions (Ps\(^{-}\)), the bound state of one positron and two electrons, are formed by thermalized positrons and are emitted efficiently from the surface of Cs coated W(100) [1-4]. The increase in efficiency compared to a clean W surface is the effect of the adsorbate on the dipole.

The Ps\(^{-}\) work function (the energy required to emit Ps\(^{-}\) from the surface) can be expressed as

\[
\phi_{Ps^{-}} = \phi_{+} + 2\phi_{-} - E_{\text{b}},
\]

where \(\phi_{+}\) and \(\phi_{-}\) are the positron and electron work functions, respectively, and \(E_{\text{b}}\) is the Ps\(^{-}\) binding energy [5]. The values \(\phi_{+}^{'\prime}\) and \(\phi_{-}^{'\prime}\) for the surface with adsorbates can be written as

\[
\phi_{+}^{'\prime} = \phi_{+} + \Delta \quad \text{and} \quad \phi_{-}^{'\prime} = \phi_{-} - \Delta
\]

respectively, where \(\Delta\) is the effect of the adsorbate dipole. Therefore, the Ps\(^{-}\) work function for the coated surface can be written as

\[
\phi_{Ps^{-}}^{'\prime} = \phi_{Ps^{-}} - \Delta.
\]

The value of \(\Delta\) is 3.0eV for a \(2.2 \times 10^{14}\) atoms/cm\(^2\) Cs coverage on W(100) [6] and hence the Ps- work function is lowered by the deposition. This indicates that the number of conduction electrons which may contribute to the Ps\(^{-}\) formation increases and therefore Ps\(^{-}\) emission is more feasible than that for the uncoated surface. The experimental value of the efficiency (the fraction of incident slow positrons yielding Ps\(^{+}\)) was 1.25% [1], which is two orders of magnitude higher than that obtained using carbon foil [7] or an uncoated W surface [8]. However, the value decreased with time and was almost constant at about 0.1% after \(6 \times 10^4\) s. The decrease may have been due to a reaction between the Cs and residual molecules in the target chamber.

In the present work, we have investigated the effect on the Ps\(^{-}\) emission efficiency using a Na coated W sample; Na is chemically less active than Cs and therefore may result in a greater stability in the efficiency.
2. Experimental Procedure

Figure 1 shows the schematic diagram of the target chamber. The chamber was similar to that used in the previous work [1-4], with the exception of the addition of a Na deposition system. The base pressure of the target chamber was $4 \times 10^{-8}$ Pa.

The target was a W(100) foil which was 2 μm in thickness and was supported on a polycrystalline W sheet. It was annealed in situ at 1800 K for 30 min by the passage of an electric current and then coated using the Na dispensers. The thickness of the Na layer was $(1.3 \pm 0.8)$ Å. The value was estimated using a quartz crystal deposition monitor system.

The target was biased at a voltage of $–3.0$ kV so that the positrons impinged on the target with an energy of 3.1 keV. The $^{26}$Na ions emitted from the target were accelerated by the electric field between the target and a grounded mesh placed 3 mm in front of it. The γ-rays emitted from $^{26}$Na self-annihilation were blue-shifted to an energy of 542 keV in the present experimental conditions and these were detected using the Ge detector in coincidence with the signal from the NaI scintillation detector placed behind the target.

![Figure 1. Schematic diagram of the target chamber.](image)

3. Result and Discussion

Figure 2 shows the annihilation photon energy spectra. The spectra for the uncoated and Na coated targets were taken over a period of 54000 s. A slight indication of a signal is noted for the uncoated sample at an energy of 542 keV. However, a more significant peak is clearly observed at this energy for the Na coated target.

![Figure 2. Annihilation photon energy spectra for uncoated and Na coated W(100) surface.](image)
The mean efficiencies over 3000 s intervals are plotted against time after the deposition in figure 3, together with the values for the Cs coated surface [1]. The emission efficiency for the Na coated W(100) sample increased and reached its maximum value after $6 \times 10^4$ s and then decreased gradually. Unexpectedly, the maximum value was 1.4%, which was higher than that for the Cs coated surface although the value of $\Delta$ for Na is smaller than that for Cs. Moreover, the efficiency was higher than 0.5% after $3 \times 10^5$ s.

The durability of the Ps$^-$ emission from a Na coated W(100) surface enables us to perform new studies on Ps$^-$. Recently, we have succeeded in the first observation of photodetachment of Ps$^-$ formed using this method [9]. It is expected that this method can also be used in the precision measurement of the decay rate of Ps$^-$ in vacuum [10, 11].

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