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Editorial

Research and Development of Ferroelectric Material

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Ferroelectric materials are widely investigated due their unique dielectric, piezoelectric, piroelectric, electrocaloric and other properties. Therefore, these materials are applied in various areas of human life, including the sonography, capacitors, ferroelectric memories and many others. Among various ''hot" topics of ferroelectrics investigations can be mentioned ferroelectric domain engineering, ferroelectric nanoparticles, thin films, 2D materials, the energy storage, electro-optical and renewable energy applications. Moreover, due to their large nonlinearity ferroelectrics are sometimes termed ''smart" materials [1]. The special issue on ''Research and development of ferroelectric material" contains original contributions devoted for investigations of various kinds of ferroelectrics, their physical properties and technological peculiarities.

We start with the paper of Padberg et al. [2], in which the DC conductivity in potassium titanyl phosphate ($KTiOPO_4$) and its isomorphs $KTiOAs_4$ (KTA) and $Rb_{1\%}K_{99\%}TiOPO_4$ was investigated. It was determined that the ionic conductivity in these crystals is related with gray tracking. Pyroelectric and ferroelectric properties of hafnium oxide doped with Si via plasma enhanced atomic layer deposition are presented by Neuber et al. [3]. It was concluded that both the dopant concentration and the distribution thereof strongly influence the pyro- and ferroelectric properties.

Ferroelectric memory based on topological domain structures investigations by phase field simulations were presented by Huang et al. [4]. The study shows that a ferroelectric topology can be used as a memory and could significantly increase the storage density of ferroelectric memory. The phase diagram of strained ferroelectric nanowire was investigated by Pavlenko et al. [5]. It was demonstrated that the nanoscale confinement of a ferroelectric forming the strained nanowire stabilizes emerging topological states bring functionalities that do not exist in bulk materials. Nanowires supporting vortices and helical phase are of special interest for applications since these topological excitations are well controlled and manipulated by electric fields. This may promote and trigger giant piezo- and ferroelectric responses.

The broadband electrical properties of $Ag_{1-x}Li_xNbO_3$ (ALNx) ceramics ($x \leq 0.1$) together with $AgNbO_3$ (AN) crystals in a wide temperature interval 20–800 K are reported by J. Macutkevic et al. [6]. For ALNx with $x \leq 0.05$ the very diffused ferroelectric phase transition is observed. For this phase transition the position of dielectric permittivity maximum is strongly frequency dependent, is described well by the Vogel-Fulcher law. Moreover, for ALN3 and ALN5 ceramics at very low temperatures (below 100 K) the behaviour typical for dipolar glasses is observed. Raman spectra of $Sr_{1-x}Pb_xTiO_3$ solid solution with x = 0.005, 0.02, and 0.04 were studied by Linnik et al. [7]. It was established that all samples undergo the structural transition from the cubic to non-polar tetragonal phase at temperature close to 90 K. It was also revealed that the PSTx with the lowest Pb concentration x = 0.05 is close to the quantum critical point where the thermal and quantum fluctuations compete.

A comparative analysis of crystal structure, Raman spectra, and dielectric hysteresis loops was carried out by Balashova et al. [8] for organic ferroelectric crystals 2-methylbenzimidazole (MBI) grown from ethanol, acetone, deuterated acetone, or prepared by sublimation from gas phase. It was demonstrated that MBI crystals grown from

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different solvents, having almost identical chemical composition and type of crystal structure, can, at the same time, have different microstructure and dielectric properties. It was explained by the presence of various crystalline MBI phases with the same structure but slightly different unit cell and microstructure parameters in crystals.

Thermal etched surface was studied in Eu modified $Na_{0.5}Bi_{0.5}TiO_3$ (NBT) by means scanning electron microscopy and Raman spectroscopy by Bikse et al. [9]. The paper shows that the different surface character in Eu modified NBT can be obtained through thermal treatment across a wide range of temperatures. Dielectric properties of $KTaO_3$ single crystals with 0.27% Li and 0.15% or 0.31% Mn were studied at low temperatures in a frequency range of 10^2–10^6 Hz by Tkach et al. [10]. It was determined that the relaxation dynamics follows the Arrhenius law with activation energy values of ~77 and 107 meV, attributing the relaxation origin to the dipoles formed by off-centre $Li^{+}{}_{K}$ and $Mn^{2+}{}_{K}$ ions, respectively.

The present Special Issue on ''Research and development of ferroelectric material" can be consider as a status report reviewing some progress that can be achieved over the past few years in selected topic areas related to ferroelectric materials.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Wadhavan, V.K.; Pandit, P.; Gupta, S.M. PMN-PT based relaxor ferroelectrics as very smart materials. *Mater. Sci. Eng. B* **2005**, *120*, 199. [CrossRef]
2. Padberg, L.; Quiring, V.; Bocchini, A.; Santadrea, M.; Gertsmann, U.; Schmidt, W.G.; Silberhorn, C.; Eigner, C. DC ionic conductivity in KTP and its isomorphs: Properties for suppression, and its connection to gray tracking. *Crystals* **2022**, *12*, 1359. [CrossRef]
3. Neuber, M.; Lederer, M.W.; Mertens, K.; Kamphe, T.; Czernohorsky, M.; Seidel, K. Pyroelectric and ferroelectric properties of hafnium oxide doped with Si via plasma enhanced ald. *Crystals* **2022**, *12*, 1115. [CrossRef]
4. Huang, J.; Tan, P.; Wang, F.; Li, B. Ferroelectric memory based on topological domain structures: A phase field simulation. *Crystals* **2022**, *12*, 786. [CrossRef]
5. Pavlenko, M.A.; Rino, F.D.; Boron, L.; Kondovych, S.; Sene, A.; Tikhonov, Y.A.; Razumnaya, A.G.; Vinokur, V.M.; Sepliarsky, M.; Lukyanchuk, I.A. Phase diagram of a strained ferroelectric nanowire. *Crystals* **2022**, *12*, 453. [CrossRef]
6. Macutkevic, J.; Banys, J.; Kania, A. Electrical conductivity and dielectric relaxation in $Ag_{1-x}Li_xNbO_3$. *Crystals* **2022**, *12*, 158. [CrossRef]
7. Linnik, E.D.; Mikheikin, A.S.; Rubi, D.; Shirokov, V.B.; Mezzane, D.; Kondovych, S.V.; Lukyanchuk, I.A.; Razumnaya, A.G. Raman response of quantum critical ferroelectric Pb-doped $SrTiO_3$. *Crystals* **2021**, *11*, 1469. [CrossRef]
8. Balashova, E.; Levin, A.A.; Fokin, A.; Redkov, A.; Krichevtsov, B. Structural properties and dielectric hysteresis of molecular organic ferroelectric grown from different solvents. *Crystals* **2021**, *11*, 1278. [CrossRef]
9. Bikse, L.; Dunce, M.; Birks, E.; Kundzins, K.; Freimanis, O.; Livins, M.; Gabrusenoks, J.; Sternberg, A. Impact of thermal treatment on the surface of $Na_{0.5}Bi_{0.5}TiO_3$-based ceramics. *Crystals* **2021**, *11*, 1266. [CrossRef]
10. Tkach, A.; Zlotnik, S.; Vilarinho, P.M. Dielectric response of $KTaO_3$ single crystals weakly co-doped with Li and Mn. *Crystals* **2021**, *11*, 1222. [CrossRef]