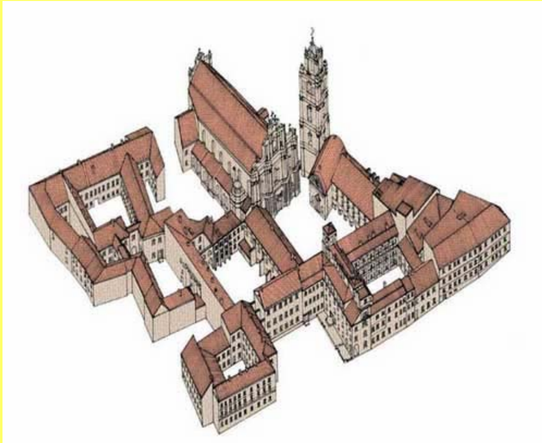

# Electronic and ionic processes influence on electrical properties of TlBr crystals

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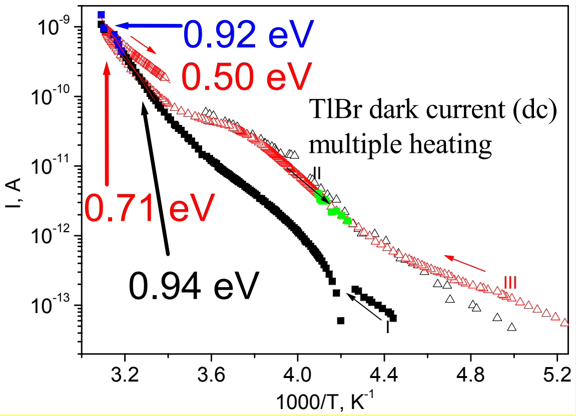
# Basic:

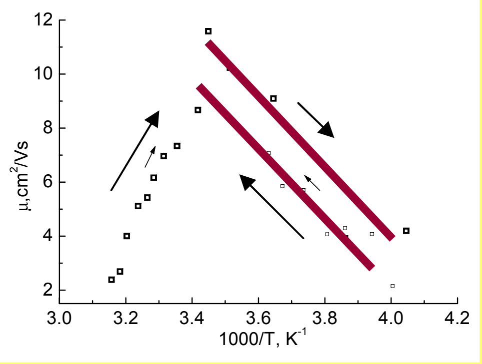
**The interest in TlBr crystal is due to its high average atomic number (Tl: 81, Br: 35), high density (7.5 g/cm$^3$) and wide bandgap (2.7 eV).**

**The photon stopping power of TlBr crystal is greater than any of the semiconductors discussed. Therefore this material is promising for X- and γ- ray detector applications.** K.S.Shah et al. IEEE Trans.Nucl.Sci. (1989) v.39(1).

# Problem:

**The stability of TlBr radiation detector is not good,**
**the investigation of degradation phenomena and improving the properties are important for the future of detectors**




**A cycle of dark current and mobility vs temperature**

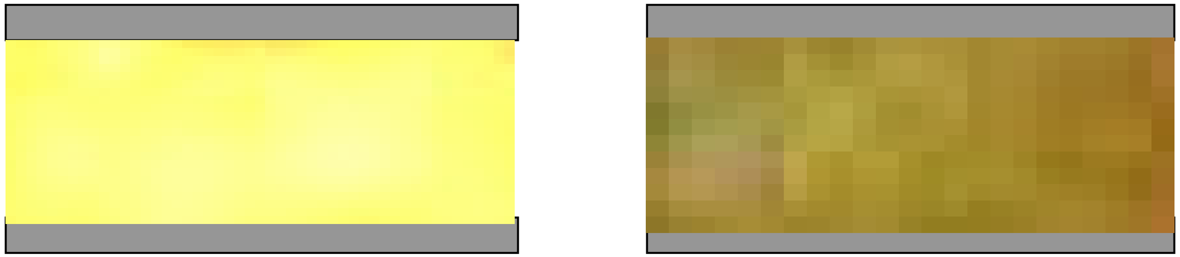
# Outline:

