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Article

Mapping of Structural Changes Induced by X-ray Nanopatterning via Nano-X-ray Diffraction and Corresponding Electrical Effects

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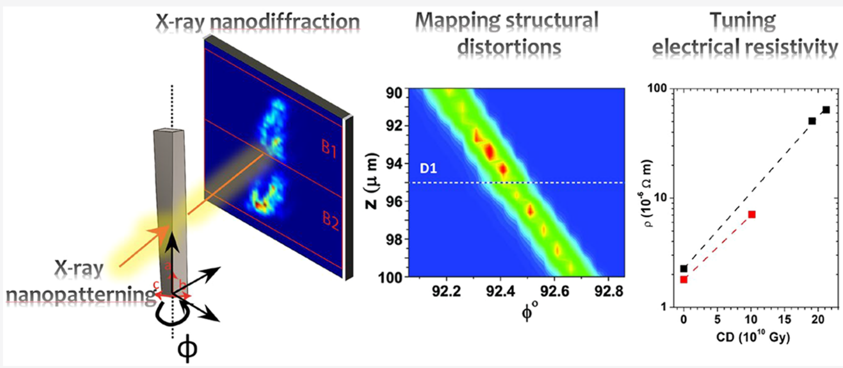

ABSTRACT: We have investigated the modifications induced in high-T_c superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi-2212) single crystals by irradiation with an X-ray nanobeam 250 × 250 nm^2 in size with E = 14.85 keV and a time-averaged photon flux $\Phi_0 = 7.53 \times 10^8$ ph s^{-1}. Crystals were mounted onto amorphous substrates with electrical contacts to allow for both X-ray diffraction (XRD) and electrical measurements on the same sample. Changes in the domain structure were monitored via space-resolved nano-XRD mapping, whereas electrical properties were measured off-line at different levels of irradiation dose. The results show that irradiation induces both an increase of the mosaicity spread and a localized release of the mechanical stress of the crystals. This implies a transient local change of mechanical properties that could be due to thermal fatigue or nonthermal melting. Analysis of the electrical properties of the irradiated regions indicates a strong underdoping effect by the nanobeam and an exponential increase of the normal-state resistivity with the irradiation dose, according to the average rate $\alpha = (1.48 \pm 0.12) \times 10^{-11}$ Gy^{-1}. These results represent an important step toward the full development of the X-ray nanopatterning technique.

1. INTRODUCTION

In the field of electronics based on complementary metal oxide semiconductor (CMOS) technology, during the past few decades the efforts to keep the pace of Moore's law have implied a general trend toward miniaturization of the transistor components in order to achieve lower power consumption and higher integration density. However, it is apparent that when approaching the length scale of solid-state interatomic distances many issues are expected to arise. For instance, larger impedances and fluctuations can be predicted, and this is the reason why the 10 nm technological node has seen the gradual use of germanium and III−V compounds instead of pure silicon for the transistor channels, because of their higher mobility.[1]

On the other hand, from the point of view of the patterning techniques, this trend has naturally pointed toward the use of shorter and shorter radiation wavelengths λ for the photolithographic processes in order to achieve higher and higher resolutions R, according to the Rayleigh criterion $R = k\lambda/NA$. Unfortunately, this route has encountered major problems concerning the power of the radiation sources, the requirements for mask contrast and alignment, and about the resist resolution. As an example, in the case of $\lambda \lesssim 10$ nm (i.e., in the soft X-ray regime), a proximity X-ray lithography technique very similar to ordinary optical photolithography has been tested,[2] but the need for very tight control over the mask−substrate separation, mask deformation problems, and sensitivity to vibrations during the masking process have prevented it from being adopted for mass production. Another example is represented by the electron beam lithography (EBL), which routinely achieves very good resolutions due to

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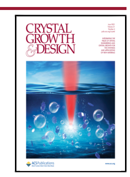

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