Noise Spectral Density and Vortex Velocity in YBCO Thin Film at High Critical Temperature

Abdelhalim HAFID
Laboratory of Superconductors Materials at High Critical Temperature University Ibn Zohr Agadir, Morocco

Ahmed TAOUFIK
Laboratory of Superconductors Materials at High Critical Temperature University Ibn Zohr Agadir, Morocco

Abella BOUAADDI
Laboratory of Superconductors Materials at High Critical Temperature University Ibn Zohr Agadir, Morocco

Hassan Elouaddi
Laboratory of Superconductors Materials at High Critical Temperature University Ibn Zohr Agadir ,Morocco

Mustapha BGHOUR
Laboratory of Superconductors Materials at High Critical Temperature University Ibn Zohr Agadir, Morocco

Habiba El Hamidi
Laboratory of Superconductors Materials at High Critical Temperature University Ibn Zohr Agadir, Morocco

Brahim LMOUDEN
Laboratory of Superconductors Materials at High Critical Temperatue University Ibn Zohr Agadir, Morocco

Ahmed Tirbiyine
Equipe MSISM
Universit´e Cadi Ayyad, Facult´e Poly-Disciplinaire, B. P. 4162 Safi, Morocco

Abdelhakim NAFIDI
Laboratory of Condensed Matter Physics and Nanomaterials for Renewable Energy, - Ibn Zohr University, morocco.

ABSTRACT
We have studied the voltage noise V_{noise} and the voltage noise spectral density S_v of YBaCuO superconductor in the regime of high magnetic field. Our measurements were taken for different temperatures covering the vortex-glass and vortex-liquid transition which represents the T_g temperature glass, The voltage noise spectral density $S_v(f, T, H)$ as a function of frequency exhibits 1/f behaviour according to a lorentzian shape $A((1+ \pi f/f_0)^B)^C$, where the constants A, f_0, B and C are all determined, and temperature has a strong influence. in addition, we study the variation in the velocity of the vortex as a function of temperature.

Keywords
Superconductors, vortex velocity, YBCO, power spectral density, dynamic of vortex.

1. INTRODUCTION
The scientists have paid a lot of attention to the dynamic of the vortices in order to comprehend to mixed state of HTC superconductors. Since the discovery of those materials in 1986, their investigation becomes the centre of interest of several works. The experimental [1, 2, 3] theoretical [4, 5] investigations show that the vortex matter exhibits diverse properties and a various phase transitions in the mixed state It is obvious that whenever a HTc superconductor carries a transport current, the vortices are induced to move along the sample. Thus, a flux flow dissipation mechanism is generated in the superconductor.

the study of noise in high temperature critical superconductor is an adequate way to search for disorder and dynamics of vortices in such materials [6], also to understand the origins of excess conducting noise [7, 8] . Van gurp and Von Ooijen were the first researchers to use this technique for this purpose [9].

In this work, we are interested with the measurements of the voltage noise spectral density S_v of YBaCuO. The main findings of this search are:

1. The voltage noise spectral density $S_v(f)$ is inversely proportional to the frequency (1/f) according to Lorentzian shape $A((1+ \pi f/f_0)^B)^C$. A, f_0, B and C are determined by fitting for a magnetic field H= 14T and several temperatures covering different states.

2. Temperature glass T_g, represents a point of transition between a high and a weak noise spectral, depending on the motion of vortex [10], and variation of vortex velocity as function as temperature.

2. EXPERIMENTAL PROCEDURE
The studied sample was a high quality single crystal $YBa_2Cu_3O_{7-\delta}$ thin film deposited by the laser ablation method on the surface (100) of a $SrTiO_3$ substrate. In zero magnetic field, the resistance vanished at T_c = 90 K. The c-axis was perpendicular to the surface of the film. Electrodes of measurements were in gold and deposited on the surface of the sample by in situ evaporation. The film thickness and width were 400 nm and 7.53 μm, respectively. The distance between electrodes of measurements was 135 μm. Contact resistances were less than R=1Ω [11].

