# Thick domain boundaries in ferroelastic $K_2Mn_2(SO_4)_3$ crystals

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## Abstract

The domain structure in the ferroelastic $K_2Mn_2(SO_4)_3$ crystals that undergo phase transition with the change of symmetry 23F222 was studied by the polarization microscope. It was found that domain structure appeared at $T_c = -76^oC$ and exists in a whole temperature region below $T_c$ down to liquid nitrogen temperature. The observed domains belong to two ferroelastic orientation states and were separated by thick walls with average thickness of 50μm. The region of the domain walls was optically isotropic and belongs to the cubic paraelastic phase. These domain-phase walls were parallel to the ( $\bar{1}10$ )-plane and are deviated from the mutually perpendicular positions by an angle ~19°.

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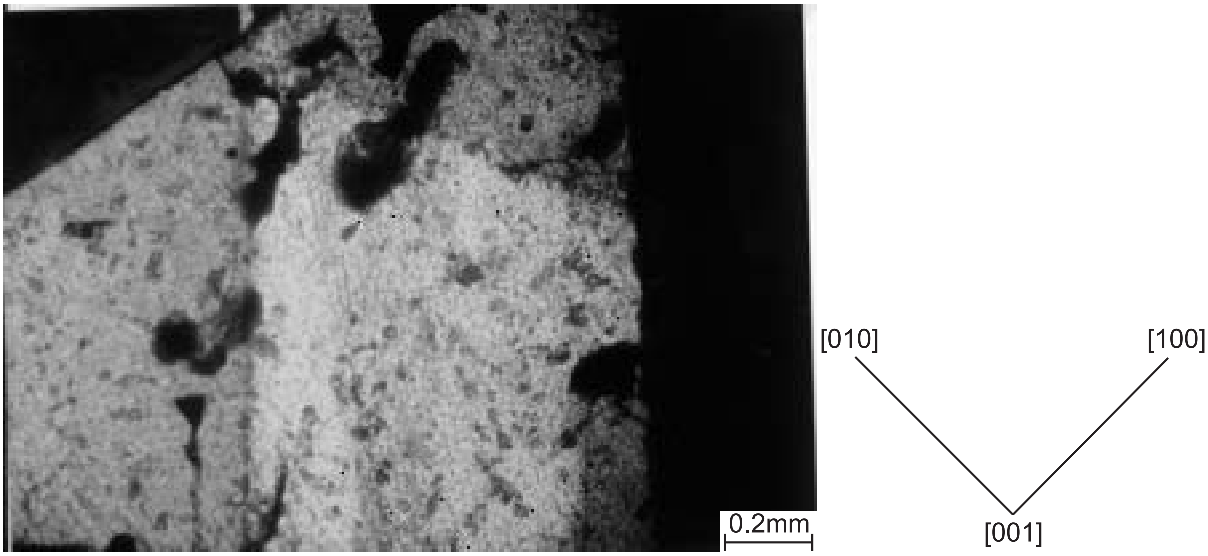
## Intoduction

$K_2Mn_2(SO_4)_3$ (KMS) and $K_2Cd_2(SO_4)_3$ (KCS) crystals belong to the langbeinite mineral family and undergo a proper ferroelastic phase transition of the first order with a symmetry change 23F222 at temperatures $T_c = -72\ ^0C$ and $T_c = 159\ ^0C$, respectively [1,2]. Phase transition in the KCS crystals is of the first order, but not far from the second one KMS crystals manifest a strong first order phase transition. The peculiarity of this phase transition, according to the theory of the J.Sapriel [3], is non-permissibility of the creation of domain structure. In our previous paper [4] we reported about the finding of the domain structure and the thick domain walls (the average thickness of walls was 16-40μm) between domains in the KCS crystals. These domain walls always extinct under crossed polarises, belong to the paraelastic cubic phase and are parallel to the ( $\bar{1}10$)-plane with a deviation of the conjugate walls from the mutually perpendicular positions with an angle ~10°. The domain structure in KCS crystals usually exists in the narrow temperature region $T-T_c \cong 2^oC$. It was also found that in $K_2Mn_{0.4}Cd_{1.6}(SO_4)_3$ crystals [5] which undergo the second order phase transition of the same nature, a ferroelastic domain structure exists in the whole temperature region below $T_c$. The domain walls are thin and exactly parallel to (011) plane.

