Optics & Laser Technology 41 (2009) 968–971

Contents lists available at ScienceDirect

Optics & Laser Technology

journal homepage: www.elsevier.com/locate/optlastec

Wide band-response laser-induced thermoelectric voltage in tilted orientation $SrTiO_3$ single-crystal coated by $La_{0.7}Sr_{0.3}CoO_3$ layer

Yuliang Zhang [a,b], Ruhua Tao [a,b,*], Weiwei Dong [a,b], Zanhong Deng [a,b], Xiaodong Fang [a,b]

[a] Key Lab of New Thin Film Solar Cells, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Hefei China 230031
[b] Anhui Provincial Key Laboratory of Photonic Devices and Materials, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Hefei China 230031

ARTICLE INFO

Article history:
Received 18 July 2008
Received in revised form
19 February 2009
Accepted 5 April 2009
Available online 12 May 2009

Keywords:
Laser induced thermoelectric voltage (LITV)
Strontium titanate oxide (STO)
Anisotropic Seebeck effect

ABSTRACT

With different wavelengths from the infrared (IR) to ultraviolet (UV) band, laser-induced thermoelectric voltage (LITV) has been observed in the vicinal cut $SrTiO_3$ (STO) single crystals, coated with $La_{0.7}Sr_{0.3}CoO_3$ (LSCO) layer. It is demonstrated that the polarity of voltage signal in the STO substrate is reversed when the STO substrate is illuminated by UV laser rather than by IR or visible laser. The polarity of voltage signal in LSCO film is always consistent with that from the STO substrate no matter 1064 or 355 nm laser irradiate the LSCO film or the STO substrate. A possible interpretation of the phenomenon is proposed.

Recently laser-induced thermoelectric voltage (LITV) was widely studied in high-temperature superconductor thin film, $YBa_2Cu_3O_{7-X}$ films and $Tl_2Ba_2CaCu_2O_8$ films [1–5], in colossal magnetoresistance (CMR) thin film, $La_{1-X}Ca_XMnO_3$ [6–9], and in the *c*-axis-oriented MgB_2 thin films [10]. Based on the Anisotropic Seebeck effect, an atomic layer thermopile [1] was proposed to explain mechanism of the phenomenon and origin of the LITV. Further researches [11–13] have been done to the effect and show a great agreement with the atomic layer thermopile model. Researches demonstrated that this kind of thin film in possess of qualities of wide-wavelength response, fast-time-response, and good linear relationship to laser power in a limited range, can be widely used as laser power/energy meter.

The photoconductivity of insulative $SrTiO_3$ (STO) single-crystal under ultraviolet (UV) light irradiation has been reported for more than 40 years [14–17]. UV LITV signal in commercial vicinal cut STO and $LaAlO_3$ (LAO) single crystals was also reported, however, infrared (IR) or visible LITV signal was not observed [18,19]. In this article, we report IR and visible LITV effect in vicinal cut STO substrate coated by $La_{0.7}Sr_{0.3}CoO_3$ (LSCO) layer.

The LSCO thin film was grown on double-polished STO (1 0 0)-oriented substrate tilted by 10° towards the [0 1 0] direction by chemical solution deposition (CSD) method with thickness of ~80 nm. The preparation of the solution was carried out in air with lanthanum acetate (Alfa Aesar), Strontium acetate (Alfa Aesar), and cobalt acetate (Alfa Aesar). Propionic acid was used as chelating agent and a solution with concentration of 0.2 M was used to prepare the film. A spin coater was used to deposit the layers, the rotation speed was selected as 4000 rpm and the deposition time was 60 s. The deposited layer was dried on a 300 °C preheated hot furnace for 30 min to expel organics, and then the dried layer was annealed at 600 °C for 2 h under flowing oxygen atmosphere at the speed of 0.45 sccm. The size of STO is $5 \times 10 \times 0.5\,mm^3$. Copper electrodes were fabricated on LSCO thin film and STO substrate, respectively, with silver epoxy. The inset of Fig. 1(a) shows the arrangement of four electrodes: A, B, C, and D. Electrodes A and B separated by 8.5 mm were always kept in the dark to prevent the influence of any electrical contact photovoltage, and the same were electrodes C and D. Table 1 shows all specifications of laser light used in this article. The signal was terminated to the digital oscilloscope, Tektronix TDS3054B, with 500 MHz bandwidth and 0.2 ns time resolution. Four times average was taken before we collected the data with the digital oscilloscope.

Fig. 1(a) shows a typical open-circuit voltage signal measured on electrodes A and B by the oscilloscope with input impedance 1 MΩ, when 1064 nm laser irradiated the LSCO film. The rise time (10–90% of the peak voltage) is 40 ns, the full width at half maximum (FWHM) is 0.6 μs and the peak voltage Vp is 16 mV. The long-time decay of the electrical signal in the system could be explained by the RC effect in the circuit [12]. In order to obtain a fast response of the signal and reduce the long tail of the decay time due to RC effect, we terminated the signal to oscilloscope with 50 Ω input impedance. As shown in Fig. 1(b), the voltage signal is symmetrical, and the rise time reduced to 13 ns and the FWHM reduced to 25 ns, which presents a good agreement with

* Corresponding author.
E-mail address: rhtao@aiofm.ac.cn (R. Tao).