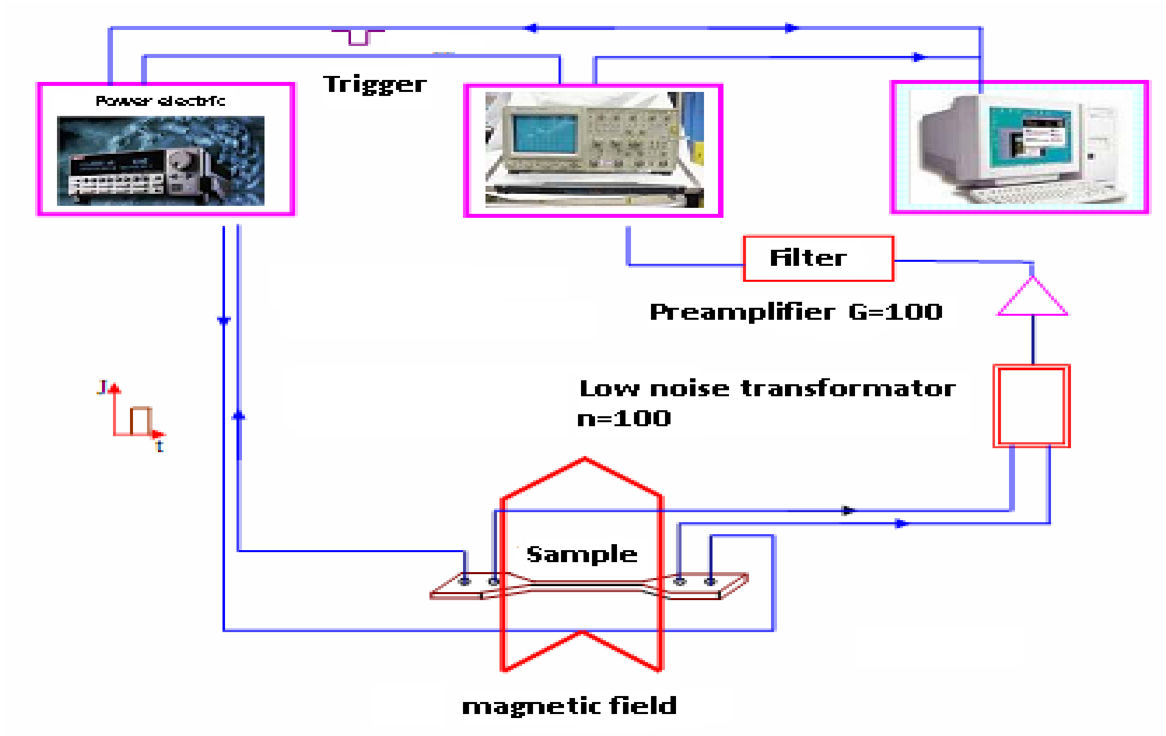


Figure 1: Schematic of measurement principe

In order to rule out distortions of the E-J curve by extensive heating that could be induced by the very high extensive heating that could be induced by the very high dissipation levels employed here, a pulsed current power supply was used with a time duration τ = 10 ms, a waveform repeat time of 2 second, and an average over 64 pulses at the same fixed J, T and H. The microstructure of several of these thin films was studied extensively, using Transmission Electron Microscopy (T.E.M.).These T.E.M. observations together with X-ray Energy Dispersion Spectroscopy (E.D.S.) as well as usual X-ray spectra show that the films are highly homogeneous and have essentially a single YBCO (123) phase.

Transmission electron microscopy (T.E.M.) observations performed on our samples revealed not only the presence of the usual twin boundaries as the major visible defect but also, a set of columnar-like defects. In addition, the sample certainly contains also point defects, in articular oxygen vacancies [13].

3. RESULTS AND DISCUSSION

3.1 The power spectral density $S_V(f)$ in $YBa_2Cu_3O_{7-\delta}$ HTC superconductor.

The voltage noise measurements of the $YBa_2Cu_3O_{7-\delta}$ HTC superconductor were performed for a range of temperature that comprises between 78K and 89K. The sample undergoes an external magnetic field of 14T parallel to *ab* plan, and carries a transport current of 3nA.

In the figure 2, we present an example of the time evolution of the voltage noise V_{noise} (ms) in YBCO superconducting and driving by a current of 3nA for an external magnetic field of B=14T parallel to (ab) plan of the sample for three values of temperature 79 °K , 84 °K and 86.6 °K. We observe that the voltage noise V_{noise} increases when the temperature raises to a temperature T_c; where the V_{noise} reaches the maximal value and where T_c temperature represents the transition from the superconducting state to normal state. Above T_c, V_{noise} decreases and reaches its minimal value.

