NEW NANOCOMPOSITES MATERIALS ON DIELECTRIC POROUS MATRICES BASE.

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Goals

The preparation of new nanostructured materials on base of porous media and the study of their macroscopic properties, phase transitions and evolution of crystal structure of these nanocomposites

Methods

High resolution X-rays and neutron diffraction, dielectric spectroscopy, electron spin resonance

Samples preparation

The embedding of substances into various porous matrices has some advantages relatively other methods:

•This method gives a possibility to produce nanostructures with a large range of controlled characteristic sizes from ~ 1 nm to ~300 nm.

•It is possible to prepare nanostructures with various geometry and topology: three-dimensional (3D) dendrite and regular structures, 2D film-like structures, 1D nanowires or 0D small nanoparticles.

•One can produce nanoparticles of various substances and compounds: metals, ferroelectrics, dielectrics, insulators, semiconductors, superconductors, magnetic materials and so on.

It is possible to prepare a very large amount (up to several cubic centimeters) of nanocomposite materials (NCM) (or materials in a restricted geometry). This permits us to use some experimental methods that require a large amount of nanostructures (for example neutron scattering, heat capacity measurements etc.).

NANOCOMPOSITES WITH MAGNETIC ORDERING

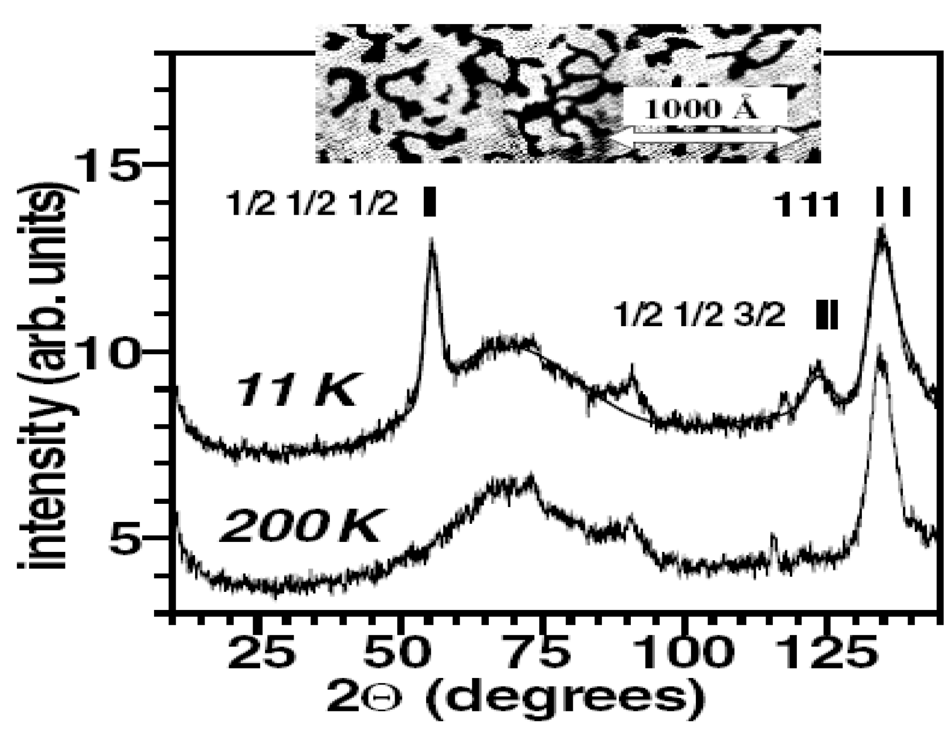

Figure 1. Neutron diffraction patterns of MnO embedded into a porous glass. In the inset the fragment of a typical micrograph of pore network in porous glasses is shown.

