

# EXAMINATION OF ELECTRIC CHARGE DEVELOPED BY LOCAL PLASTIC DEFORMATION OF QUENCHED NaCl SINGLE CRYSTALS

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It is well known that the electric charge appears on electrodes placed on the surfaces of alkali halide crystals during plastic deformation, although they show no piezoelectric effect [1].

No doubt, the phenomenon is mainly related to the movement of dislocations [2] but in particles it is not clear. Some experimental results on quenched NaCl crystals are given in this work.

Three types of NaCl single crystals were used, denoted *A*, *B*, *C*. Crystals *A* were grown in air by the Kyropoulos method. Crystals *B* were grown as crystals *A* but NaOH impurities were added to the melt, crystals *C* were grown in special circumstances [3] practically containing no impurities but 0.1 mol % Ca.

Samples of  $3 \times 3 \times 4$  mm<sup>3</sup> size were cleft from single crystals. Quenching was carried out in the following way: samples were kept at the quenching temperature during one hour and they were cooled down to room temperature within a controlled time. Quenching processes were realised in air or in analytically pure nitrogen. After quenching the samples were plastically deformed by a local stress. The scheme of the measuring system is seen in Fig. 1. The

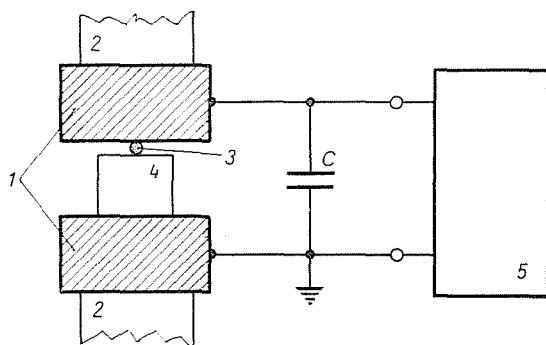


Fig. 1. Instrument arrangement. 1 — Steel plate, 2 — quartz bar, 3 — wire, 4 — crystal, 5 — electrometer, C — condenser

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capacity of the condenser  $C$  was  $3\text{nF}$  and the potential was measured by a vibrating electrometer type RFT VAJ-52.

The local strain was implemented by a wire of  $0.15\text{ mm}$  in diameter (edge-like load) or by a Vickers pyramid (point-like load) by pressing them onto the upper (001) plane of the sample. The strain was the same i.e. the indentation depth was kept constant.

The values of relative charge ( $Q/Q_0$ ) for quenched  $A$  samples obtained by point-like strain plotting against quenching temperature are seen in Fig. 2 ( $Q$  and  $Q_0$  being charges obtained on quenched and non-quenched samples,

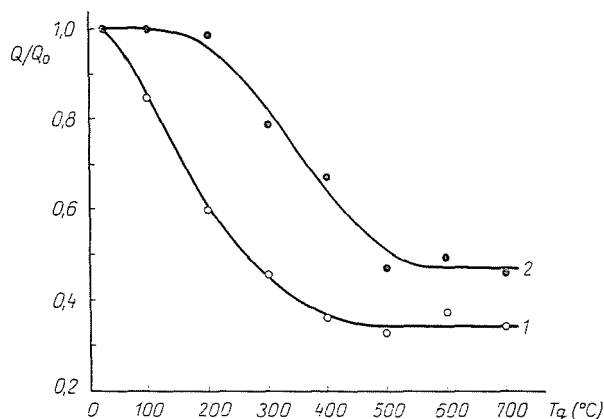


Fig. 2. Relative charge developed under point-like local deformation on quenched NaCl crystals as a function of quenching temperature. 1 — Quenching in silica oil, 2 — quenching in gas stream (at about  $200\text{ }^\circ\text{C}/\text{minute}$ )

respectively). Curve 1 shows results for samples cooled down very rapidly (the sample was thrown into silica oil just from the furnace), while results for samples cooled in gas stream are shown in curve 2 (the rate of cooling was at about  $200\text{ }^\circ\text{C}/\text{minute}$ ). The values of relative charge obtained by edge-like local strain of  $A$ ,  $B$ ,  $C$  samples are displayed in Fig. 3. Cooling rate was  $200\text{ }^\circ\text{C}/\text{minute}$ . Every point on the curves is a mean value of at least 10 results. It should also be noted that the sign of charge measured on the indenter is positive for  $A$  and  $C$  samples while it is negative in the case of  $B$  samples (anion impurities), which are in good agreement with literature data [2].

