Defining insulating regions on TiO_2 thin films by laser heating

S.E. Ahmed,[1,2] J.R. Ritter,[2] M.D. McCluskey[1,2,3 +]

[1] Materials Science Program, Washington State University, Pullman, WA, USA 99164

[2] Dept. of Physics and Astronomy, Washington State University, Pullman, WA, USA 99164

[3] Klar Scientific, 1615 NE Eastgate Blvd., Unit G, Ste. 3E, Pullman, WA, USA 99163

Optically defining conducting and insulating regions on an oxide thin film could provide a means for writing and rewriting transparent electronic circuits. Titania (TiO_2) films are straightforward to deposit and exhibit *n*-type conductivity that depends strongly on the concentration of oxygen vacancies, which act as shallow donors [1,2]. Heating in a reducing atmosphere, such as vacuum or hydrogen, increases the density of oxygen donors and hence the conductivity [3]. Conversely, heating in an oxygen atmosphere reduces the oxygen vacancy concentration and makes the sample insulating. While electrons in the rutile phase are small polarons, those in anatase TiO_2 behave as free electrons [4]. This property makes the anatase structure preferable for applications requiring high electrical conductivity.

In the present work, 300 nm thick anatase TiO_2 films were sputtered on fused silica substrates. Heating under a rough vacuum (30 mTorr) produced conducting films with free-carrier absorption in the visible and IR. A green laser (532 nm wavelength, 1-5 W power) was then focused on regions of the sample, in the open air. Localized laser heating resulted in a 7 order-of-magnitude increase in resistance, from 10 kΩ to >100 GΩ. The heated area became transparent due to the loss of free-carrier absorption (Fig. 1). Scanning electron microscopy (SEM, Fig. 2) and optical transmission spectroscopy indicate that laser heating does not degrade the films. The process is reversible – conductivity is restored after annealing in vacuum again. The effect of interface heat conduction will be discussed.

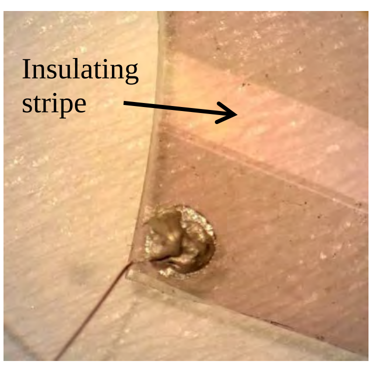

Figure 1. Sample with a laser annealed stripe (~1.5 mm wide) and pressed In contact.

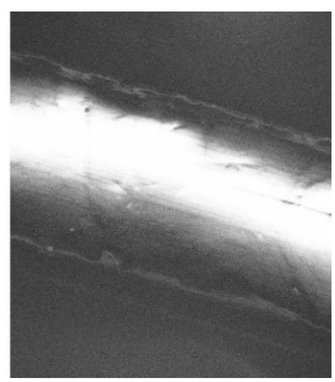

Figure 2. SEM image of the insulating stripe; the bright region is due to electrical charging.

[1] G. Mattioli, P. Alippi, F. Filippone, R. Caminiti, and A.A. Bonapasta, J. Phys. Chem. C **114**, 21694 (2010).
[2] P. Deák, B. Aradi, T. Frauenheim, Phys. Rev. B **86**, 195206 (2012).
[3] D.C Cronemeyer, Phys. Rev. **87**, 876 (1952).
[4] L. Forro, O. Chauvet, D. Emin, L. Zuppiroli, H. Berger, and F. Lévy, J. Appl. Phys. **75**, 633 (1993).

[+] Author for correspondence: mattmcc@wsu.edu