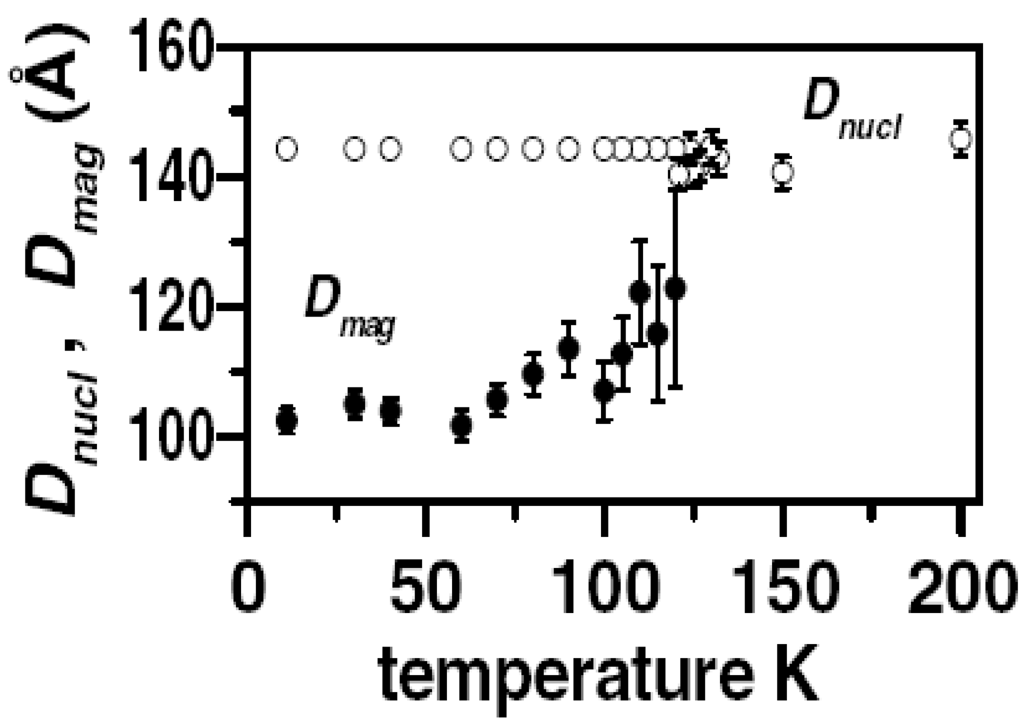

Figure 2. Temperature dependencies of the volume-averaged diameters of magnetic (D_{mag}) and nuclear (D_{nucl}) regions, solid and open circles respectivelyAt B=0

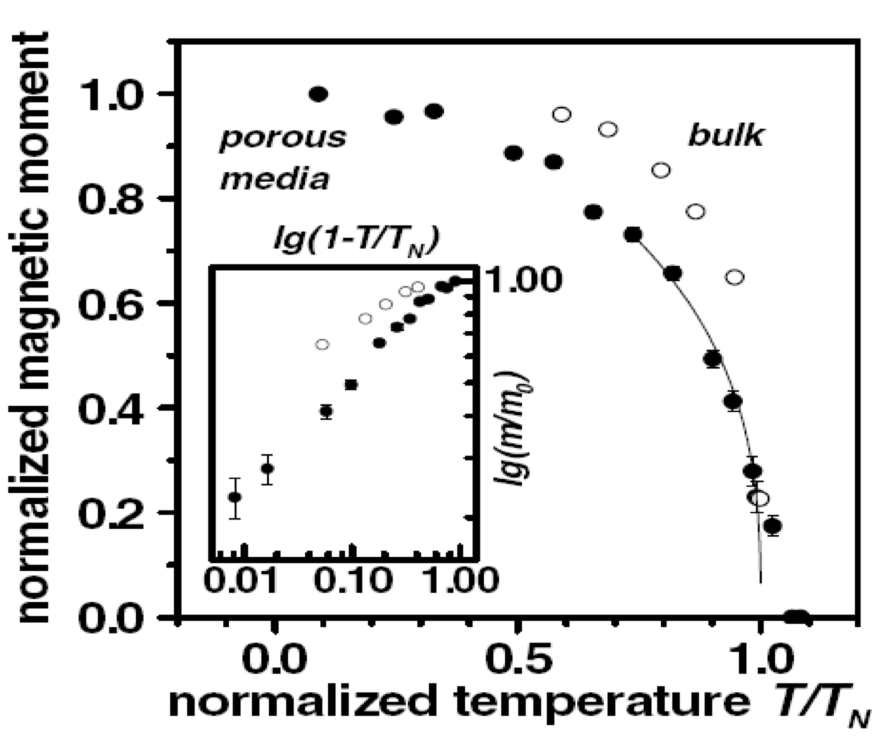

Figure 3. Temperature dependence of the scaled magnetic moment of MnO embedded in a porous glass (solid circles) and in the bulk MnO (open circles). The solid line corresponds to a fit with a power law. The moment dependencies on a logarithmic scale are shown in the inset.