It may be said on the basis of experimental results that the charge value measured on the indenter for quenched samples strongly depends on the quenching temperature. This value is in a given proportion to the charge carried by dislocations. Supposing that the dislocations pick up their electric charge during movement [4] and the sign of charge of dislocations is determined by the sign of free vacancies with the higher concentration, the results can be explained in the following way.

As it is known, additional cation vacancies appear in the lattice of NaCl containing Ca impurities (samples C). A great part of the extra vacancies are attached to  $\text{Ca}^{++}$  ions creating complexes, that is, they are not free at room emperature. Increasing the temperature, the complexes break up, and the number of free extra cation vacancies in the lattice will be higher than those at room temperature if this dissociated condition is "frozen in" by quenching: This probably may be the cause of increase in the charge of dislocations.

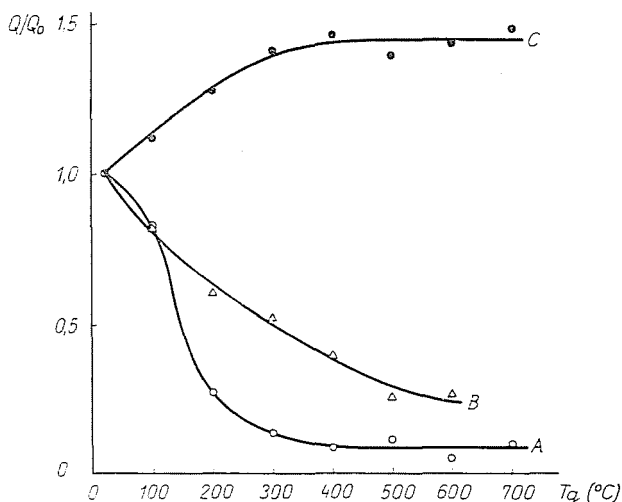


Fig. 3. Relative charge developed under edge-like local deformation on quenched NaCl crystals as a function of quenching temperature. *A* — nominally pure crystals, *B* — crystals *A* doped with NaOH, *C* — crystals containing only Ca contamination

The number of vacancies which can be "frozen in" is limited by the restricted cooling rate, and therefore the charge tends to a saturation value. The increase of charge could also be explained by ever more Ca impurities dissolving in the lattice upon elevating the temperature, but our ionic conductivity measurement and literature data [5] show that the Ca impurity at a concentration of 0.1 mol % is dissolved in the lattice at room temperature.

It is peculiar that increasing the quenching temperature the measured charge will reduce in crystals mentioned in the literature as "nominally pure" ones (*A*-type), although they contain about the same concentration of divalent cation impurity as samples marked *C*. The two crystals differ mainly by a prominent quantity of anion impurity got into the *A* types during growth [6], while there is no anion impurity in the *C* types. It may be concluded that the presence of anion impurities plays a decisive role in decreasing the charge. A similar statement can be made on crystals of *B* type. Probably, a chemical reaction takes place between the anion and cation contaminants of these

crystals and it has an influence upon the concentration of cation and anion vacancies. Further investigations are necessary to detect the processes in the crystal lattice containing also divalent cation and anion impurity during heat-treatment and quenching.

As a conclusion it can be stated that the change of the charge on the moving dislocations in a crystal contaminated only by Ca is in accordance with the present concept of charged dislocations. The results support the concept that both rate and sign of charge are decisively influenced by the quantity and the sign of free vacancies of the lattice. In the so-called "nominally pure" crystals, which contain a divalent cation and also an anion impurity, very complicated processes might occur, and therefore a special care must be given to the interpretation of test results obtained on crystals of the sort.

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### Summary

The effect of quenching on the electric charge developed by local plastic deformation has been examined for differently grown NaCl crystals. By increasing the quenching temperature, the value of charge for samples doped with Ca increased, but it strongly decreased in case of samples grown in air and of crystals containing NaOH impurities. The different nature of the latter samples may be due to the effect of anion contamination.

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