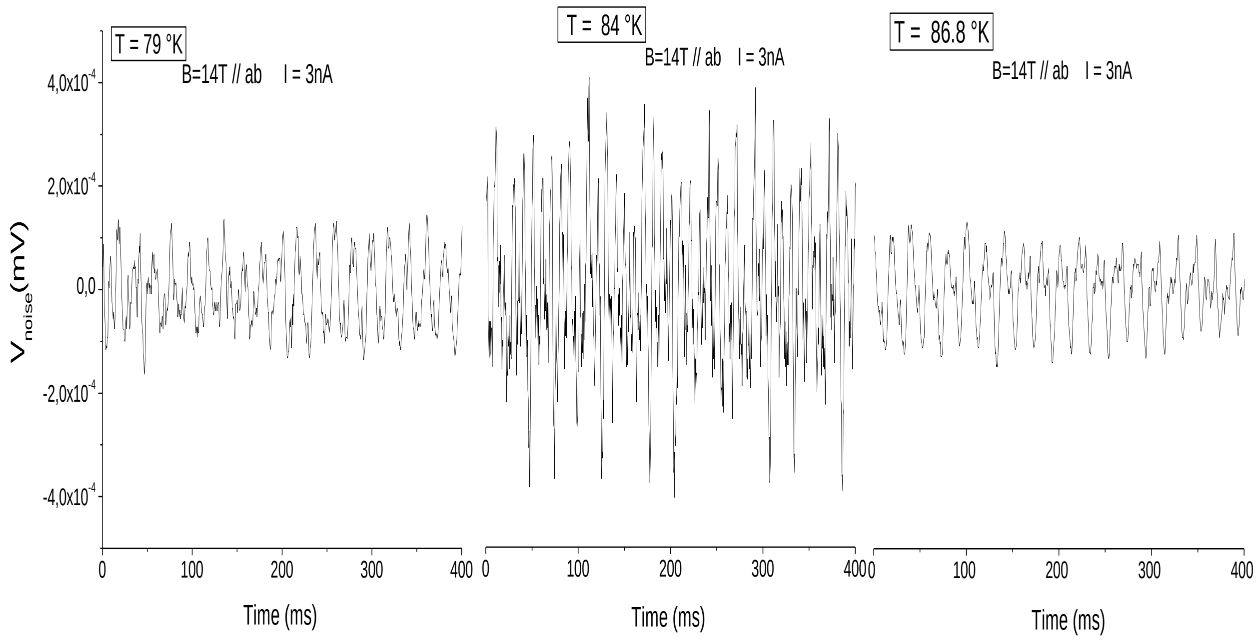
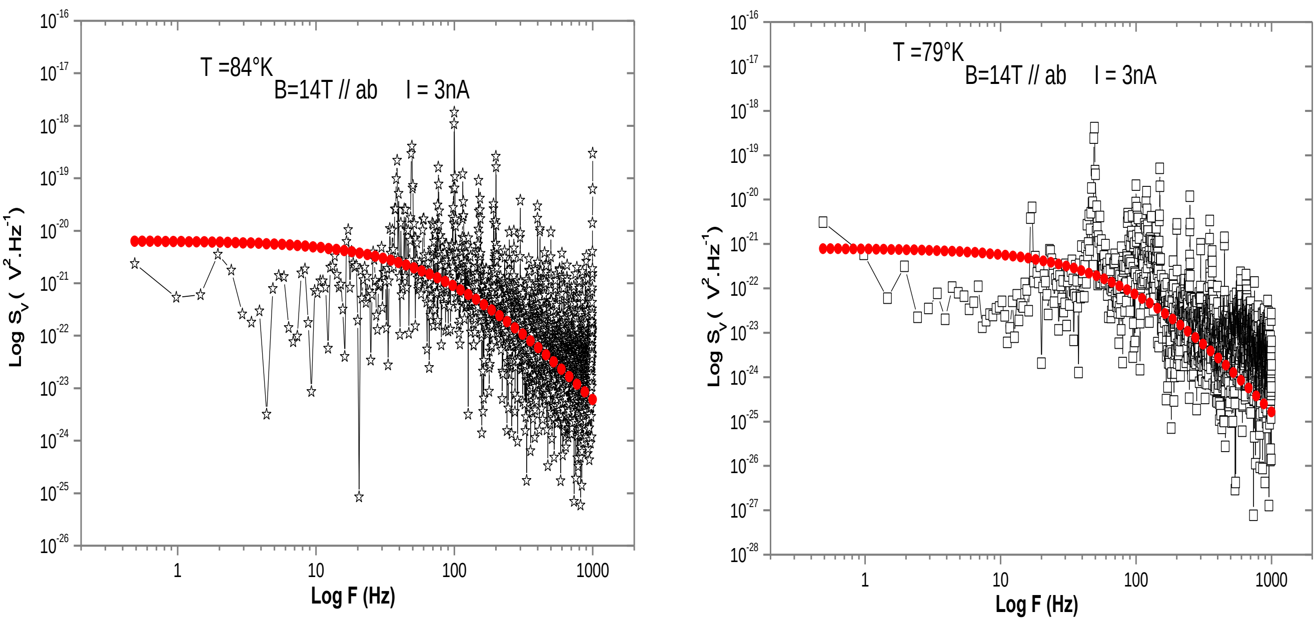