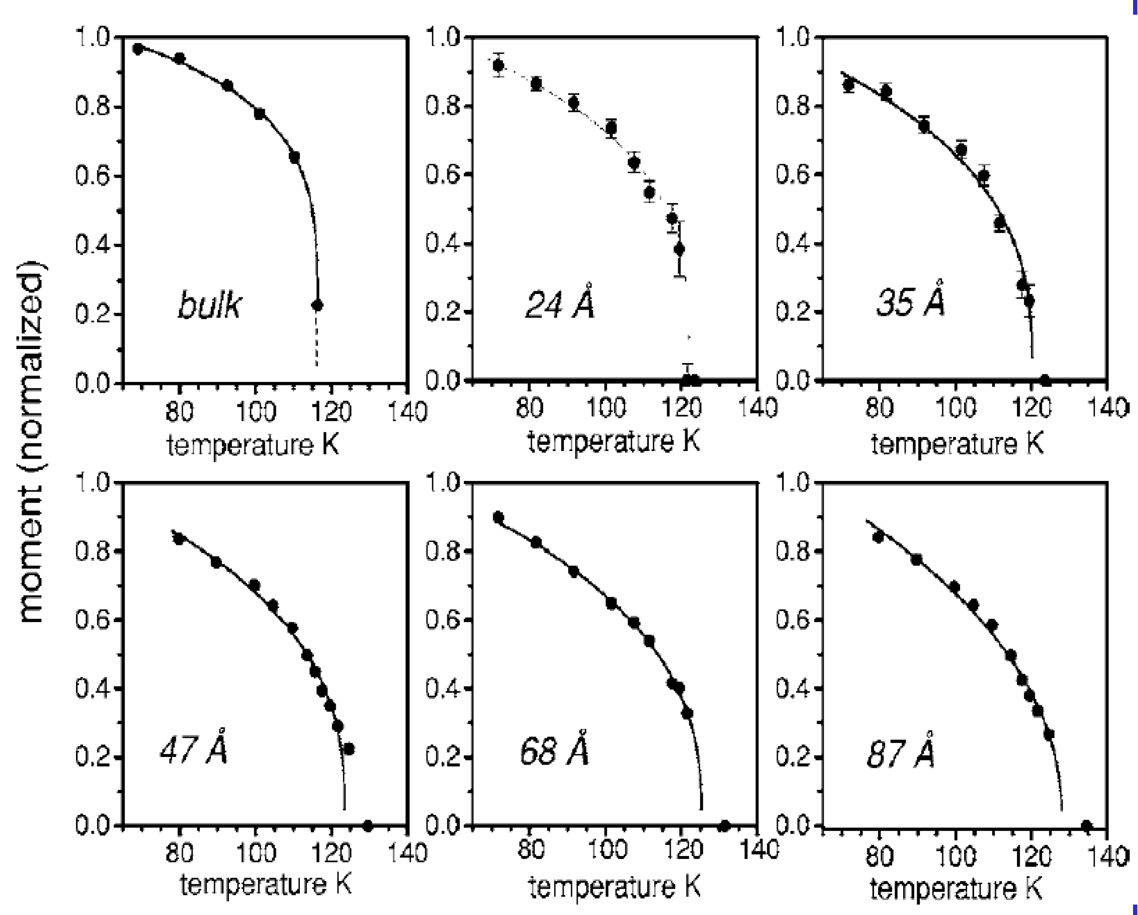

Figure 4. Temperature dependence of the magnetic moment for MnO confined to the channels of different diameter. The solid line corresponds to a fit with a power law.

