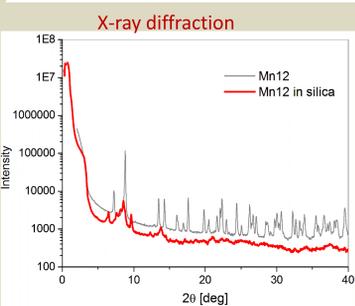
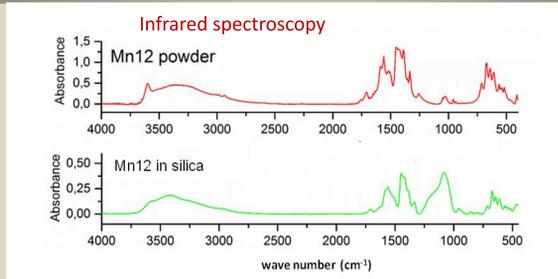
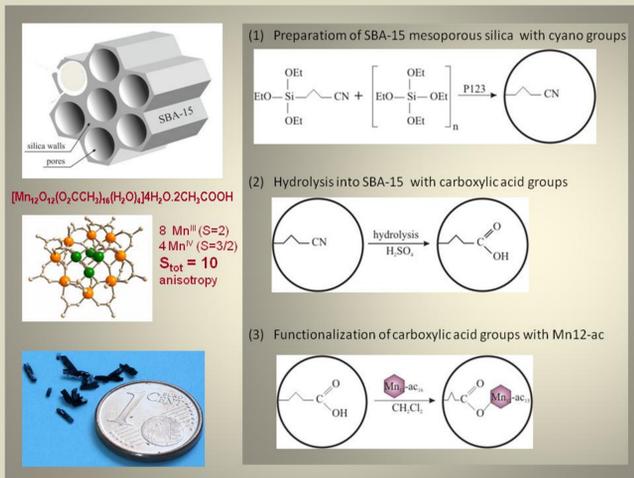


# Magnetocaloric effect and relaxation of Mn12 nanomagnet incorporated into mesoporous silica: comparative study

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**Aim of the work:** study the relaxation and MCE of magnetic Mn12 molecular clusters ( $[\text{Mn}_{12}\text{O}_{12}(\text{CH}_3\text{COO})_{16}(\text{H}_2\text{O})_4] \cdot 2\text{CH}_3\text{COOH} \cdot 4\text{H}_2\text{O}$ ) incorporated into the SBA-15 mesoporous silica.  
 Activation energy  $E_a$  for the relaxation and the pre-exponential factor  $\tau_0$  ( $\tau = \tau_0 \exp(E_a/k_B T)$ ) were determined from AC susceptibility. Distribution of relaxation times has been estimated. Magnetocaloric effect was determined from the isothermal demagnetization curves, measured under decreasing field from 5T to 0T at small temperature intervals.

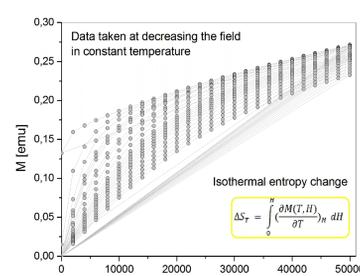
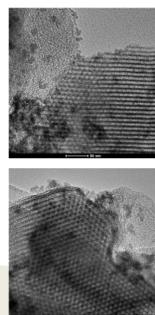
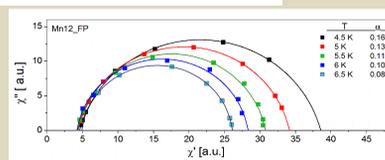
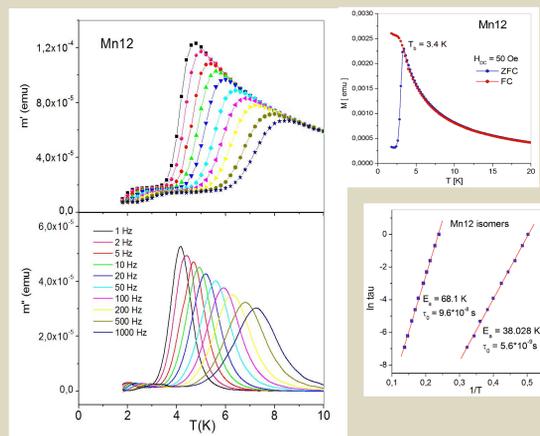
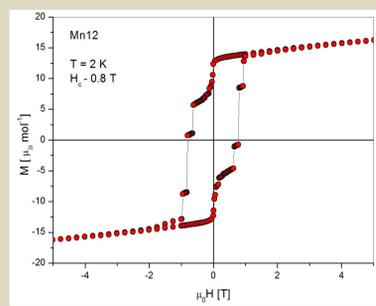
## Synthesis and characterization of the mesoporous silica functionalized with Mn12 clusters (20%)