Figure 2. The temporal evolution of voltage noise at 79°K and 84° and 86.8°K for H= 14T parallel to (ab) plan and I= 3nA

In figure 3,we present an example of the voltage noise power spectral density $S_V(f)$ as a function of frequency for an external magnetic field of 14T parallel to ab plan, and carries a transport current of 3nA, the value of temperature is 79K, 84°K and 86.8°K which belongs to the mixed state of the sample.

In this curve, the red line represents the fitting curve and one can conclude that the power spectral density $S_V(f)$ exhibits at high frequencies a $1/f^{\alpha}$ behavior, where α is the exponent that was calculated using the Lorentzian shape $A[(1+\pi f/f_0)^B]^C$



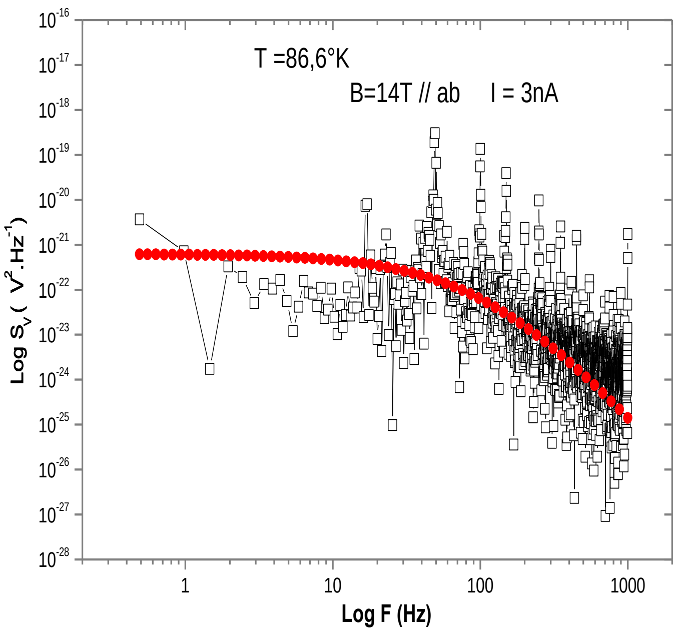


Figure 3. The frequency dependence plotted in Log-Log scale of the voltage noise spectral density $S_v(f)$ for three values of temperature T= 79°K, T=84°K and T= 86.8 °K under a magnetic field H= 14T. The red line represents the fit curve.

We can also see from these curves that there are two different regimes in which $S_v(f)$ exhibits 1/f behavior: the first is from 1Hz to nearly 10Hz, the second is from 10Hz to 1000Hz, for all cases of temperature. By fitting we are determined in *table* I a different constants A, B, C and f_0 of the used function for a magnetic field H= 14T, I= 3nA and for a range of temperature from 79K to 86.8 K with a step of 1K. In *table* I we can observe that the exponent (α = - B*C) for all temperatures is almost equal a '-2'.

Table I. Values of the constants for several temperatures and H= 14T parallel to (ab) plan.

μ_0H= 14T	A	f_0	B	C	B*C
T= 79K	7.9192E-22	333.01469	1.90941	-1.8948	-3,617950068
T= 80K	6.3788E-22	380.99621	2.00067	-1.85447	-3,7101824949
T= 81K	2.9664E-22	381.03553	2.96263	-1.06949	-3,1685031587
T= 82K	4.1506E-22	393.63841	2.77542	-1.001	-2,77819542
T= 83K	9.1506E-22	374.23306	2.13672	-1.13254	-2,4199208688
T= 84K	4.98E-21	399.9924	2.95454	-0.75891	-2,2422299514
T= 85K	1.2413E-21	345.14567	1.78985	-1.25556	-2,247264066
T= 86K	9.2413E-22	366.33378	1.64642	-1.25556	-2,0671790952
T= 86.8K	6.2095E-22	369.00039	1.97489	-1.88608	-3,7248005312
				Average	-2,88624729

The mean value of the determined exponent for a large range of temperature (79 to 87) leads to the value 2.89. Paltiel et al. [14] found in this researches a value of 4, while Eggenhöffner et al. obtained α comprised between 1 and 2 [14] Scola and al. determined that this exponent varies from 2 and 4.5 [15]. For several other works this parameter is calculated to be fairly equal to 2 [16, 17].

