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Ultraviolet laser-induced voltages in $LaSrAlO_4$ single crystal*

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Laser-induced ultrafast photovoltaic effect is observed in $LaSrAlO_4$ single crystal at ambient temperature without any applied bias. An open-circuit photovoltage is obtained when the wafer is irradiated by a 248-nm-KrF laser pulse of 20 ns duration. The response time and full width at half maximum of the photovoltage pulse are 6 ns and 19 ns, respectively, indicating that $LaSrAlO_4$ single crystal has potential application in ultraviolet detector.

Keywords: photovoltaic effect, $LaSrAlO_4$ single crystal
PACC: 7847, 7240, 4280

1. Introduction

The addition of divalent cations in $LaAlO_3$, such as Mg, Ca, Sr and Ba ions to replace Al and La, is expected to enhance the conductivity of aluminates.[1,2] In this family, $LaSrAlO_4$ single crystal is a promising candidate of microwave dielectric material because of its good dielectric properties, low cost and low loss at microwave frequencies.[3,4]

Studies of laser-induced voltage in materials have attracted much attention, and fast photo response information has been observed in the perovskite oxide materials, heterojunctions and some single crystals.[5−9] However, there is no report about ultrafast photovoltaic effect in $LaSrAlO_4$ single crystal. In this paper we will report the ultraviolet (UV) laser-induced photovoltaic effect in the tilted and untilted orientation $LaSrAlO_4$ (LSAO) single crystal at ambient temperature without any applied bias. The open-circuit photovoltaic pulse with a rise time of 6 ns and full width at half-maximum (FWHM) of 19 ns was observed, indicating that LSAO has promising potential application in the ultraviolet selective and sensitive photodetector.

2. Experimental details

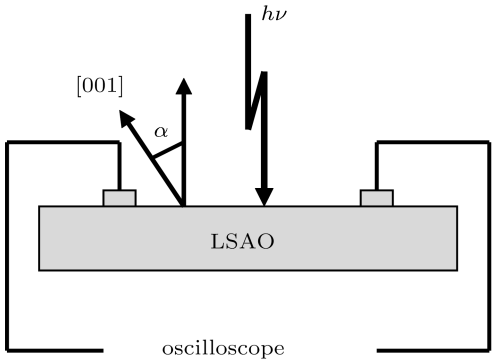


Fig.1. The schematic circuit of the measurement.

The LSAO single crystal wafers used in the study are mirror double polished and the geometry of the sample is 5 mm × 10 mm with the thickness of 0.5 mm. The (001) plane is tilted at an angle of α with respect to the surface. The angle α taken is 0° and 10° respectively. Two silver electrodes were separated by 3 mm on the LSAO surface, which was irradiated with 248 nm KrF laser for a duration of 20 ns at ambient temperature. The pulse energy density was 1.37 mJ/mm^2 and the on-sample laser area is 4 mm

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× 5 mm, including the two electrodes under illumination. The photovoltaic signals were recorded by an oscilloscope terminated into 1 MΩ and 50 Ω. The pulsed laser irradiated the sample from the front and back sides of the wafer. The schematic circuit of the measurement is shown in Fig.1.

3. Results and discussion

The sample was characterised by $\theta/2\theta$ x-ray diffraction (XRD) and the result is shown in Fig.2. The distinguishable $K\alpha_1$ and $K\alpha_2$ peaks in the $\theta/2\theta$ pattern of diffraction indicate that the sample is of high crystal quality.

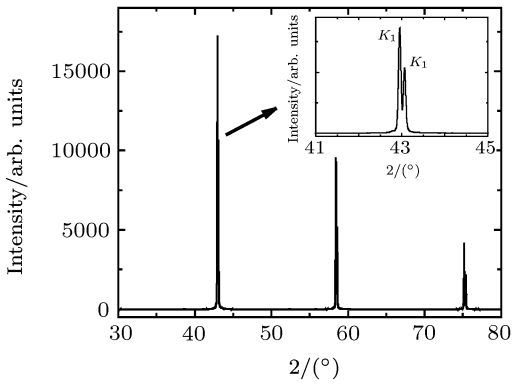


Fig.2. XRD pattern of LSAO single crystal.

