Influence of Annealing Temperature on Photoelectrochemical Performance of Nb-doped $SrTiO_3$ Film

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Abstract: The photoelectrochemical performances of Nb-doped $SrTiO_3$ films and their photochargeability to hydrogen storage alloy films were investigated. The Nb-doped $SrTiO_3$ films were deposited on nickel substrate by rf magnetron sputtering. After annealed at 300 ~ 600℃, the $LaNi_{3.9}Al_{1.3}$ hydrogen storage alloy films were deposited on the back of the Ni substrate by DC magnetron sputtering to form the Nb-doped $SrTiO_3$/Ni/hydrogen storage alloy (SHN) electrodes. With increasing the annealing temperature of the $SrTiO_3$ film, the anodic photocurrent and photochargeability first increased, then decreased.

Key words: Strontium titanate; hydrogen storage alloy; photoelectrochemical performance; annealing temperature
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Whereas electrical needs are largely continuous, clouds and darkness dictate that photovoltaic solar cells have an intermittent output. Hydrogen storage alloy such as $LaNi_5$ can store energy chemically or electrochemically[1]. Several attempts[2-3] present a promising method to solve the problem by using metal hydride, in which AlGaAs/Si semiconductor and $SrTiO_3$ single crystalline acted as the photoelectrodes. TiO_2 only photocharges the alloy with the assistance of current[4]. As a photoanode, strontium titanate has a slightly higher flatband potential than TiO_2[5]. This means that a higher photovoltage for $SrTiO_3$ can be obtained in photoelectrochemical cells.

In this work, Nb-doped $SrTiO_3$ films on Ni substrate were deposited by rf magnetron sputtering method. After annealing treatment, a hydrogen storage alloy films were deposited on the back of the Ni substrate to form the $SrTiO_3$/Ni/hydrogen storage alloy (SNH) electrodes. The photoelectrochemical performances of the electrodes were investigated.

1 Experimental

Deposition of Nb-doped $SrTiO_3$ films with thickness of 300 ± 10 nm on the Ni substrate (10 mm × 15 mm in size) was carried out on an rf sputtering method. The target was $SrTiO_3$ doped with 0.5% Nb_2O_5. The films were annealed at temperatures from 300 ℃ to 600 ℃ in H_2 atmosphere for 5 h.

After annealed, a $LaNi_{3.9}Al_{1.3}$ hydrogen storage alloy film with a thickness of 8 μm was deposited on the back of the nickel substrate by DC magnetron sputtering to form an $SrTiO_3$/Ni/hydrogen storage alloy (SNH) electrode. The photocharge-discharge behaviors of the SNH electrodes were measured with a battery program-control test system (Hg/HgO/6 mol/L KOH as the reference electrode, 6 mol/L KOH as the electrolyte). The light intensity of xenon lamp was set 5 W/cm². After photocharged, the electrodes were discharged at a current of 20 μA to a cutoff voltage of 0.5 V.

2 Results and discussion

Fig.1 shows the anodic polarization curves obtained from the Nb-doped $SrTiO_3$ film annealed at 500 ℃. The dark current is basically constant and the photocurrent increases with increasing the potential up to 0.4 V. Fig.2 shows the net anodic photocurrents of the annealed $SrTiO_3$ thin film electrodes. The anodic photocurrent first increases with the annealed temperature. When the annealed temperature is 500 ℃, the anodic photocurrent is the largest. When an UV photo is absorbed by the film, an electron (e^-) / hole (h^+) pair is generated. With the assistance of the field in the film, the holes migrate to the surface and the electrons migrate to the Ni substrate. But the recombination may occur at the defects inner the grain or at the grain boundary. As the annealed temperature increased from 300℃ to 500℃, the $SrTiO_3$ films were well crystallized and the amount of the grain boundary decreased.

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Therefore, the anodic photocurrents increased from 300℃ to 500℃. However, the field in the films decreased with the increase of grain size. As a result, the anodic photocurrent decreased in the film with large grain size after annealed at 600℃.

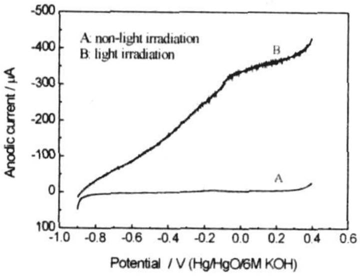

Fig. 1 Typical anodic polarization curves obtained from the Nb-doped $SrTiO_3$ thin film annealed at 500℃

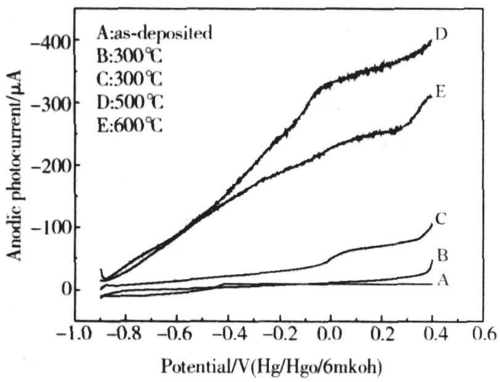

Fig. 2 Net anodic photo- currents of $SrTiO_3$ film electrodes

Fig. 3 shows the discharge characteristics of the SNH electrodes. After photocharged, the discharge time of the SNH electrode formed with the $SrTiO_3$ thin film annealed at 500℃ was the longest. At the surface of hydrogen storage alloy, the electrons reduce the alloy to form metal hydride. The larger photocurrent, the more metal hydride may be formed.

3 Conclusion

The annealing temperature plays an important role in the photoelectrochemical performances of the Nb-doped $SrTiO_3$ thin film electrodes and their photochargeability to $LaNi_{3.9}Al_{1.3}$ hydrogen storage alloy film. With increasing the annealing temperature, the anodic photocurrent and photochargeability first increased, then decreased. When the annealing temperature was 500℃, all of them reached to the highest values.

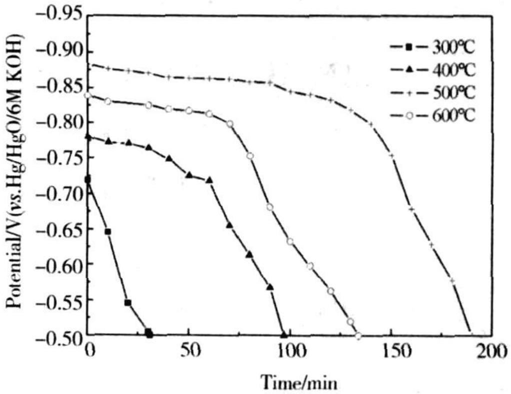

Fig. 3 Glvaostatic discharge profiles of the SNH electrodes after photocharged

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退火温度对 Nb掺杂 $SrTiO_3$ 薄膜光电化学性能的影响

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摘　要：研究了 Nb掺杂 $SrTiO_3$薄膜的光电化学性能及其对储氢合金薄膜的光充电性能。采用射频磁控溅射将 $SrTiO_3$薄膜沉积在镍片基体上，在 300~600℃退火处理后，采用直流磁控溅射将 $LaNi_{3.9}Al_{1.3}$储氢合金薄膜沉积在镍片基体的背面构成 $SrTiO_3$/Ni/储氢合金电极。随着 Nb掺杂 $SrTiO_3$薄膜热处理温度的升高，阳极光电流和光充电性能先增大后减小。

关键词：钛酸锶；储氢合金；光充电；退火温度
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