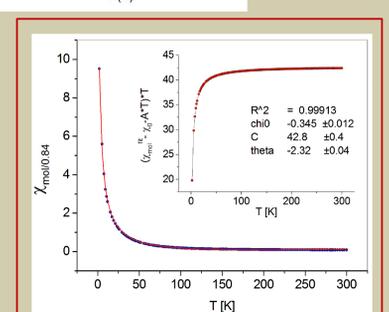
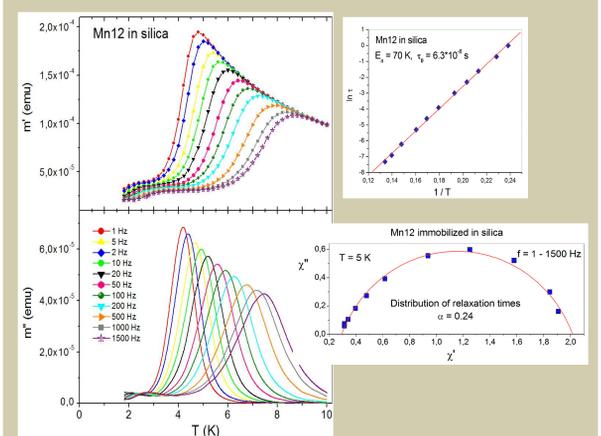
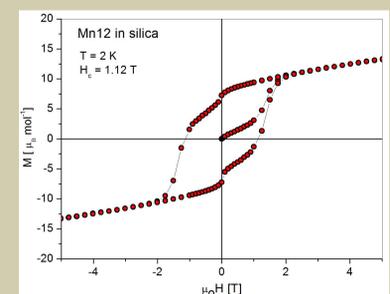
Low angle peak (100) from the SBA-15 structure of hexagonal symmetry  
 $\rightarrow d = 12.6 \text{ nm}$

Nitrogen sorption / desorption measurements:  
 average pore diameter - 4.95 nm  
 specific surface area - 724 m<sup>2</sup>/g

