Revista Brasileira de Física, Vol. 21, nº 2, 1991

# Magnetic noise in the disordered system $Ni_{1-x}Mn_x$

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Received August 30, 1990

**Abstract** Magnetic noise measurements of the Barkhausen type in the reentrant spin glass system NiMn are reported for samples of **19, 23** and **25** at% Mn. The first points of a phase diagram for the magnetic noise are proposed and for the sample with 19 at% Mn the autocorrelation functions of the noise and the $V^B_{RMS}$ x H curves at selected temperatures are presented.

## 1. Introduction

Magnetic noise of the Barkhausen type has been studied in classical materials since many years ago. The motivation of these studies was to understand the magnetization processes, in particular the domain wall dynamics. Recently, Senoussi et al[1-3] reported the observation of a domain structure in systems with reentrant spin-glass behaviour. The observations were made in amorphous $(Fe_{78}Mn_{22})_{75}P_{16}B_6Al_9$, $Fe_{90}Zr_{10}$ and crystalline $Ni_{81}Mn_{19}$ alloys using a transmission electron microscope in the Lorentz configuration. They verified that the domain structure appears at $T < T_c$ and remains visible below $T_{fg}$. However, with respect to domain-wall motion, the observations were rather poor and they lead to the suspicion that this motion is viscous[3,4].

The characteristic dynamics of the domain walls in these and analogous systems is an open question. In particular one asks about the effect of the competitive

Work partially supported by CNPq and FINEP

exchange interactions and temperature in the dynamics. Within this context, the use of the Barkhausen noise techniques is an adequate way to elucidate questions of this kind.

The purpose of this work is to suggest the first few points delimiting the regions of occurrence of the Barkhausen noise in the magnetic phase diagram for the system NiMn. This is the only crystalline alloy where the domain structure was observed (for a 19 at.% Mn alloy). The first measurements of the autocorrelation function for the magnetic noise in this peculiar system are presented.

NiMn exhibits reentrant spin glass behaviour after a thermal treatment ensuring disorder, and the known magnetic phase diagram is shown in figure 1 after recompilation of the results from the literature[2,5-13]. One sees that at some points in fig. 1, a large dispersion exists, as for example at 25 at% Mn. This can be attributed to the strong dependence on the thermal history of this system as shown by Schaf et al.[14-15].

As determined by Kouvel et al[9] the tricritical point occurs at x=23.9 atomic percent of Mn. For larger concentrations, the system exhibits a pure spin glass behaviour and for lower x one obtains the peculiar ferro spin glass behaviour. The hysteresis effects observed in this part of the phase diagram are attributed by Kouvel and collaborators[8-12] to a rotational behaviour of the magnetization, while Senoussi and co-workers[1-7] associate these effects to domain wall motion.

Another interesting aspect of this system, as nieasured by Pureur et al[13] in a 22 at% Mn sample, is that the critical exponents for the para-ferromagnetic transition temperature deviate with respect to pure ferromagnets.

In this work samples with the concentrations x=0.19, x=0.23 and x=0.25 were selected for our magnetic noise measurements.

## 2. Experimental

The measuring system is shown in the form of block diagram in figure 2. We can detect Barkhausen jumps greater than $10^{-6}$ e.m.u.. The noise can be viewed by the use of an osciloscope or digitalized using the DMA coupled ADC, and the data stored for further analysis, i.e., the relevant statistical functions are

