

## On the “Critical Properties and Vortex Matter”

(Response to Roger Woerdenweber’s Comment)

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**Abstract** – The authors of ST-1 note that their model is proposed only for the case of twinned epitaxial YBCO films and is not general. However, it accounts for the experimental observations of González *et al.* and brings insights on the physics of twinned YBCO films by suggesting that the twin boundaries behave as rows of Josephson weak links with energy  $k_B T$  in the critical state.

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Reacting to the contribution we wrote for the News Forum (ST-1, “*Vortex Dynamics at the Transition to the Normal State in  $YBa_2Cu_3O_{7.8}$  Films*” by P. Bernstein, J.F. Hamet, M.T. González and M. Ruibal Acuña), Dr Woerdenweber has sketched his views on flux pinning in superconductors in a comment (ST1-D1, *Critical Properties and Vortex Matter*). In this reply we don’t want to rebut Dr Woerdenweber’s views, that we share for the most part, but to precise how we have addressed the question of vortex dynamics in twinned YBCO films.

The system we have considered was an epitaxial YBCO thin film micro-bridge with no applied external magnetic field, deposited on a (100)  $SrTiO_3$  single crystal. We have studied this system first in the critical state, second at the transition to the normal state.

The determination of the mechanisms that, according to our views, are involved in the vortex dynamics was based on experimental observations reported by various groups :

- 1 The introduction of oxygen in YBCO and the corresponding structural transition from the quadratic to the orthorhombic phase cause twinning. Twinning occurs along the (110) and the  $(1\bar{1}0)$  directions [1].
- 2 The twin boundaries (TBs) are the first areas of YBCO single crystals penetrated by the magnetic flux [2].
- 3 The TBs stretch over several micrometers and the TBs planes can act as grooves channeling the vortices. [3,4,5] .
- 4 Vortex pinning occurs mainly at the TBs intersections [1].
- 5 The vortex motion is thermally activated.

These observations suggest that when no magnetic field is applied, vortices are at first generated along the TBs (by the bias current). They can move along the TBs, if the bias current is large enough, since whatever the current direction, the angle between this direction and one of the TBs directions is at least equal to  $45^\circ$ . As a result, we don’t have to consider the highly complex picture sketched by Dr Woerdenweber, but a much simpler situation. Of course, proceeding this way we trade off a general understanding of the vortex dynamics in YBCO for simplicity. The domain of validity of our model is restricted to the dynamics of vortices moving along the TBs of films. As a consequence, the model can’t describe the vortex dynamics if a strong magnetic field is applied, since we expect that the vortices settle in the whole material in this case. In addition, for other reasons, it is not valid at very low temperature. However, in addition to accounting for the experimental observations of

González *et al.* [6] on the transition to the normal state, this model brings unexpected insights on the physics of twinned YBCO films, in particular the suggestion that the twin boundaries behave as rows of Josephson weak links with energy  $k_B T$  in the critical state.

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