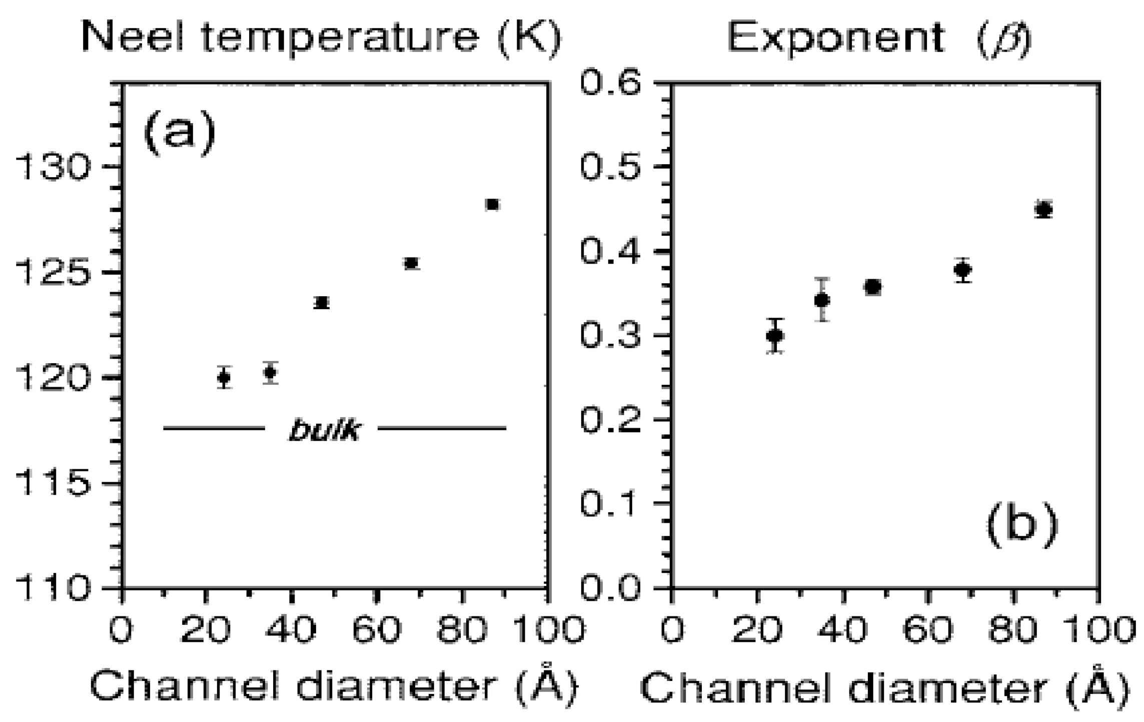

Figure 5. Dependencies of the Néel temperature T_N (a) and exponent β (b) on channel diameters from the fitting with a power law.

FERROELECTRICS IN A RESTRICTED GEOMETRY

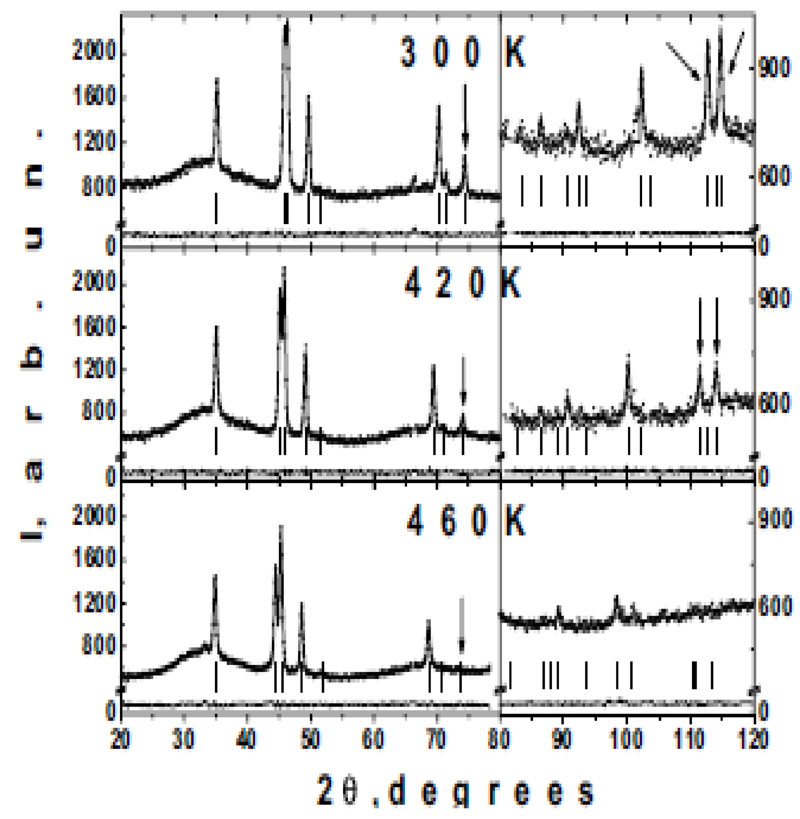

Figure 6. NaNO2 within 7 nm porous Glasses. Neutron diffraction patterns at 300 K, 420 K and 460 K. The arrows indicate the positions of (022), (132) and (123) Bragg peaks in the ferroelectric phase.

