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SUPERLATTICES OF HTS CUPRATES: INVESTIGATIONS OF 2D ULTRATHIN LAYERS AND THE CROSSOVER TO 3D ANISOTROPIC FILMS.

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It has been found that the high temperature superconducting cuprates can be produced in thin film form by a layer by layer growth. This has allowed to produce superlattices of various combinations of these materials. In particular, in the $YBa_2Cu_3O_7$/ $PrBa_2Cu_3O_7$ system superlattices with individual layers as thin as one c-axis lattice parameter have been synthesized. In such materials it is possible to vary both the coupling between the individual layers as well as their thickness in a controlled manner. It is thus possible to study both the ideal 2D behaviour of these materials and the crossover behaviour to thicker films. This text is a short summary of the oral presentation and for more detailed information we refer to the various papers given in the reference list.

The work reported here was carried out on samples produced by sputtering[1,2]. However, multilayers have now been produced by several groups[1-12] using various techniques: sputtering, laser ablation, electron beam evaporation and molecular beam epitaxy and to the extent that the results can be compared the results obtained with the various techniques are largely equivalent. The YBCO/PrBCO multilayers are particularly interesting since PrBCO is an insulator (with a hopping like conductivity at low temperatures). By inserting PrBCO layers between the YBCO layers one can make ultrathin YBCO layers and thus study the properties as the system approaches an ideal 2D system made of a thin film having the thickness of a single c-axis unit cell. It is found that T_c of such a 12Å layer depends on the number of PrBCO layers separating it from the next YBCO layer[2,3,4]. As the PrBCO thickness increases up to about 60Å, T_c decreases and then saturates at a value in the range 10-30K[3,4,6,12]. Thus a double CuO_2 sheet is superconducting. The question whether the T_c reduction is intrinsic to the 2D nature of the ultrathin films or is related to the particular insulator, PrBCO, used in this case, has received considerable theoretical attention recently[13-15] and needs still further experimental efforts to be fully settled. However, it is clear that the thinner the films, the broader the transitions and first efforts to relate this to a possible Kosterlitz-Thouless-Berezinskii transition have been reported[15,- 18].

We have used these multilayers to study the resistive behaviour of the mixed state. Specifically, we have studied the thermally activated behaviour and we have determined the activation energies as a function of the thickness of the individual layers[19, -22]. When the magnetic field is perpendicular to the layers and when the PrBCO thickness is 48Å or more we find that the YBCO layers behave as independent layers and that the activation energy is proportional to the YBCO thickness up to 264Å. This shows that bulk YBCO is a 3D (anisotropic) material and that the vortices have a certain stiffness so that in the very thin YBCO layers the vortex lattice is in the 2D limit. This is further corroborated by the logarithmic field dependence of the activation energies which is consistent with an interpretation of the resistance in terms of thermally activated edge dislocation pairs in the vortex lattice[23] When the magnetic field is parallel to the layers, we observe that there is no field dependence of the activation energy up to a field of the order of H_{c1} of the individual layers. Thus for a multilayer composed of two unit cells of YBCO and 8 unit cells of PrBCO (24Å/96Å) the resistive transition shows no broadening up to 20 a field of tesla[22,24,25].

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