1. Investigation of photoconductivity spectra & electrical conductivity (at different frequencies and temperature)

2. The contacts degradation phenomena.

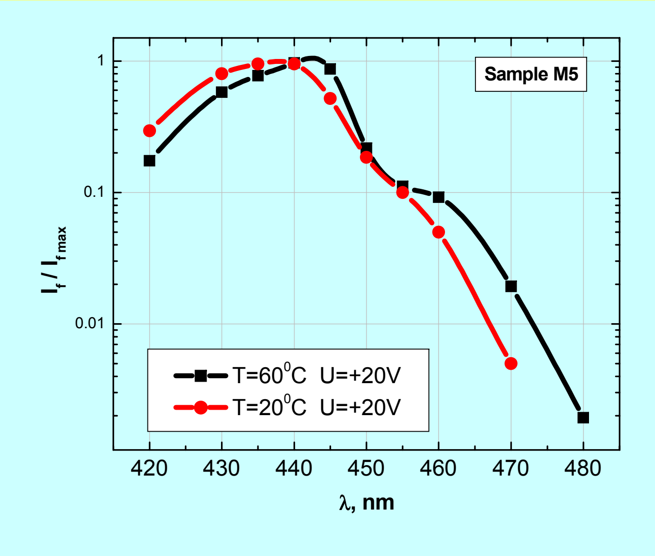
3. A fractal approach.

The schematic view on the samples: the true photos of the crystals but not the contacts



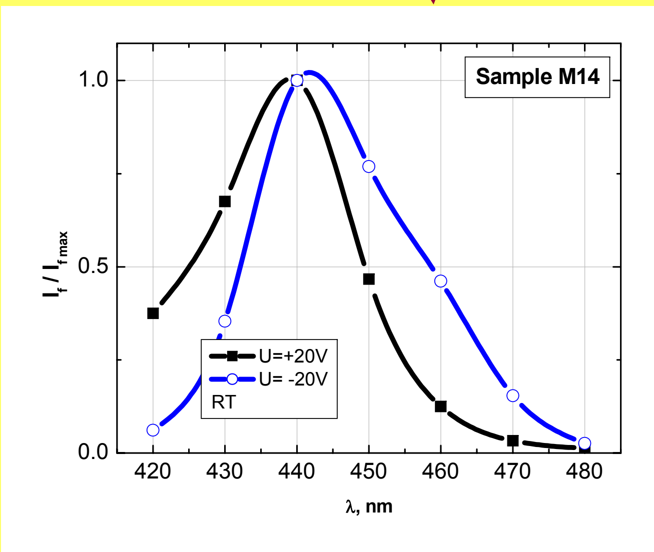
A fresh crystal A “tired” crystal

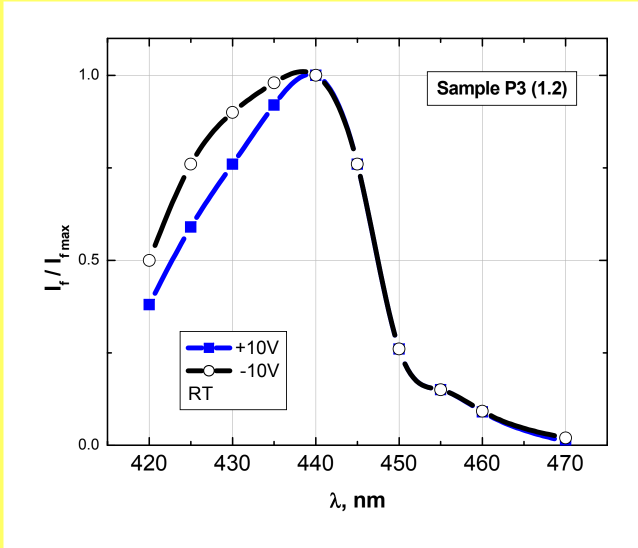
# Spectral Dependencies of Photoconductivity




