Peeling high-T_c superconductivity - one atomic layer at a time

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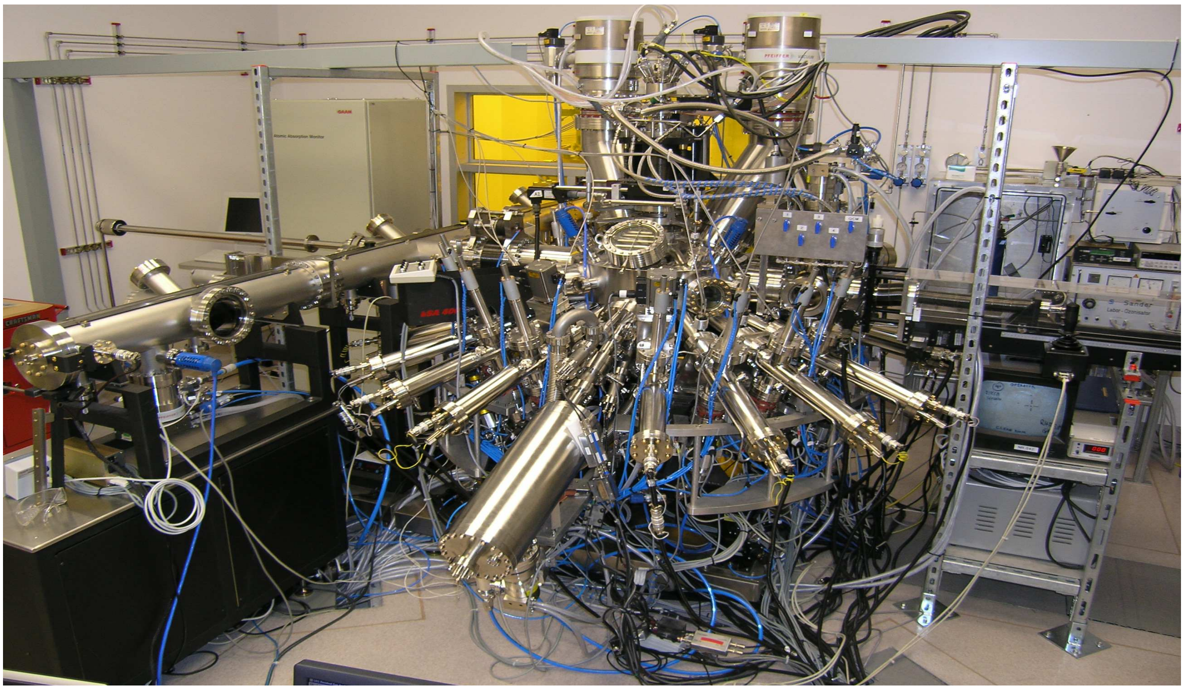
Using a unique molecular beam epitaxy system we synthesize digitally (atomic-layer-by-layer) thin films, multilayers and superlattices of cuprates and other complex oxides. The constituent layers can be just one-unit-cell thick and the interfaces atomically perfect. Various heterostructures are designed to enable novel experiments that probe the basic physics of high-temperature superconductivity (HTS).



In this talk, I will review our recent experiments on such films and superlattices. Some key questions in HTS physics - about the dimensionality, relevant interactions, the roles of (in)homogeneity and fluctuations – are answered as follows.

(i) In an isolated single CuO_2 plane without holes, quantum spin liquid forms.[1]
(ii) In a single CuO_2 plane doped with holes, HTS can occur with T_c even higher than in the bulk.[2]
(iii) HTS cuprate samples can be quite homogeneous (e.g., have a very sharp and uniform SC gap).[3]
(iv) HTS and anti-ferromagnetic phases separate on the scale of 1 Å in space and 1 eV in energy.[1,4]
(v) Pseudo-gap state mixes with the SC state on the 1,000 Å length scale ("Giant Proximity Effect")[5]
(vi) *In-plane* charge excitations are strongly coupled to *out-of-plane* lattice vibrations.[6]
(vii) Local pairs and vortices exist on the insulating side of the S-I quantum phase transition.[7]
(viii) Strong *phase* fluctuations drive the SC transition, but 10-15 K above T_c they fade out.[7]

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[1] Suter *et al*., *PRL* 106, 237003 (2011).
[2] Bozovic *et al*., *PRL* 89, 107001 (2002); Gozar *et al*., *Nature* 455, 782 (2008); Smadici *et al*., *PRL* 102, 107004 (2009), Logvenov *et al*., *Science* 326, 699 (2009), Butko *et al*., *Adv. Mater.* 21, 1 (2009), Zhou *et al*., *PNAS* 107, 8103 (2010).
[3] Abbamonte *et al*., *Science* 297, 581 (2002); Shim *et al*., *PRL* 101, 247004 (2008).
[4] Bozovic *et al*., *Nature* 422, 873 (2003).
[5] Bozovic *et al*., PRL 93, 157002 (2004); Morenzoni *et al*., *Nature Comm.* 2, 272 (2011).
[6] Gedik *et al*., *Science* 316, 425 (2007); Radovic *et al*., *PRB* 77, 092508 (2008)
[7] Sochnikov *et al*., *Nature Nanotech.* 5, 516 (2010); Bilbro *et al*., *Nature Physics* (2011); Bollinger *et al*., *Nature* 472, 458 (2011).