# Strain-induced inhomogeneity of the superconducting state in strongly underdoped $La_{2-x}Sr_xCuO_4$ thin films

I. Zajcewa[1,*], M. Chrobak[2,3], I. Abaloszewa[1], M. Ożga[1], P. Gierłowski[1], M. Talacko[4], M. Španková[4], Š. Chromik[4], and Marta Z. Cieplak[1]

[1]Institute of Physics, Polish Academy of Sciences, Lotników 32/46, 02-668 Warsaw, Poland
[2]Faculty of Physics and Applied Computer Science, AGH University of Krakow, Mickiewicza Av.30, 30-059, Krakow, Poland
[3]Academic Centre for Materials and Nanotechnology, AGH University of Krakow, Mickiewicza Av.30, 30-059, Krakow, Poland
[4]Institute of Electrical Engineering SAV, Dúbravská cesta 9, 84104 Bratislava, Slovakia
[*]*zaytseva@ifpan.edu.pl*

In ultrathin epitaxial films, superconductivity can be strengthened by strain caused by lattice mismatch between the film and substrate [1]. This work investigates how film morphology relates to the uniformity of the superconducting (SC) state in underdoped thin films of $La_{2-x}Sr_xCuO_4$ with substrate-induced compressive strain, which increases the superconducting transition temperature ($T_c$).

Surface imaging techniques are used to characterize the film topography, while resistance and magnetoresistance measurements are performed and analyzed using effective medium theory (EMT). The results show that the thinnest films, around 10 nm thick, have the smoothest surfaces, the highest internal strain, and the greatest increase in $T_c$ onset. However, EMT analysis reveals that superconductivity in these films is highly non-uniform, and their magnetoresistance behavior is similar to that of Josephson junction arrays.

As film thickness increases to about 70–110 nm, the surface becomes rougher and the enhancement of $T_c$ is reduced, but the SC state becomes significantly more homogeneous. This indicates that surface smoothness alone does not determine superconducting uniformity. The strong inhomogeneity in the thinnest films is likely due to spatial variations in unrelaxed built-in strain, possibly coupled with uneven carrier distribution. In thicker films, partial relaxation of strain leads to a more uniform superconducting state [2].

**References**

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