A Ferroelectric Field Effect-Driven Transition from Semiconducting to Metallic Behavior Observed by Scanning Tunneling Spectroscopy

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A scanning tunneling microscope (STM) was used to investigate ferroelectric polarization effects in all-perovskite field effect devices. The samples grown by off-axis radio-frequency magnetron sputtering were composed of a single crystalline ferroelectric film of $Pb(Zr_{0.2}Ti_{0.8})O_3$ (PZT) deposited on a conducting gate electrode substrate and covered with an ultra-thin highly resistive channel of $Sr(Ru_{0.37}Ti_{0.63})O_3$ (SRTO). STM topography investigations of the SRTO channel revealed smooth surfaces with a corrugation of $\sim$5Å rms over $2\mu m \times 2\mu m$ areas as shown in figure 1a. Scanning tunneling spectroscopy (STS) studies of the SRTO electrode current-voltage (IV) characteristics as a function of the two PZT polarization states evidenced a transition from semiconducting to metallic behavior as shown in figure 1b. Taking advantage of this phenomenon, we demonstrated the ability to use the STM to write single ferroelectric domains using pulses. The reading of the domains was performed by current imaging tunneling spectroscopy (CITS), i.e. by recording locally the current contrast at a suitable bias (dotted line in figure 1b). An example of ferroelectric domain imaging using CITS is shown in figure 1c. The written dot presents a uniform metallic IV characteristic, whereas the surroundings show a semiconducting behavior. A trace across the domain shown in figure 1d allowed to measure its size, which is $\sim$450 long and $\sim$300nm wide. Using the STM/STS technique described here, we were able to write nanoscopic domains with a size reaching 20nm.

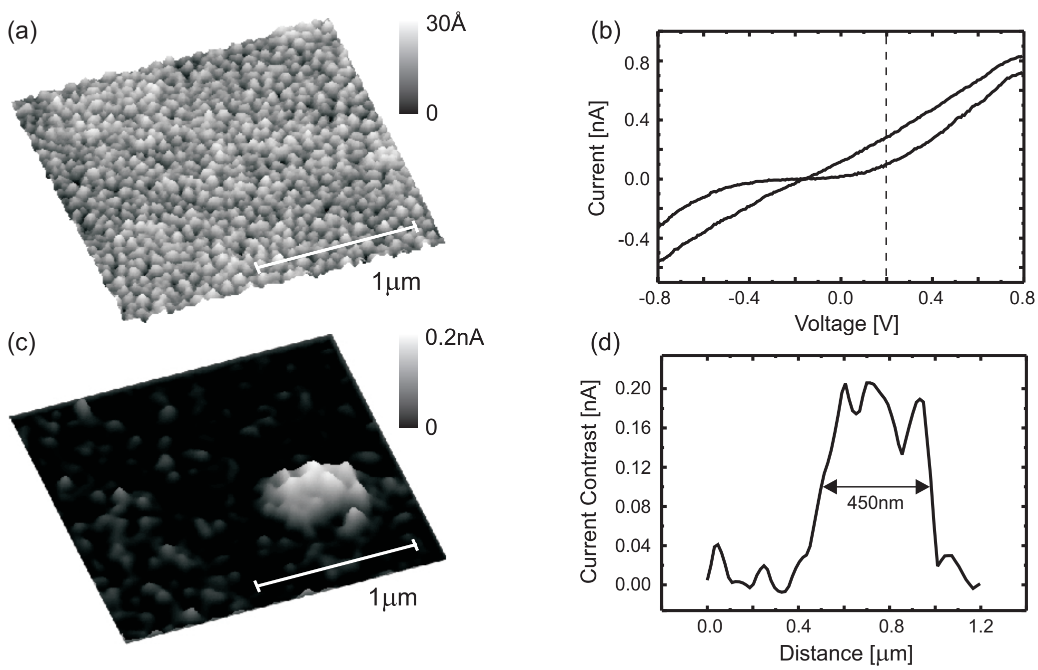

Figure 1: Investigation of ferroelectric domains using STM/STS. Shown left (a) is the STM topography image (V_t = 1V) of the SRTO surface recorded simultaneously with a current map (c) (CITS, V_{image} = 0.2V), and (b) is the comparison of the semiconducting and metallic IV characteristics outside and inside the written domain. The dotted line indicates V_{image}. The size of the domain is $\sim$300nm wide and $\sim$450nm long as shown in the bottom right (d) by a trace across the dot.