$I \sim |F|^2 = F^2_{real} + \eta^2(T) \quad F^2_{im},$

Table 1 Real and imaginary parts of the structure factor for sodium nitrite in the ferroelectric phase for different reflections.

H	K	L	F^2_{real}	F^2_{im}
1	1	0	6.74	0.07
1	0	1	8.17	0
2	0	0	8.18	0
0	2	0	10.82	0.009
0	2	2	0.254	3.864
2	2	0	3.81	0.054
1	3	2	0.054	2.762
1	2	3	0.3	2.718

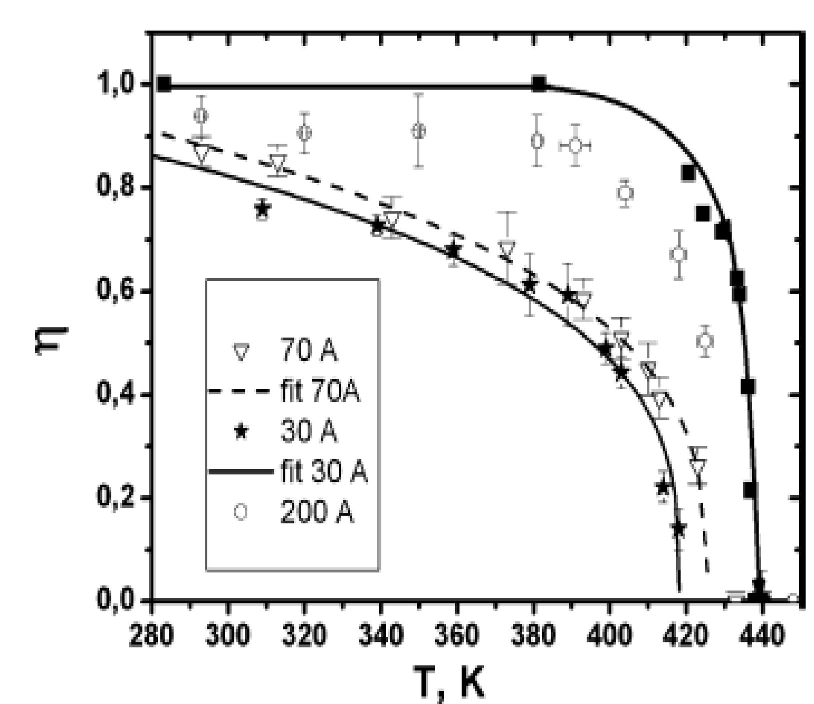

Figure 7 Temperature dependences of the order parameter for the bulk and NaNO2 embedded into porous glasses with average pore diameters 30 Å (stars), 70 Å (open triangles) and 200 Å (open circles)

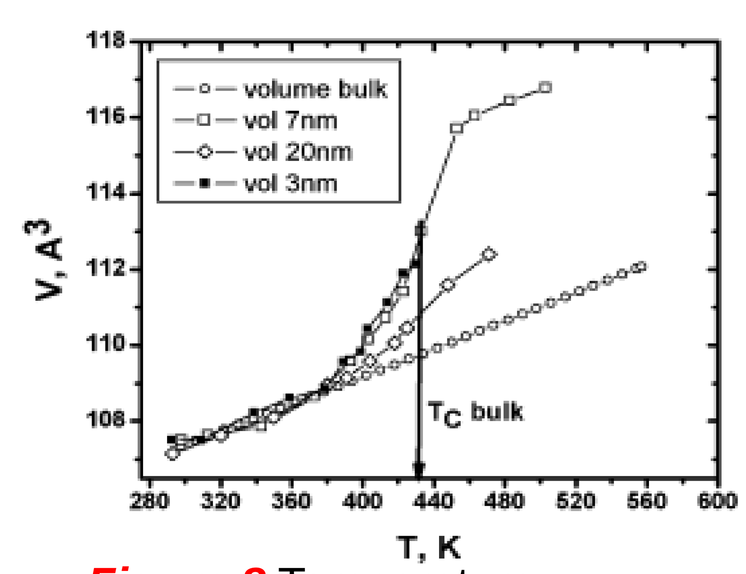

Figure 8 Temperature dependences of the unit cell volume for 3 nm (black squares), 7 nm (open squares) and 20 nm (open rhombuses) porous glasses and the massive sodium nitrite