Figure 4 shows the variations of noise spectral density S_v in Log scale as function of a range of temperature from 78K to 88.6 °K including T_g with a frequency f = 500 Hz, . We explain that with a variety of pinning sites distributed at the edge of the sample, the main reason is due to the energy dissipation generated by the vortex bundles motion [10]. So, at the $T < T_g$, the pinning force is very important than thermal activation, the vortex bundles are pinned, then the weaker dissipation causes a weaker noise detected. For $T > T_g$ the depinning is governed by thermal activation giving start to motion of vortex bundles, that causes a greet dissipation, and then a strong noise detected**.**

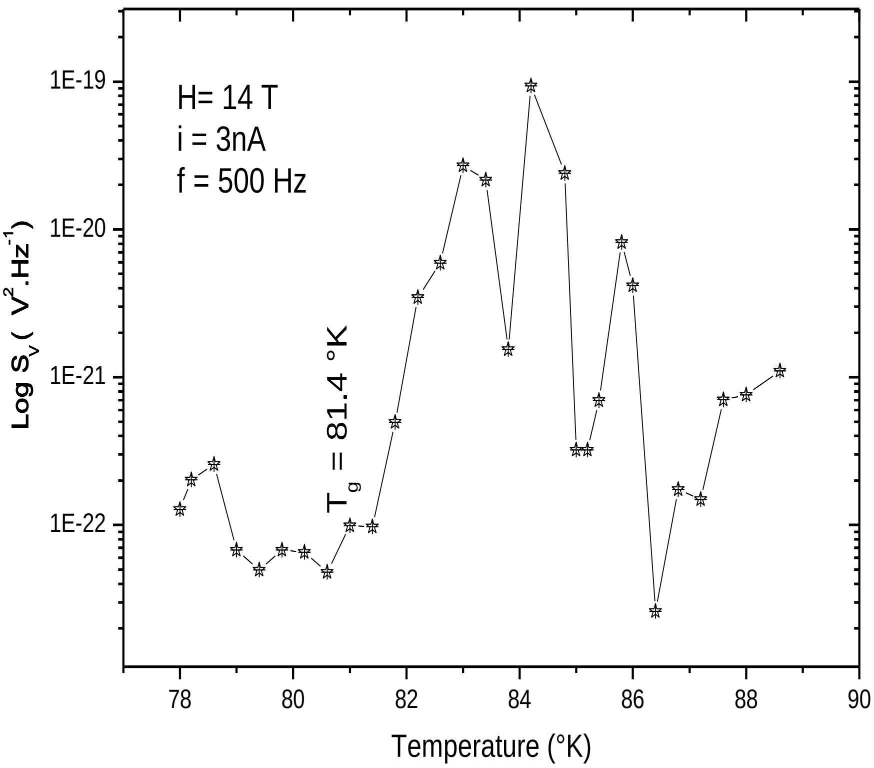


Figure 4. Temperature dependence of the Noise spectral density $S_v(T)$ for f= 500Hz, I= 3nA and H= 14T parallel to (ab) plan.

3.2 Vortex velocity in YBCO thin film.

Figure 5 shows the temperature dependence of the vortex velocity at H=14 T . The velocity is obtained from the measured voltage V via the relation, we recall that the length of our samples is L = 135 µm, the width is l = 7.53 µm, while its thickness is w = 400 nm.

From this curve, it is clear that the vortex velocity remains almost stable until the temperature 81.4 °K, approaching the transition temperature T_g of the vortex glass vortex liquid, the vortex velocity increases to a maximum of 3.75 m/s at a temperature of 83.8 °K, which represents the transition temperature to the normal state. Then it decreases to its initial value.

