Photoinduced resistivity changes in $Bi_{0.4}Ca_{0.6}MnO_3$ thin films

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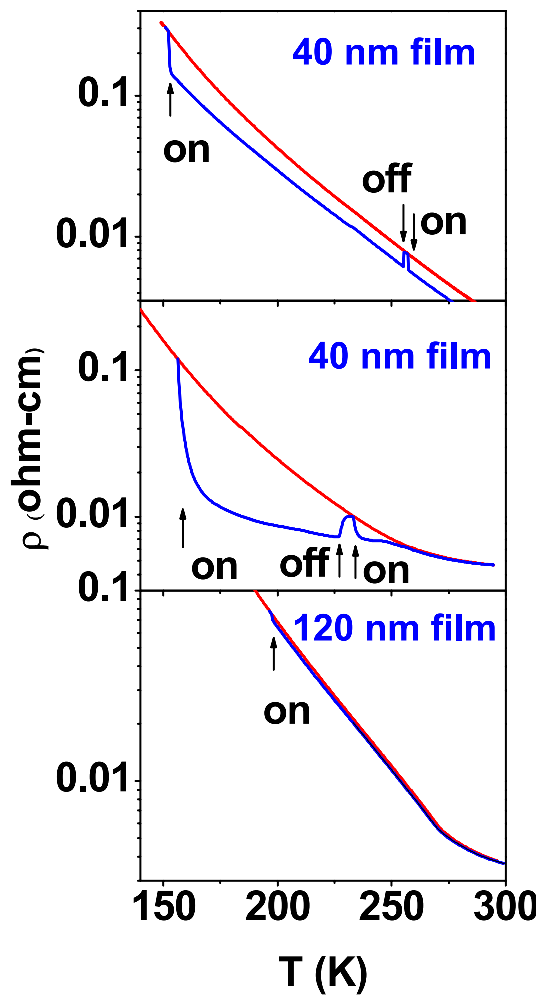
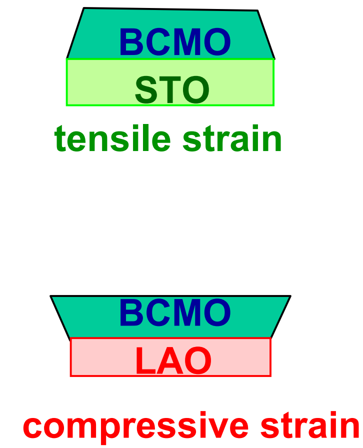
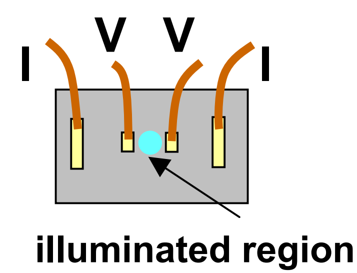
A photoinduced insulator to metal transition in manganese oxides is especially interesting from the point of view of creating photonic band-gap materials. The goal of this work is to create a charge-ordered material in thin film form, which exhibits a strong photoinduced effect.

We have studied the growth of $Bi_{0.4}Ca_{0.6}MnO_3$ thin films utilizing Pulsed Laser Deposition and achieved charge-ordering near room temperature for the first time. We observed large photoinduced resistivity changes in these films associated with melting of the charge ordering by visible light with wavelength around 500 nm (Fig. 1). Substrate-induced strain makes the charge ordering less stable and more susceptible to the photo-induced effect. Thinner films grown on different substrates exhibit a larger drop in resistivity under illumination than do thicker films. The largest photoinduced resistivity changes were observed for thin, 40 nm, films grown under small compressive strain (on $LaAlO_3$ (LAO)). The lifetime of the photoinduced low-resistance state is on the order of half a minute and increases with intensity. The photoinduced resistivity changes in thin films of $Bi_{0.4}Ca_{0.6}MnO_3$ make this material in this form very promising for photonic device applications. A paper based on this work was submitted to Applied Physics Letters.







experimental current and voltage contact configuration

Fig. 1. Photoinduced resistivity changes for $Bi_{0.4}Ca_{0.6}MnO_3$ thin films with (blue) and without (red) illumination. Arrows indicate the temperatures at which laser light was switched on or off.

Doped rare-earth manganites $R_{1-x}A_xMnO_3$ (R being a trivalent rare earth and A being a divalent alkaline-earth ion) exhibit a large diversity in electronic, magnetic, and orbital states . Application of modest external fields may drastically modify the state of such materials (especially of charge-ordered manganites), e. g., induce an insulator to metal transition. One can anticipate that a high refractive index contrast between the photoinduced conducting and insulating phases of charge-ordered manganites would be sufficient for development of a photonic crystal material, which allow control of dispersion and propagation of light. Since visible light penetrates into the bulk of this material only to a depth of about 300 nm, thin films of $Bi_{1-x}Ca_xMnO_3$ with charge ordering at room temperature are necessary for photonics applications.

The main results of this work is the first preparation of charge-ordered $Bi_{0.4}Ca_{0.6}MnO_3$ thin films with charge-ordering temperature near room temperature, and observation of large photoinduced resistivity changes in these films. This development became possible due to the key role of strain on the photosensitivity of thin $Bi_{0.4}Ca_{0.6}MnO_3$ films. It opens real possibilities for photonics device applications of these materials. Light-induced resistivity changes in $Bi_{0.4}Ca_{0.6}MnO_3$ thin films are shown in Fig. 1. In order to study the nature of photoinduced changes for future applications it is important to investigate this phenomenon in wide temperature range. The largest photoinduced effect was observed for the 40 nm film grown on LAO. When this film was illuminated, its resistivity decreased by about one order of magnitude, almost returning to the value of resistivity for temperatures above the charge ordering transition. This photoinduced change persist up to the charge ordering temperature (256 K). This indicates that the observed photoinduced resistivity change is associated with melting of the charge ordering. Therefore, we have locally induced a metallic region, which has different reflectivity. Another interesting feature of the observed photoinduced resistivity changes in the 40 nm $Bi_{0.4}Ca_{0.6}MnO_3$ thin film on LAO is the relatively long lifetime of the photoinduced low-resistance state. The lifetime of the photoinduced low-resistance state (on the order of half a minute) is increasing with the increase in intensity of the light, which is promising for photonic device applications. This increase in the relaxation time with intensity gives us reason to expect a permanent (more than one hour) photoinduced optical reflectivity changes for light of higher power density.

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Education:

Towson University is an undergraduate institution with strong emphases on the undergraduate research. Six undergraduate students (Luis Aldaco, Robert Kennedy, Bryce Taylor, Euming Kong, Luanje Tifang, Alozie Nwoko) were involved in this research. International student from Cameroon Luanje Tifang had an opportunity to participate in assembling the experimental set-up. Luis Aldaco and Bryce Taylor presented the results of their research at the Student Research and Scholarship Expo and College of Science and Mathematics Honors Convocation, Towson University (2004)

Outreach:

The PI participated as a mentor scientist for a high school student Amber Porter in the Academy for Applied Science Intern Program (three week program, Summer 2004).

High school intern Amber Porter is conducting measurements.