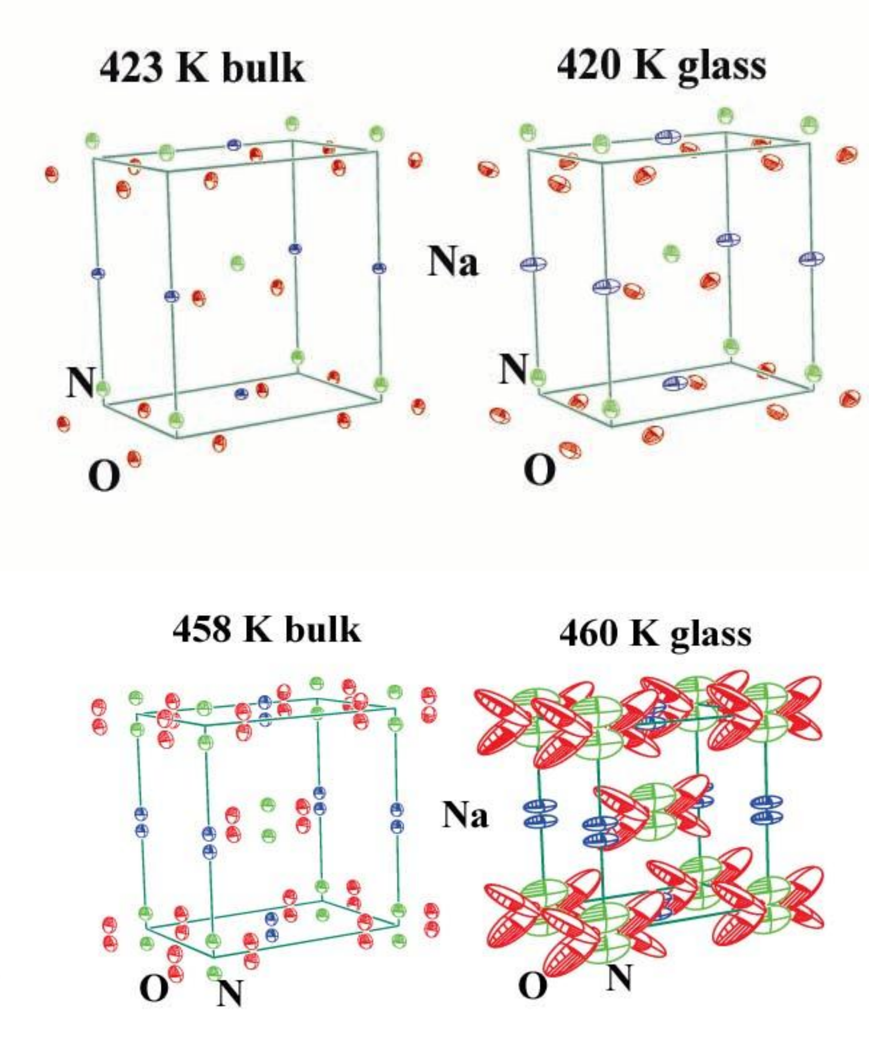

Figure 9 Ellipsoids of thermal motions for the bulk (left) and confined within 7 nm porous glasses (right) $NaNO_2$ below (upper part) and above T_C (bottom part)

Conclusion

-1 - Embedding from wetting melt and chemical embedding produce nonspherical clusters with average diameter larger than the pore diameter.

2 - For some NCMs there are the critical size of nanoparticles when the crossover of PT type is observed.

3 - Examined ferroelectric NCMs with small particles demonstrate the giant dielectric permittivity in the paraelectric phase.

4 - A new volume pre-melted state with extremely large thermal motions of constituent ions has been recovered for sodium nitrite

5 - The confinement can stabilize the usually metastable phases.