Shows the edge of intrinsic PC at 2.75 eV and a deep level at 2.63 eV

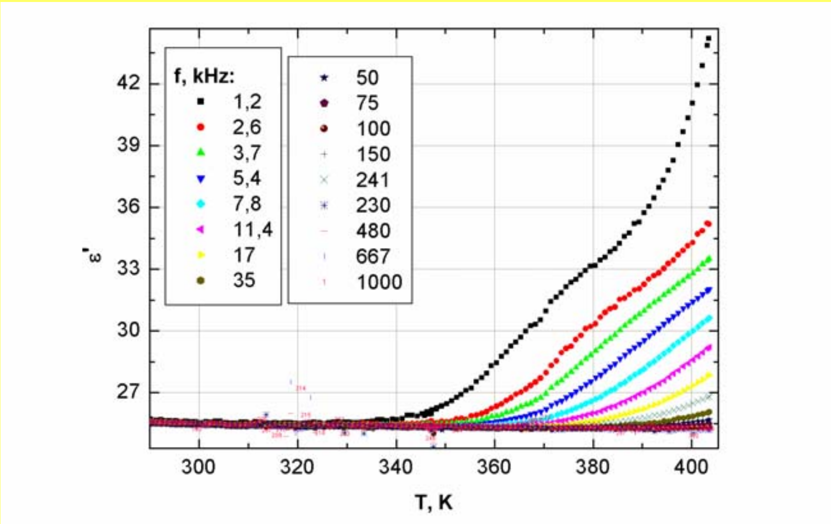
**The spectra shows PC is related with the space charge regions, and they changes with bias voltage and a sign**

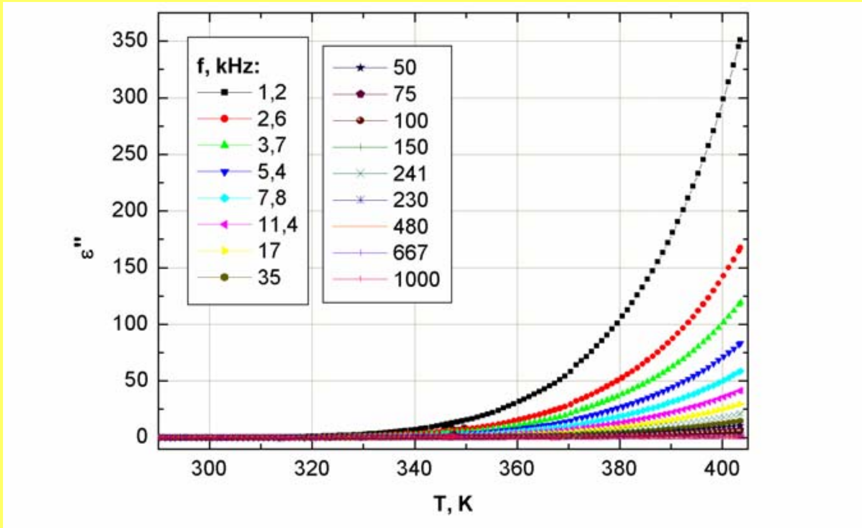


# The dielectric spectroscopy

The complex dielectric permittivity $\varepsilon^* = \varepsilon' - i\varepsilon''$ was measured by a capacitance bridge HP4284A in the frequency range 20 Hz - 1 MHz.



