Persistent Optically Induced Magnetism in Oxygen-Deficient Strontium Titanate

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Introduction

Strontium titanate ($SrTiO_3$, or STO) is a foundational material in the emerging field of complex oxide electronics. While its electronic and optical properties have been studied for decades, STO has recently become a renewed materials research focus catalyzed in part by the discovery of *magnetism* and *superconductivity* at interfaces between STO and other oxides (eg, LAO/STO). The formation and distribution of oxygen vacancies is believed to play an essential but as-yet-incompletely understood role in these effects. Moreover, recent signatures of the Kondo effect and magnetization in gated bulk STO have further galvanized interest in the emergent properties of this nominally nonmagnetic material.

Experimental

To explore the relationship between oxygen vacancies (V_O) and magnetism in STO, we prepared a series of slightly oxygen-deficient $SrTiO_{3-\delta}$ single crystal samples by annealing (reducing) nominally pure commercial STO substrates in ultra-high vacuum at varying temperatures. Isolated V_O in STO are shallow donors: if every V_O donates one to two electrons to the conduction band, the total V_O concentration can be approximately inferred by measuring the electron density *n*. Here, *n* ranged from $3x10^{12}$ to $8x10^{17}$/cc. To probe magnetism in these samples we use magnetic circular dichroism (MCD) spectroscopy, wherein small differences between the transmission of right- and left-circularly polarized (RCP/LCP) probe light are sensitively measured (see Figure 1). Non-zero MCD signals typically imply the presence of broken time-reversal symmetry (*e.g.*, magnetism). The samples could also be weakly illuminated with a separate source of wavelength-tunable, polarization-controlled pump light.

We observe an *optically induced* and *persistent* magnetization in oxygen-deficient $SrTiO_{3-\delta}$. This zero-field magnetization appears below ~18K, persists for *hours* below 10K, and is tunable via the polarization and wavelength of sub-bandgap (400-500nm) pump light. These effects occur *only* in oxygen-deficient samples, revealing the detailed interplay between magnetism, lattice defects, and light in an archetypal oxide material.

Acknowlegment

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References

[1] W. D. Rice et al, *submitted*.

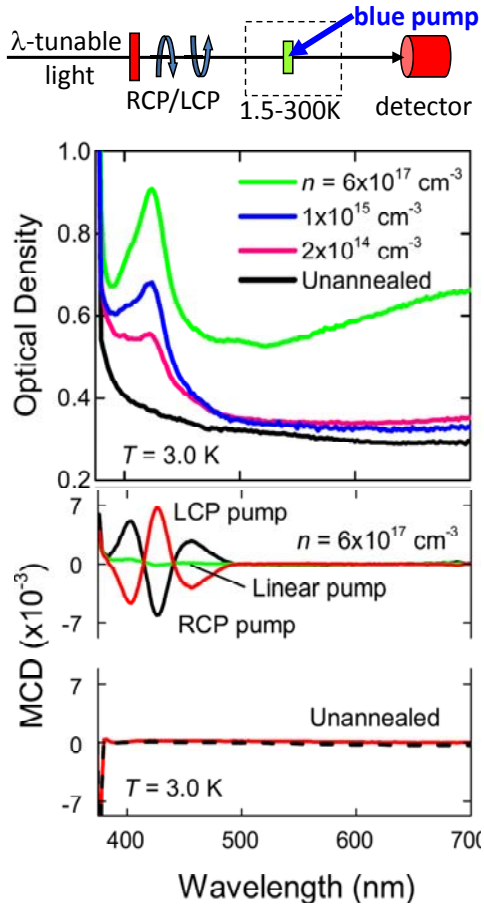

Fig. 1 The MCD setup. Optical absorption and MCD at B=0 from $SrTiO_{3-\delta}$ with varying V_O density. Non-zero MCD signals indicate a net magnetization.

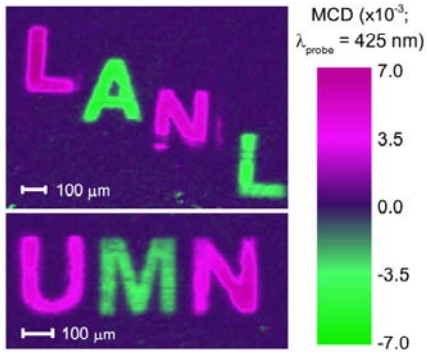

Fig. 2 An image of optically-written and optically-detected magnetic patterns in $SrTiO_{3-\delta}$. The magnetization direction was reversed for each letter.