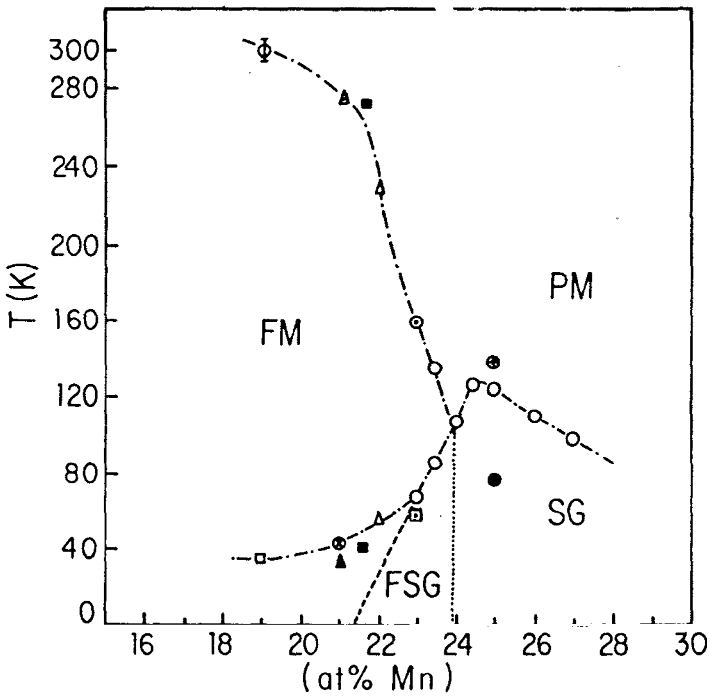


Fig. 1 – Known phase diagram of NiMn as recompiled from the literature. Each symbol indicates a different reference: o - 10, A - 13, □ - 2, ⊕ - 12, X - 8, Φ - this work o - 11, □ - 7, A - 6, + - 9, ⊗ - 5. The symbols ⊙ = o = ⊕ and ,\ indicate coincidence of data points: ⊙ = o = ⊕ = X = Φ = + ; □ = X = + ; △ = △ = 8. The dotted line separates the pure spin-glass (SG) phase from the mixed ferro spin-glass (FSG) one. The dashed line indicates the boundary between the (FSG) phase and the ferromagnetic (FM) one as proposed in ref. 10. (PM) stands for the paramagnetic phase.

obtained Using the RMS module, we obtained $V^B_{RMS}$, which is a measure of the Barkhausen activity (BA) at a given field. Measurements of the M×T and M×H curves (not shown here) were made in order to indicate the convenient points at which the Barkhausen noise should be measured: for the visual inspecion or for the $V^B_{RMS}$ x H measurement, a small field with triangular waveform is applied to the samples and its behaviour is recorded as a function of the temperature. For

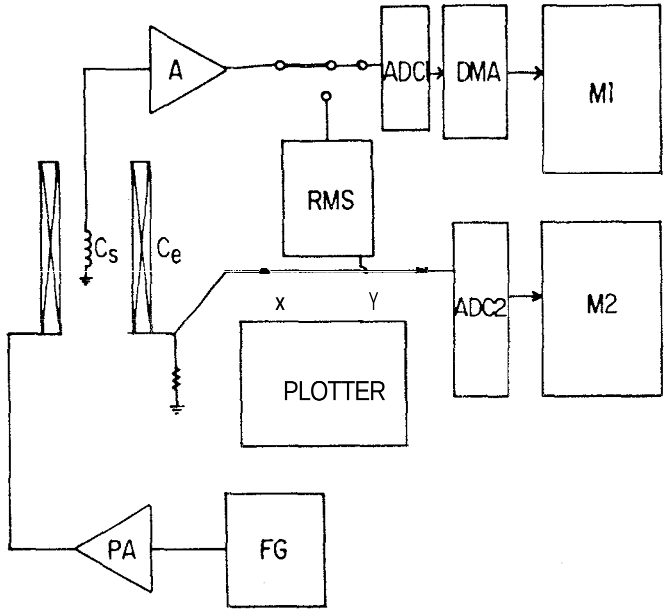


Fig. 2 - Block diagram of the measuring system. (C, ) excitation coil, (FG) function generator, (PA) power amplifier, (C, ) sensor coil, (A) preamplifier, (ADC1) 8-bit analog to digital converter, conversion time: 3.3 ms, (DMA) duect memory access module, 1) microcomputer 1, (ADC2) 12-bit analog to digital converter for detection of the stating point of the measurement at the hysteresis curve of the sample, (M2) microcomputer 2, (RMS) precision RMS converter module.

the autocorrelatíon function measurement, we start in the ferromagnetic phase (information obtained from the M $\times$ T curves) in the vicinity of the coercive field and then the temperature is changed to the neighbourhood of the transitions. The temperature range used was from 300 to 4.2 K except for the x=0.19 sample where the lowest temperature was 77.4 K.

The samples were prepared from high purity metals, meted in arc furnace, laminated, quartz sealed and submitted to annealing at 900 °C for one week followed by quenching in water at room temperature. For comparison, samples not submitted to the thermal treatment were also measured.

## Results and Discussion

The results for the existence or not of the Barkhausen noise are summarized in figure 3. The concentration affects the existence or not of the noise in a complex way. For the x=0.19 samples the annealing/quenching process does not seem to make any difference and the noise exists in both situations. For the x=0.25 samples, the noise does not exist in either case. In the x=0.23 sample, noise apears in the as cast/laminated sample and disappears in the annealed/quenched sample. Still more ineresting is the fact that the noise appears in the non-annealed sample just in the range of temperatures corresponding to the ferromagnetic reentrant phase (60-160K), as indicated in the phase diagram of fig. 3.