0030-3992/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.optlastec.2009.04.006

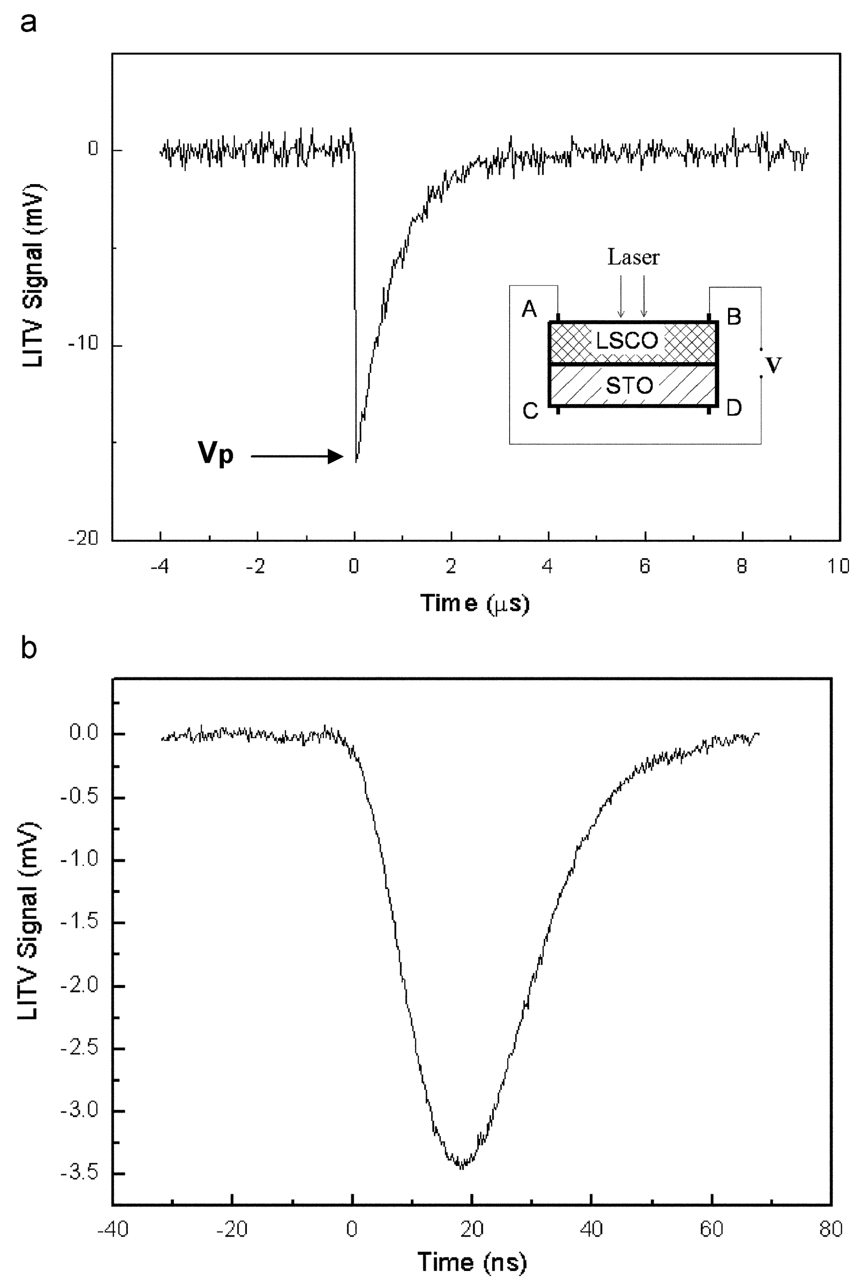

Fig. 1. (a) The inset shows the contact arrangement of the sample and the schematic circuit of the measurement. A typical voltage signal measured on electrodes A and B when the LSCO film was illuminated by 1064 nm laser with 1 MΩ and 50 Ω and (b) input impedance to oscilloscope. Vp is the peak voltage.

Table 1
Parameters of light sources in this article.

Wavelength	355 nm	1064 nm
Energy density	$\sim$1 mJ mm^{-2}	$\sim$1.2 mJ mm^{-2}
Pulse duration	4 ns	6 ns
Diaphragm/on-sample energy	2×3 mm^2/6 mJ	ϕ2 mm/3.6 mJ

laser pulse duration. We also got analogical result with 532 nm laser irradiation and these experimental results accord with other reports [6–13].

Fig. 2 demonstrates the relation between the peak voltage Vp and the incident laser energy. The very good linear relationship provides the possibility of making use this effect as laser power/energy meter at the wavelength of 1064 nm. Peak voltages Vp in LSCO film on STO substrates with tilted angle 10° and 4° are studied. According to Zhao's theory [18], we get $Vp(\alpha)\propto(\cos\alpha-\sin\alpha)\sin(2\alpha)$ and $Vp(10^\circ)/Vp(4^\circ) = 2.15$. α is the tilted angle of STO substrate. In this case, $Vp(10^\circ)/Vp(4^\circ) = 18.6/9.6\,\text{mV} = 1.94$. The result is in good agreement with the theory.

Fig. 3 presents the voltage signal measured on electrodes C and D with irradiation of 1064 and 355 nm, respectively, on the STO substrate. An interesting phenomenon is the inversion of the signal and explanation based on the Seebeck effect was given as the following.

According to the atomic layer thermopile [1,7] and the anisotropic Seebeck effect, the gradient of the electrical potential generated by the STO substrate is a function of the gradient of the lattice temperature as below:

$$\nabla\Psi = S_{il}\nabla_j T \tag{1}$$

where S_{il} is the Seebeck tensor. In this case, the gradient of the electrical potential $\nabla\Psi$ is related with the gradient of the lattice