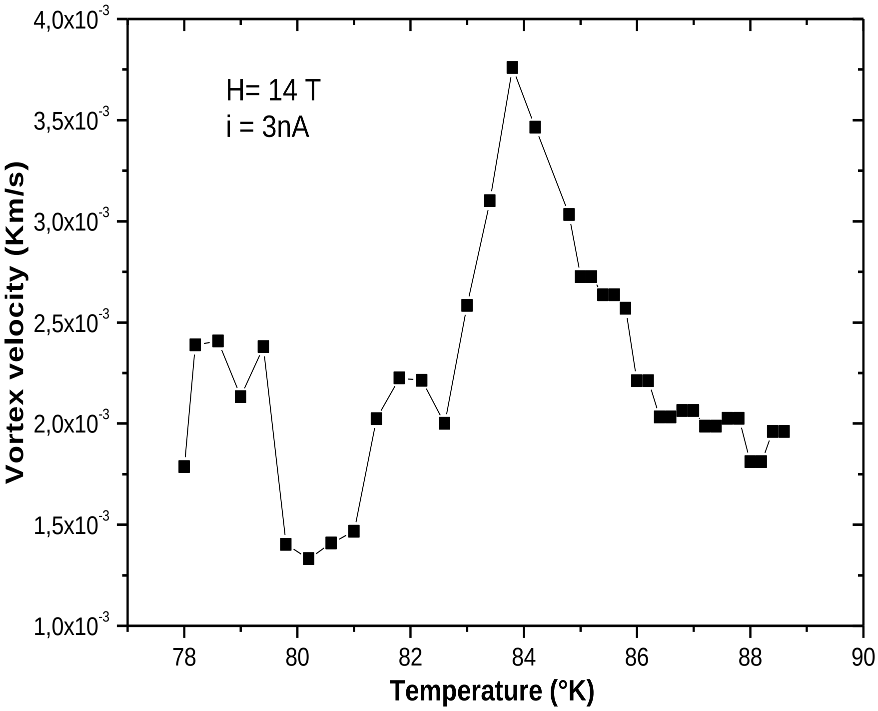


Figure 5. Temperature dependence of the vortex velocity at H=14T and I = 3nA.

4. CONCLUSIONS

In this work a voltage noise power spectral density was studied for the YBaCuO HTC superconductor. Those materials exhibit a $1/f^{\alpha}$ noise. The shape of the noise in our sample is common to many electronic systems even though the noise in those systems is found to be very smaller compared with that of superconductors. The major source of the noise in our sample is supposed to be the vortex fluctuations in the mixed state.

The motion of vortex is a main cause which creates the noise in these materials, so in this research the effect of temperature is strongly observed giving start to vortex motion.

5. REFERENCES

[1] S. Bhattacharya, M.J. Higgins, Physical Review Letters 70, 2617 (1993).

[2] A.C. Marley, M.J. Higgins, S. Bhattacharya, Physical Review Letters 74, 3029 (1995).

[3] M.C. Hellerqvist, D. Ephron, W.R. White, M.R. Beasley, A. Kapitulnik, Physical Review Letters 76, 4022 (1996).

[4] A.E. Koshelev, V.M. Vinokur, Physical ReviewLetters 73, 3580 (1994).

[5] T. Giamarchi, P. Le Doussal, Physical Review Letters 76, 3408 (1996).

[6] J.R. Clem, Physica, Volume 55, 376-385 (1971).

[7] B.W. Ricketts, R. Driver, and H. K. Welsh, Solid State Commun. 67, 133-136 (1988).

[8] L. B. Kiss and P. Svedlindh, Phys. Rev. Lett. 71, 2817-2820 (1993).

[9] D.J. van Ooijen, G.J. van Gurp, Physics Letters.

[10] P. J. M. WÖltgens, C. Dekker, S. W. A. Gielkens, and H. W. de Wijn, Physica C 242, 67-73.

[11] A.Taoufik, thèse d'état, Université Ibnou Zohr, Agadir, 68, (1995).

[12] A.Ramzi, A.Taoufik, S.Senoussi, A. Tirbiyine and A. Abaragh, Physica A 358 (2005) 119.

[13] M. Daeumling, J.M. Seuntjens and D.C. Larbalestier, Nature 346 (1990) 332.

[14] Eggenhö_ner et al., Appl. Phys. Lett. 86, 022504 (2005).

[15] J. Scola, PhD thesis, Université de Caen (2005).

[16] K.E. Bassler, J. Davidsen, M. Paczuski, cond-mat 0110641 v1 (2001).

[17] D. Doenitz, R. Straub, R. Kleiner, D. Koeller, cond-mat 0407733 v1 (2004).