In the case of the sample x=0.19, the $V^B_{RMS}$ x H curves and the autocorrelation functions $g(t)$ were obtained for some values of the temperature. These are shown in figures 4 and 5 respectively. The $V^B_{RMS}$ measurement indicates the evolution of the BA with temperature in the field excursion ($-650e \rightarrow 0 \rightarrow 65Oe$). One sees that the intensity of the BA changes with the increase of temperature. A maximum in the activity occurs at 150K. In the paramagnetic phase very close to $T_c$, the small activity beyond H $\cong$ 0 does not correspond to Barkhausen noise, but to magnetization reversal. The autocorrelation function also changes as the temperature increases, showing a structure of characteristic times for this system[16]. Studies concerning the effect of the competitive exhange interactions and unidirectional anisotropies in the autocorrelation function are in course. It should be noted that each autocorrelation function is independently normalizd and the amplitude comparison is not yet available at present.

## Conclusions

From the results presented, we conclude that changes in Mn concentration, modifying the degree of competition among the exchange interactions, affect the niagnetic noise response. This is only one of the several possible factors involved in the wall dynamics, such as the local order, defects, extra anisotropies etc..

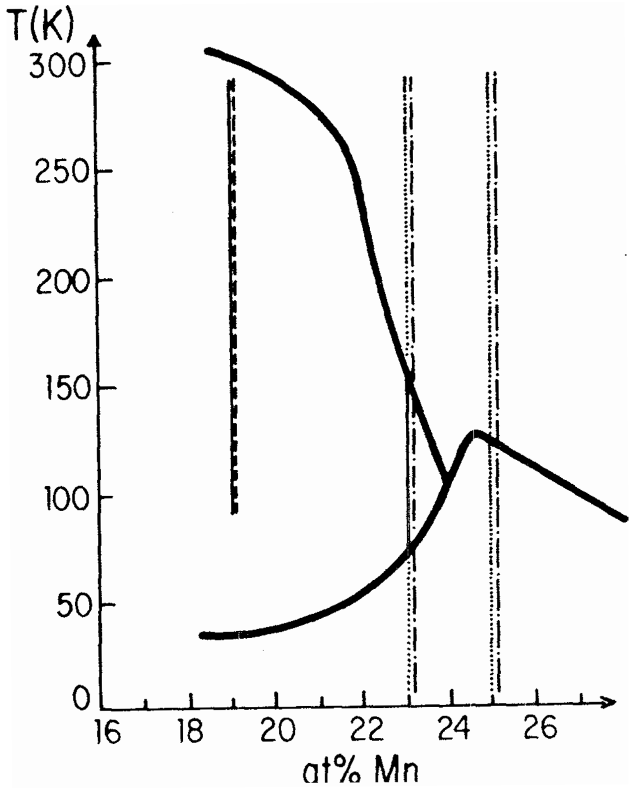


Fig. 3 – Summary of the results obtained concerning the existence of the noise. Disordered samples: (- - -) the noise exists; (-.-.-) the noise does not exists. As cast and laminated samples: (—) the noise exists; (.....) the noise does not exits. The phase diagram of fig.1 is superpoaed to the experimental results to locate the regions where the noise was observed.

