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Research Article

Load-Resistance- and Voltage-Tunable Photovoltaic Effect in Tilting Manganite Films

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The photovoltaic properties of miscut $La_{2/3}Ca_{1/3}MnO_3$ films were systematically investigated with different bias voltage (V_b) and load resistance (R_S). The photoresponse depended strongly on V_b and R_S and was improved greatly by increasing V_b and R_S. The maximum photovolvaic sensitivity reached 62.5 mV/mJ. The present results suggested the promising potential of increasing V_b and R_S in high-sensitivity detectors.

1. Introduction

Hydrocarbon resource is important and strategic for the national modernization, defense, and security. Present concept of Digital Oilfield suggests that an optical detector in oil well can operate at high temperature upto ~500°C and high pressure upto ~100 MPa with high-speed response. Recently there have been active studies of the photoresponse characteristics in the manganite thin films which can work in a harsh environment (features such as thermal instability and high pressure). Technological interest has centered on bolometers [1], while more basic issues have involved quasiparticle generation and carrier relation times [2–6]. Ultrafast photovoltaic effect has been observed in manganite oxide with a picosecond response time, which was due to a combination mechanism of photoinduced carriers and Seebeck effect [7–9].

In this work, to improve the photosensitivity of manganite films and meet the needs of oil and gas optical engineering, we focused on load-resistance- (R_S-) and bias-voltage- (V_b-) tunable lateral photovoltages of $La_{2/3}Ca_{1/3}MnO_3$ (LCMO) films grown on miscut $LaSrAlO_4$ (LSAO) substrates with 10° tilted to [001] direction of LSAO. The laser-induced voltage (LIV) depended strongly on V_b and R_S. Under an irradiation of 248 nm ultraviolet laser, when V_b is changed from 30 to −30 V, the LIV peak sensitivity can be tuned from −10.8 to 12.5 mV/mJ and from −52.1 to 62.5 mV/mJ at R_S = 10 and 72 Ω, respectively.

2. Experimental

A LCMO (120 nm) thin film was deposited by facing-target sputtering technique on the LSAO substrate cut along the (001) surface with an intentional 10° vicinal angle toward the [010] direction [10, 11]. The substrate temperature was kept at 680°C with the oxygen pressure of 30 mTorr during deposition. After the deposition, the vacuum chamber was immediately backfilled with 1 atm oxygen. The LCMO film was then cooled to room temperature with the substrate heater power cutoff.

Figure 1 shows the schematic circuit of the photoresponse measurement. Before the measurement, the sample was carefully cleaned using alcohol and acetone. Two colloidal silver electrodes of 1 mm × 2.5 mm area were prepared on LCMO surface. Compex 50 excimer-pulsed laser was used as the light source, operating at a wavelength of 248 nm with 20 ns duration at a repetition rate of 1 Hz. The on-sample

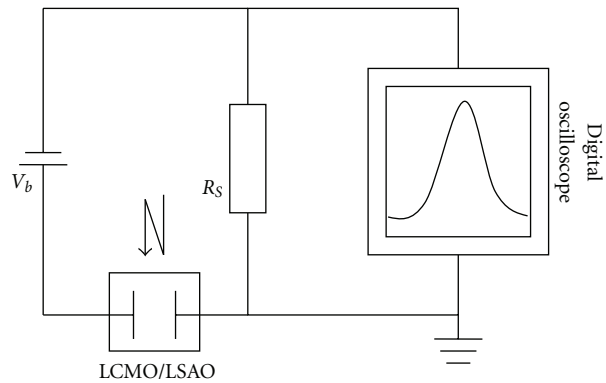

Figure 1: The schematic circuit of the sample measurement.

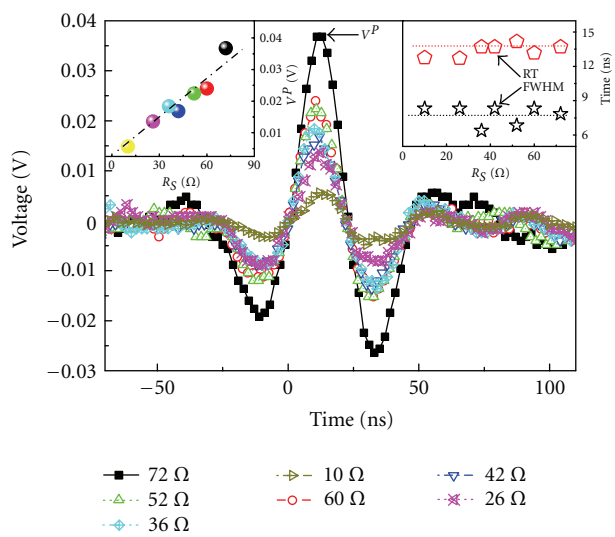

Figure 2: Waveforms for different load resistance R_S at $V_b = 0$ V under the 248 nm laser illumination. The left inset shows the dependence of V^P on R_S. The right inset displays the RT and FWHM as functions of R_S.

laser pulse energy is 2.88 mJ. The waveforms were recorded by a sampling oscilloscope with an input impedance of 1 MΩ. All the measurements were carried out at room temperature.