The absorption spectrum of LSAO single crystal measured is shown in Fig.3. The absorption peak is

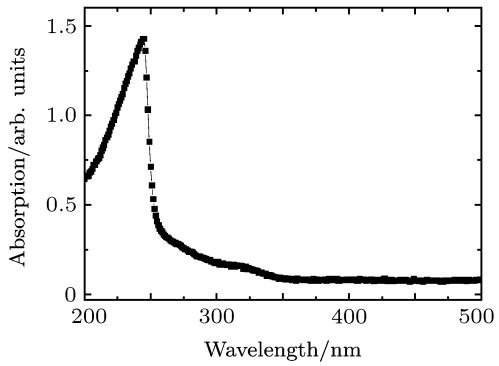


Fig.3. The absorption spectrum of LSAO single crystal.

located at 245 nm and the absorption edge is at about 252 nm. The optical band gap of LSAO can be determined to be about 4.9 eV by using the absorption spectrum, suggesting that the nonequilibrium charge carriers in LSAO wafers can be created under the 252 nm UV irradiation. Therefore, the pulsed photovoltage occurred when the LSAO single crystal surface was irradiated directly with a 248-nm-KrF laser pulse without any applied bias, as shown in Fig.4.

Figures 4(a) and 4(b) show the typical open-circuit photovoltage transient of the 10° and 0° tilting $LaSrAlO_4$ single crystal, respectively, measured by using 1 MΩ input impedance of the oscilloscope. To understand the mechanism of the photovoltaic effect, LSAO single crystal was irradiated on the front-side that contains the electrodes and on the back-side of the wafer as well. From Fig.4(a) we can see that the rise time and FWHM are 7 μs and 96 μs, 5 μs and 83 μs under front and back sides irradiations for the 10° tilting LSAO single crystal, respectively. Figure 4(b) shows that the rise time of the transient pulse is 30 μs (50 μs) and the FWHM is 280 μs (260 μs) under front (back) side irradiation for 0° tilting single crystal.

To reduce the influence of the measurement system for the response time, we change the import impedance of the oscilloscope from 1 MΩ to 50 Ω. Figure 4(c) shows the transient pulse of the 0° tilting LSAO single crystal. Under the same experimental conditions, the rise time of the photovoltaic pulse is dramatically reduced to about 6 ns and the FWHM reduced to 19 ns.

Previously, ultrafast photovoltaic effect was observed in tilting orientation $LaAlO_3$ and $SrTiO_3$ single crystals, which can be explained by photoelectric effect and Seebeck effect based on the phenomena that the signal polarity is reversal when the crystal is under front and back-side irradiations and the photo-induced voltage is higher for a tilted single crystal than that for a non-tilted single crystal.[8,10] As for exact cut crystals, the angle between the surface normal and *c*-axis is not precisely 0° and a small angle may be induced by cutting substrates and the defects in the crystals, so a temperature gradient can still be generated, and gives rise to a thermoelectric field, resulting in a movement of the photo-induced carriers and leading to a lateral voltage. Furthermore, from Fig.4, the interpretation in terms of the Seebeck effect is of equally doubtful validity since the signal polarity is not reversal in the present case under the front and back irradiations. The peak voltage for 0° tilting LSAO is ten times larger than that for 10° tilting LSAO, while the response time of the latter is faster than that of the former. In previous work, the terrace model was proposed to elucidate the miscut angle dependence of the ultrafast photovoltaic effect in semiconducting Nb-doped $SrTiO_3$.[11] In fact, the mechanism in insulating LSAO crystals is not very clear yet and further investigation is in process.