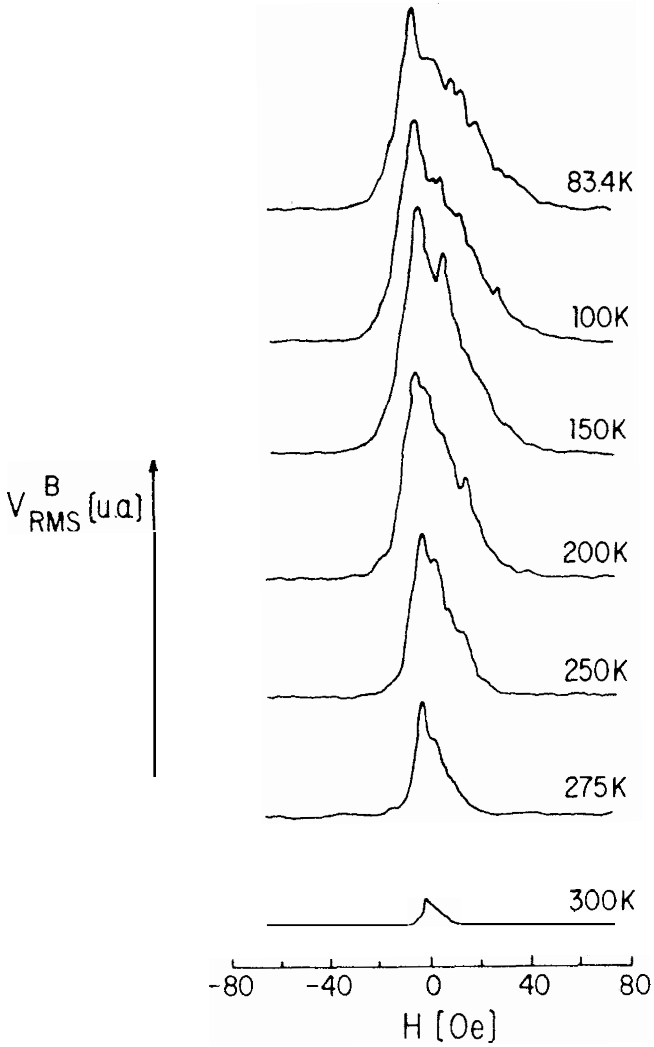


**Fig. 4 - $V^B_{RMS}$ x H curves at temperatures: 83.4K, 100K, 150K, 200K, 250K, 275K and 300K for the x=0.19 sample. At 300K no magnetic noise was observed on the osciloscope (see text).**

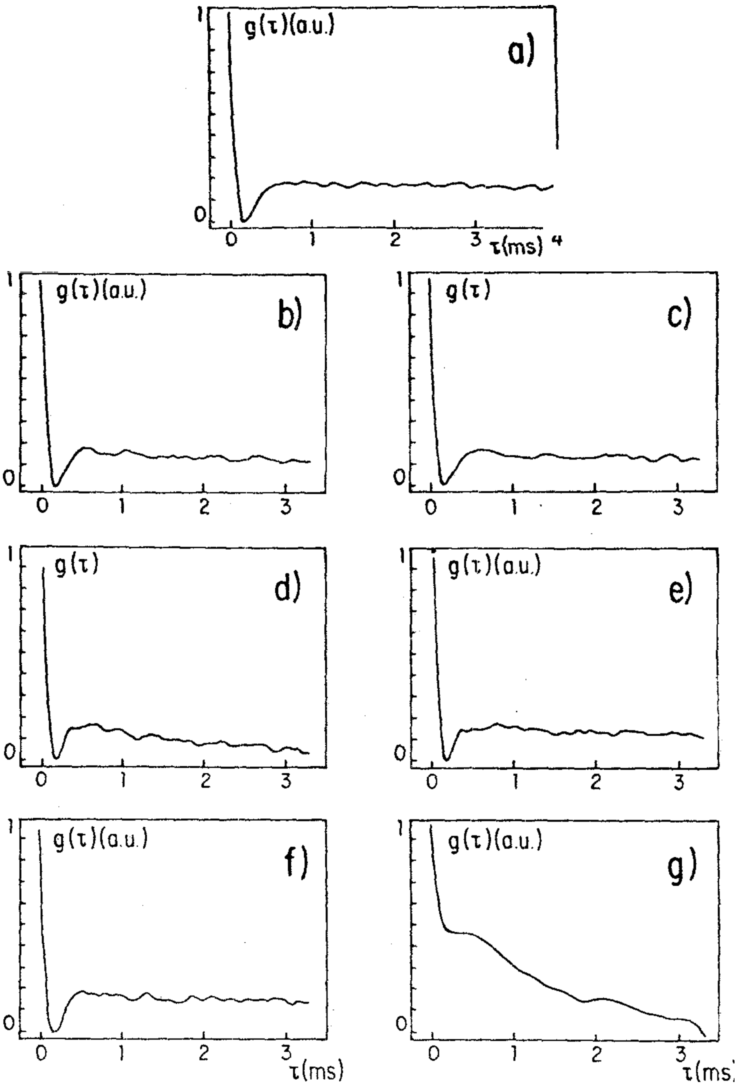


**Fig. 5 - Autocorrelation functions obtained for the $x$=0.19 sample (disordered). In (a) for comparison we show the autocorrelation function of classical material: mono-crystalline $FeSi_{9\%}$. From (b) to (g) we show the results for 83.4, 100, 150, 200, 250 and 300K Compare the details close to the minima and at the end of the $\tau$ scale.**

Further experiments to clarify some of these points are in course for larger ranges of temperature and concentration.

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## Resumo

Medidas de ruído magnético do tipo Barkhausen são apresentadas para o sistema reentrante NiMn em amostras com **19, 23** e **25** at% Mn. São propostos os primeiros pontos de um diagrama de fases para o ruído magnético. Para a amostra com **19%** at Mn, as funções de autocorrelação do ruído e as curvas $V^B_{RMS} \times H$ a temperaturas selecionadas são apresentadas.