Electrostatic Control of the Evolution from Superconductor to Insulator in Ultrathin Films of Yttrium Barium Copper Oxide

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The electrical transport properties of ultrathin $YBa_2Cu_3O_{7-x}$ films have been modified using an electric double layer transistor (EDLT) configuration employing the ionic liquid, DEMEM-TFSI. The films were grown on $SrTiO_3$ substrates using high pressure oxygen sputtering. A clear evolution from superconductor to insulator was observed in nominally seven unit cell thick films. Using a finite size scaling analysis, curves of resistance versus temperature, $R(T)$, over the temperature range from 6K to 22K were found to collapse onto a single scaling function, which suggests the presence of a quantum critical point. However the scaling failed at the lowest temperatures suggesting the presence of an additional phase between the superconducting and insulating regimes similar to that found in the superconductor-insulator transition of granular superconductors. A striking feature of the data is the similarity between the phase diagram and the bulk phase diagram. This is surprising considering that the active layer of the film is the order of one or two unit cells and that there are high electric fields in the double layer of the EDLT. This work was supported by the National Science Foundation under grant NSF/DMR-0709584. JGB thanks the Spanish Ministry of Education for financial support through the National Program of Mobility of Human Resources (2008-2011).