3. Results and Discussion

Figure 2 shows a typical voltage transient of LCMO film under the 248 nm laser irradiation without bias (V_b = 0 V). The rise time (RT) and full width at half-maximum (FWHM) are independent of R_S and 7 ns and 13 ns, respectively. As reviewed in the left inset of Figure 2, the peak voltage signal V^P has a linear relationship with the R_S from 10 to 72 Ω.

The laser-induced voltage waveform is plotted in Figures 3(a) and 3(b) as a function of time, and the photovoltage peak value V^P increases monotonously from −0.15 to 0.18 V and from −0.031 to 0.036 V with V_b from 30 to −30 V at R_S = 72 and 10 Ω. Figure 3(c) reviews V^P as a function of applied bias voltage V_b, which depended linearly on V_b and showed no saturation for selected R_S. In addition, V^P is also very sensitive to the load resistance R_S and shows a higher value for a larger R_S. As shown in Figure 3(d), the10–90% rise time RT of the photovoltaic signals nearly keeps constant with varying R_S, while the response speed is faster for the lower bias and the RT difference between V_b = 0 and 30 V is about 10 ns.

Figure 4 summarizes the spatial distribution of the V^P as a function of R_S and V_b. $|V^P|$ shows a higher value for a larger V_b while a lower value for a smaller V_b and increases with increasing load resistance R_S. The result indicates the potential possibility to improve the photovoltage sensitivity by introducing the load resistance and applying bias voltage.

Since the photon energy of 248 nm wavelength (4.86 eV) is above the bandgap of LCMO (∼1.2 eV), electron-hole pairs