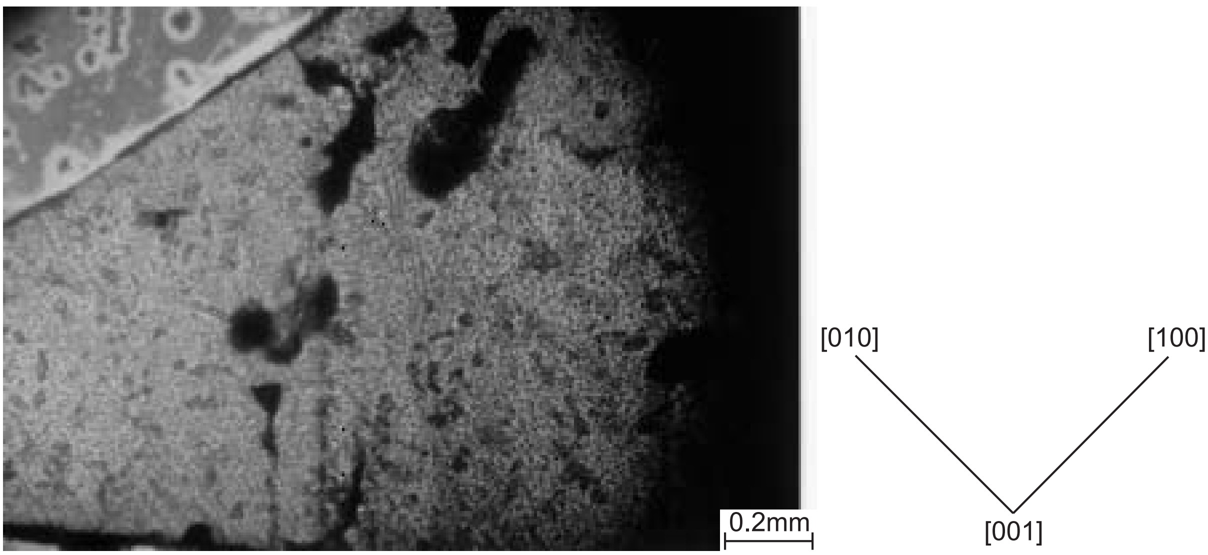
The present study is devoted to the investigations of the domain structure in pure KMS crystals that manifest strong first order phase transition.

## Experimental procedure and results

The investigation of the domain structure of the KMS crystals in the ferroelastic phase was made with the help of the optical polarisation microscope with a temperature cooling cell which permits temperature control down to liquid nitrogen temperatures with a precision close to 0.1K. Sometimes for the distinguishing the areas with little difference of the birefringence we used the compensator with small optical retardation. The




a




b

Fig.1. Domain structure in KMS crystals at the T=100K:two domains separated by thick optically isotropic domain wall (a) without retardation plate and (b) with retardation plate (violet area correspond to the domain wall region).