## Mn12 reference

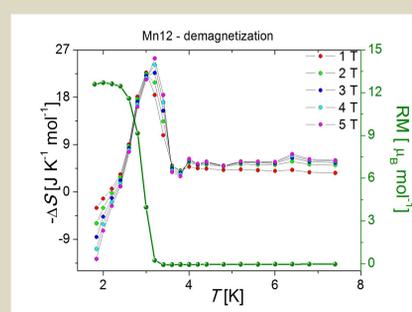


## Mn12 in silica

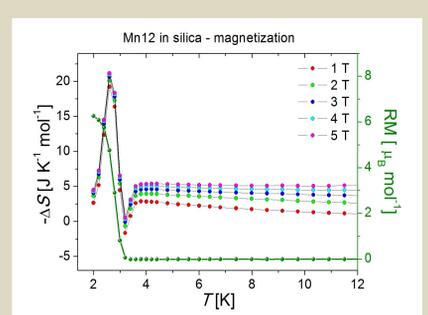
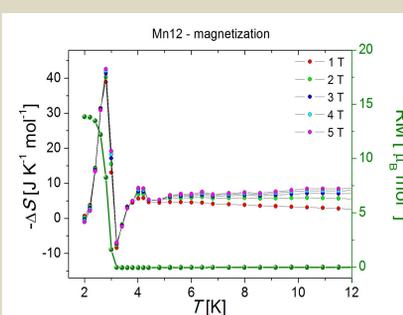
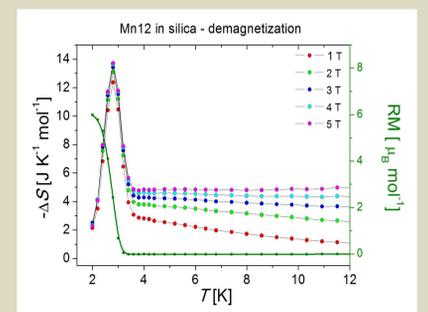


## Magnetocaloric effect

### Mn12 reference

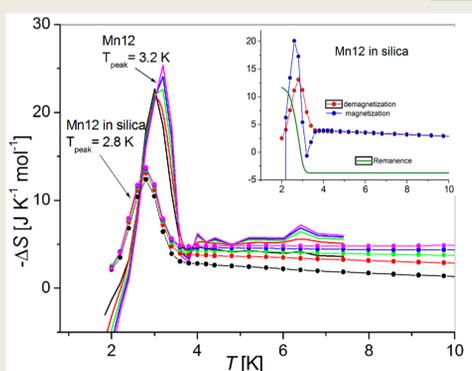


### Mn12 in silica



## Conclusions:

- increase of energy barrier
- decrease and shift of MCE peak
- narrow MCE peak due to small applied field sweeping rate
- inter-cluster coupling present
- homogenous distribution of Mn12-clusters in silica matrix
- high efficiency of synthesis
- S=10 state preserved at high T



	Mn12	Mn12 in silica
Activation energy $E_a$	68.1 K	70.0 K
$\tau_0$	$9.6 \cdot 10^{-8} \text{ s}$	$6.3 \cdot 10^{-8} \text{ s}$
Distribution of relaxation times $\alpha$	0.11	0.24
Temperature of MCE peak	3.2 K	2.8 K
Entropy change $\Delta S_{\text{max}}$	$25.3 \text{ J K}^{-1} \text{ mol}^{-1}$	$13.8 \text{ J K}^{-1} \text{ mol}^{-1}$
$\Delta S$ level at $T > T_{\text{blocking}}$	$5.9 \text{ J K}^{-1} \text{ mol}^{-1}$	$4.8 \text{ J K}^{-1} \text{ mol}^{-1}$
Magnetic remanence	$20 \mu_B \text{ mol}^{-1}$	$6.2 \mu_B \text{ mol}^{-1}$

[1] M. Evangelisti and E. K. Brechin, Dalton Trans. 39 (2010) 4672.  
 [2] F. Torres, J. M. Hernandez, X. Bohigas, and J. Tejada. Appl. Phys. Lett. 77 (2000) 3248  
 [3] T. Coradin, J. Larionova, A. A. Smith, G. Rogez, R. Clerac, Ch. Guerin, G. Blondin, R. E. P. Winpenny, C. Sanchez, and T. Mallah, Adv. Mater. 14 (2002) 896.  
 [4] S. Willemin, G. Arrachart, L. Lecren, J. Larionova, T. Coradin, R. Clerac, T. Mallah, Ch. Guerin, and C. Sanchez, New J. Chem., 27 (2003) 1533.  
 [5] M. Clemente-Leon, E. Coronado, A. Forment-Aliaga, P. Amoroz, J. Ramirez-Castellanos, J. M. Gonzalez-Calbet, J. Mater. Chem., 13 (2003) 3089.  
 [6] B. Folch, J. Larionova, Y. Guari, C. Guerin, A. Mehdi, and C. Reye, J. Mater. Chem., 14 (2004) 2703.  
 [7] Ł. Laskowski, M. Laskowska, M. Bałanda, M. Fitta, J. Kwiatkowska, K. Dziliński, A. Karczmarek, Micropor. Mesopor. Mat., 200 (2014) 253-259