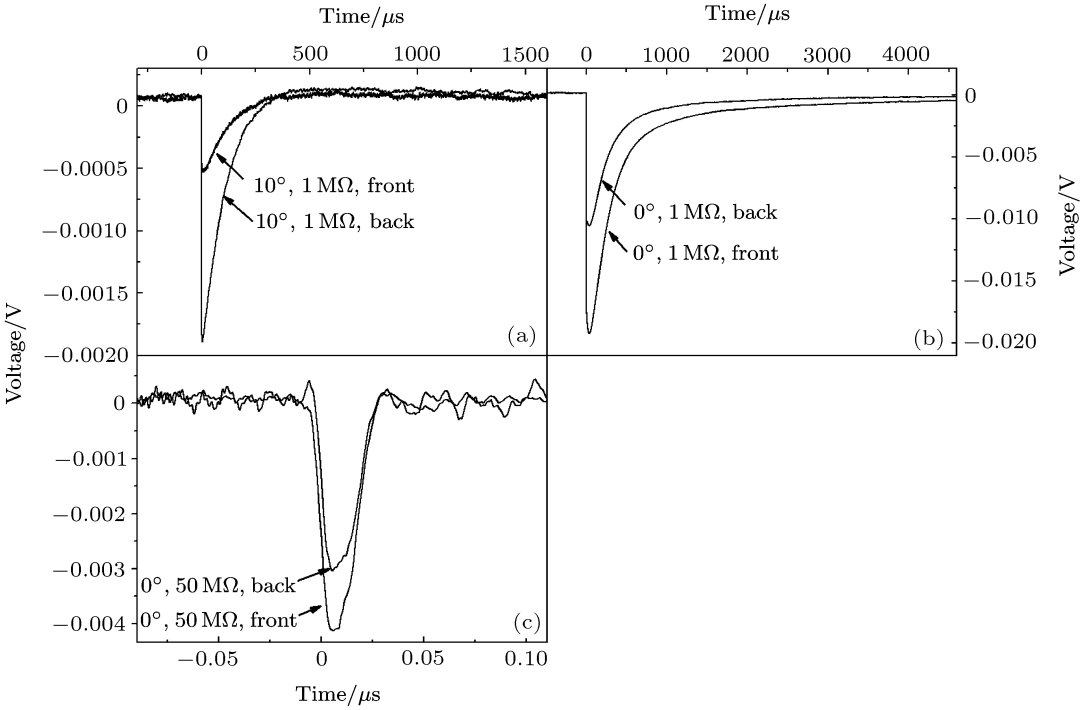


Fig.4. The open-circuit photovoltaic pulses for (a) tilting 10° and (b) tilting 0° LSAO wafer with 1 MΩ input impedance, and (c) tilting 0° LSAO wafer with 50 Ω input impedance.

4. Conclusions

In conclusion, we have observed the ultrafast photovoltaic effect in LSAO crystal under the irradiation of 248-nm laser pulse. The rise time is 6 ns and the FWHM is 19 ns for the open-circuit photovoltage pulse. It is worth while noting that the ultrafast UV photovoltaic effect in LSAO occurs at ambient temperature and without any applied bias, suggesting that LSAO single crystal has potential application in UV photodetector (wavelength ≤ 252 nm).

References

[1] Enrique L, María E V C, José M S, Alejandro I P, Jorge E S S and Luis J A 2008 *Solid State Ionics* **178** 1944
[2] Chen T Y, Pan R Y and Fung K Z 2008 *J. Phys. Chem. Solids* **69** 540
[3] Liu X Q and Chen X M 2004 *Mater. Sci. Eng.* B **110** 296
[4] Liu X Q, Chen X M and Xiao Y 2003 *Mater. Sci. Eng.* B **103** 276
[5] Zhao K, Huang Y H, Lü H B, He M, Jin K J, Chen Z H, Zhou Y L, Cheng B L, Dai S Y and Yang G Z 2005 *Chin. Phys.* **14** 420
[6] Zhao K, He M and Lü H B 2007 *Chin. Phys.* **16** 840
[7] Xing J, Wang X, Zhao K, Li J, Jin K J, He M, Zheng D N and Lü H B 2007 *Chin. Phys. Lett.* **24** 530
[8] Wang X, Xing J, Zhao K, Li J, Huang Y H, Jin K J, He M, Lü H B and Yang G Z 2007 *Physica* B **392** 104
[9] Huang Y H, Zhao K, Lu H B, Jin K J, He M, Chen Z H, Zhou Y L and Yang G Z 2006 *Physica* B **373** 313
[10] Zhao K, Jin K J, Huang Y H, Zhao S Q, Lü H B, He M, Chen Z H, Zhou Y L and Yang G Z 2006 *Appl. Phys. Lett.* **89** 173507
[11] Zhou N, Zhao K, Liu H, Lu Z Q, Zhao H, Tian L, Liu W W and Zhao S Q 2009 *J. Appl. Phys.* **105** 083110