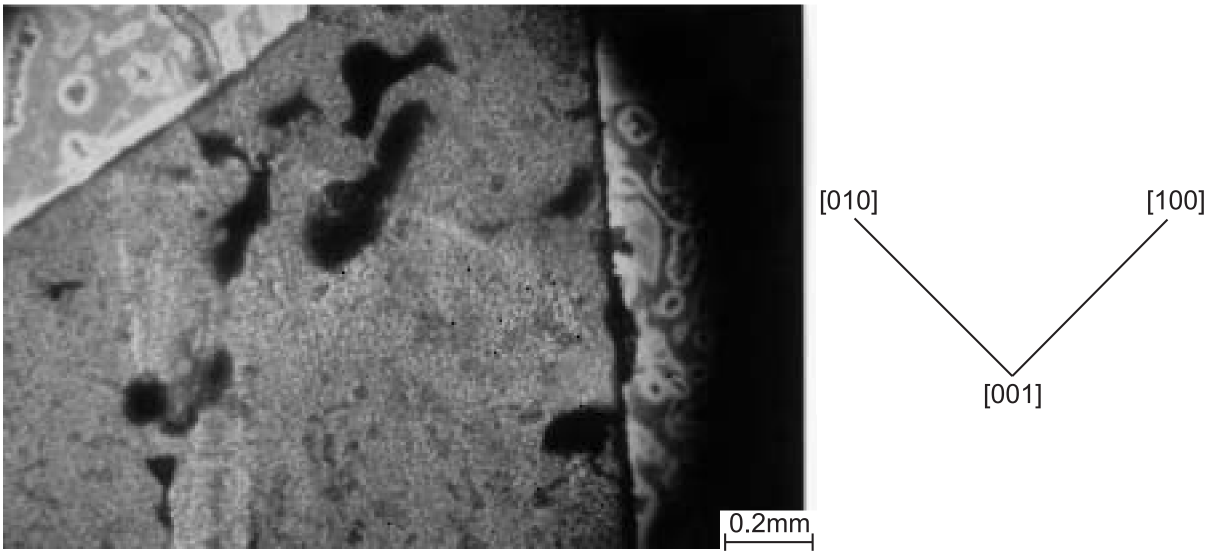



Fig.2. Appearing of the third domain (yellow area) at $T=T_c$ at cooling rate (movement of the phase boundary is visible).

photographing was made by using a photo-camera. The KMS crystals were grown by the Bridgmann method. Good optical quality crystals of average size of 10×10×5mm$^3$ were obtained. Crystal plates of <001> orientation with a thickness of 0.3mm were cut by a diamond wire from bulk samples and were polished by a diamond paste.

On cooling the $K_2Mn_2(SO_4)_3$ crystal we observed the appearance of ferroelastic domains at the $T_c = -76^oC$ that exist in the whole temperature region below $T_c$. The observed domains belong to two ferroelastic orientation states and were separated by thick walls with an average thickness of 50μm. These domain-phase walls were parallel to the ($\bar{1}10$)-plane and are deviated from the mutually perpendicular positions by an angle ~19$^o$. The region of the domain walls was optically isotropic and belonged to the cubic paraelastic phase (Fig.1a,b). On the following cooling the third orientation state appeared but strong internal strains lead to its displacement from the crystal and appearance of cracks (Fig.2).

As it follows from our previous analysis [4] ferroelastic domains that appear at the phase transition 23F222 in langbeinites exist only due to the possibility of the existence of a parent phase in these crystals with a point group of symmetry $\bar{4}3m$. In this case in the ferroelastic phase 222 six orientation states can appear - three right and three left and some of the enantiomorphic–ferroelastic domains can be elastically compatible. The existence of the domain structure in KMS crystals in a wide temperature region below $T_c$ is connected with the insignificant temperature dependencies of the lattice parameters [1] (spontaneous deformations) and elastic modules below $T_c$ [6]. Such temperature behavior of the elastical properties of KMS crystals should lead to the insignificant temperature dependence of the energy of elastic adaptation of neighboring domains and saving of the multi-domain state in KMS in whole temperatures below $T_c$. However, KCS crystals possess strong temperature dependencies of elastic modules [7] and spontaneous deformations [2] that lead to the equilibrium single domain state at $T<T_c$-2$^o$C.

## Conclusions

The domain structure in the ferroelastic $K_2Mn_2(SO_4)_3$ crystals that undergo a phase transition with the change of symmetry 23F222 was studied with a polarization microscope. It was found that domain structure appeared at $T_c = -76^oC$ and exists in a whole temperature region below $T_c$ down to liquid nitrogen temperature. The observed domains belong to two ferroelastic orientation states and were separated by thick walls with an average thickness of 50μm. The region of the domain walls was optically isotropic and belongs to the cubic paraelastic phase. These domain-phase walls were parallel to the ($\bar{1}10$) – plane and deviated from the mutually perpendicular positions at an angle ~19$^o$.

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