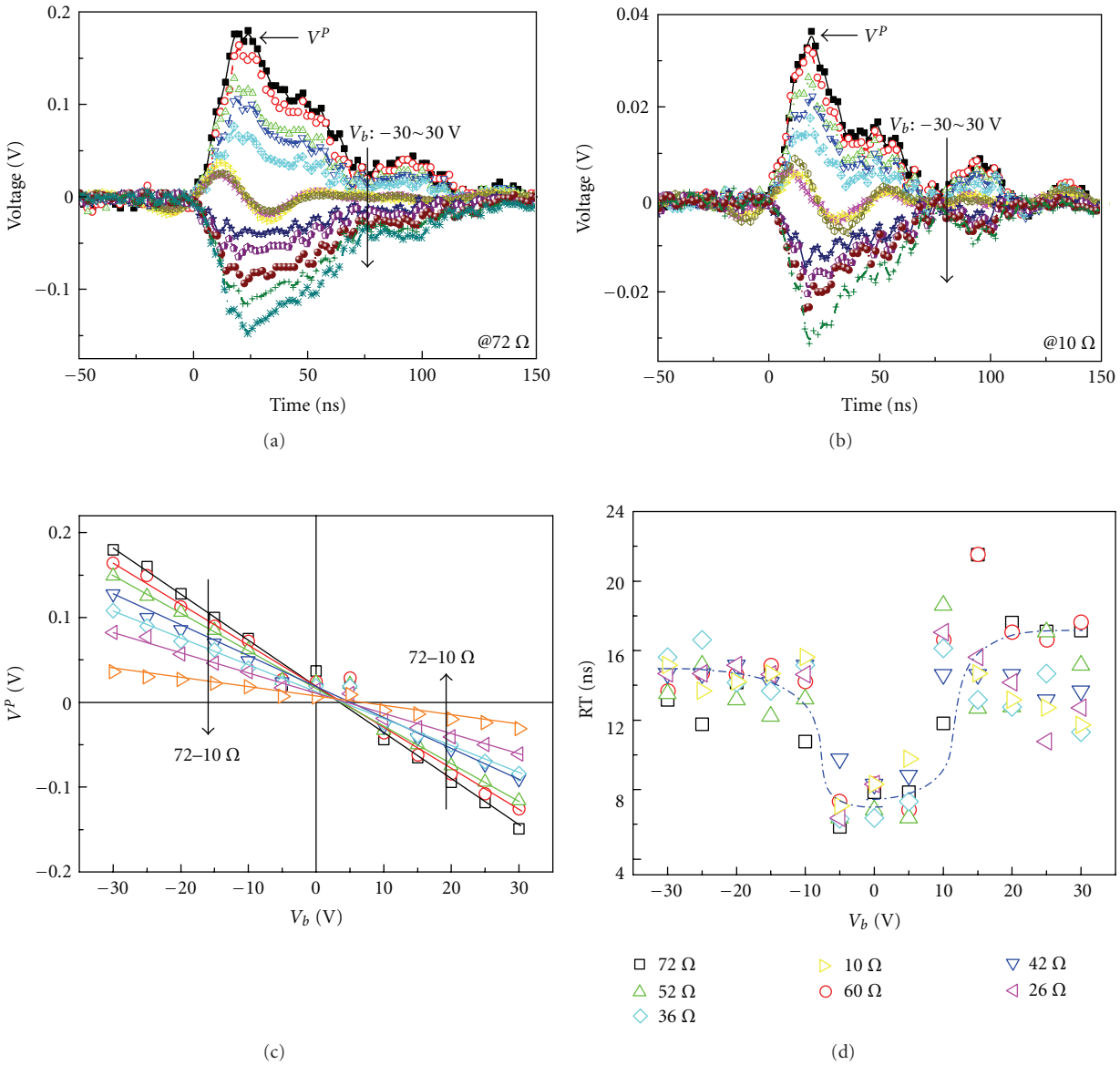

Figure 3: Photovoltage as a function of time with (a) $R_S = 72\,\Omega$ and (b) $R_S = 10\,\Omega$ under 248 nm laser pulses at different bias voltage V_b. (c) V^P and (d) rise time RT as a function of V_b.

are generated in the LCMO film. In our case, the laser we used is a 248 nm KrF excite laser beam in duration of 20 ns, so the amount of laser-induced carriers should be comparable with or even much larger than that of the majority carriers in the LCMO; on the other hand, there exists no built-in field which exists in the p-n junction to separate holes and electrons. Therefore, both the electrons and holes play an important role in the photovoltaic. Under the external bias, the carriers are sped up and the photoresponse is enhanced.

From the basic laws of circuit networks, the readout voltage V_S from the oscilloscope can be calculated from $V_S = (V_b - V_0)R_S/(R_S + R_0)$, where V_0 is the voltage signal generated in the sample and R_0 is the sample impedance. In our case, the load resistance is small and $R_S \ll R_0$. Thus, V_S can be presented as $V_S \approx (V_b - V_0)R_S/R_0 \propto R_S$ as shown in Figures 2 and 4.

4. Conclusions

In summary, the bias and load resistance-dependent photovoltaic effects in LCMO thin film grown on miscut LSAO were studied systematically. With the increase in V_b and R_S, the peak photovoltage signals increase monotonically and a maximum of 0.18 V was achieved at $R_S = 72\,\Omega$, $V_b = 30$ V. The experimental results showed that increasing V_b and R_S is an effective method for improving the photovoltage sensitivity in manganite, suggesting the potential for optoelectronic detection applications.

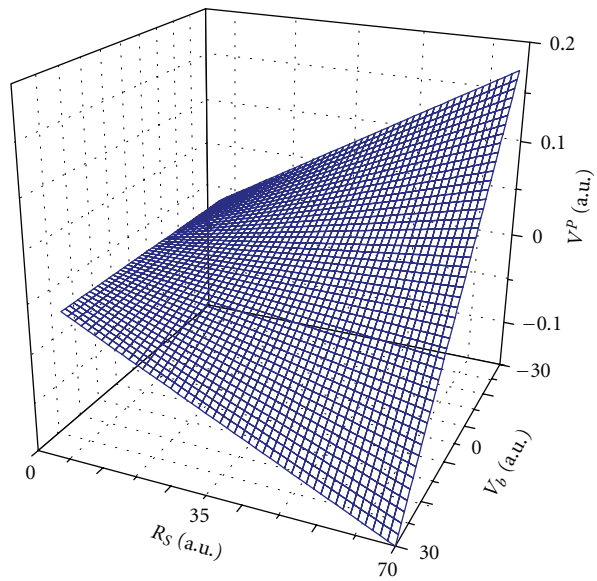

Figure 4: Three-dimensional plot for V^P as a function of R_S and V_b.

Acknowledgments

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