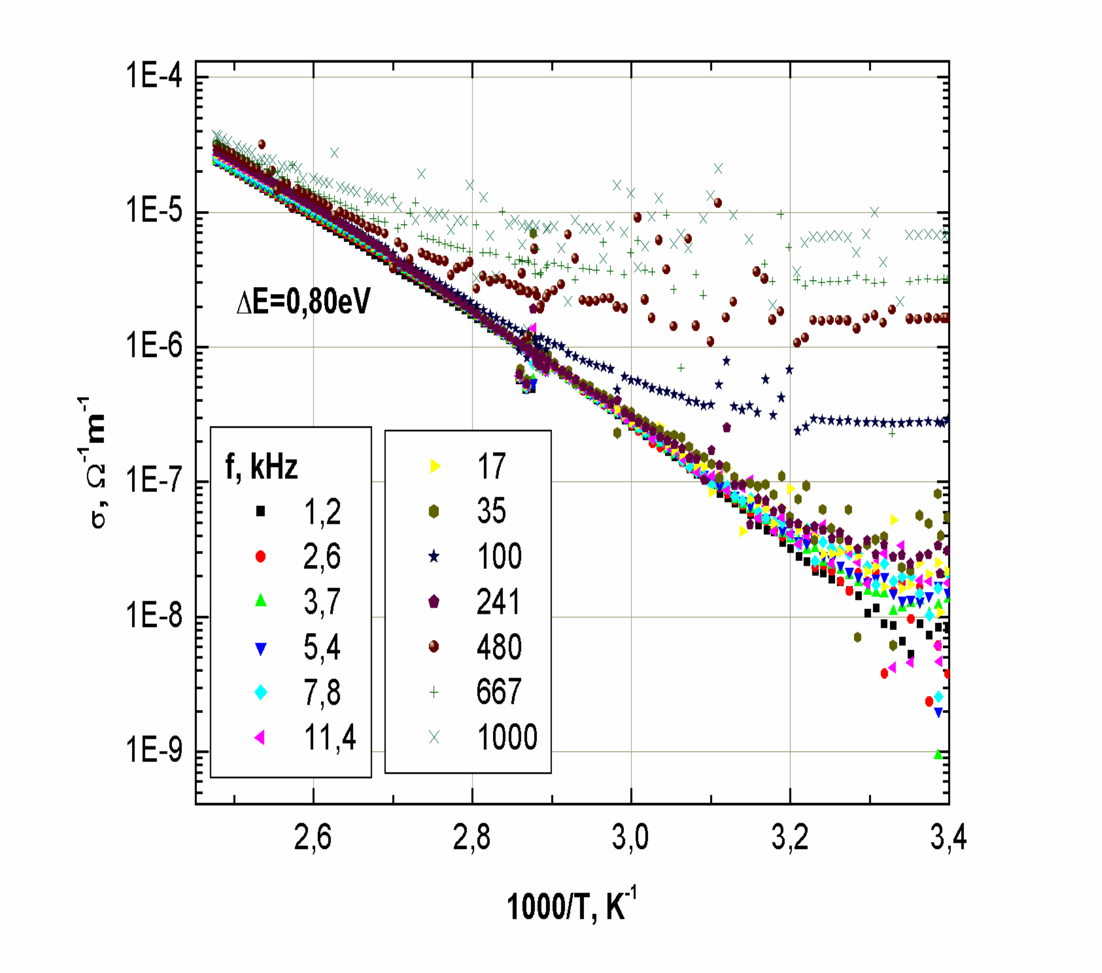




Temperature dependence of **the real part** and of **the imaginary part** of dielectric permitivity at different frequencies.

At low frequencies dielectric losses increase with increasing temperature and cause increase of the real part of the dielectric permittivity. If can be caused by the big ionic conductivity as it was already shown previously [Secco, R.A., Secco, E.A. and Chen, Q. Defects and ionic conductivity in TlCl, TlBr and TlI at high pressure and temperature. Journal of solid state chemistry **141** (1998) 462-465p.].

At low frequencies, the conductivity phenomena dominate in the dielectric spectra. With such a high value of conductivity the contacts and barrier regions  can play an important role.

# Electrical conductivity at high temperature




The electric conductivity:

$\sigma = \omega\varepsilon_0\varepsilon''$.

$\sigma = \sigma_{DC} + A\omega^s$,

where $\sigma_{DC}$ is the DC conductivity and $A\omega^s$ is the $\sigma_{AC}$ conductivity.

(A.K.Joncher, *Dielectric relaxation in solids*, London, Celsea Dielectric Press (1983).)

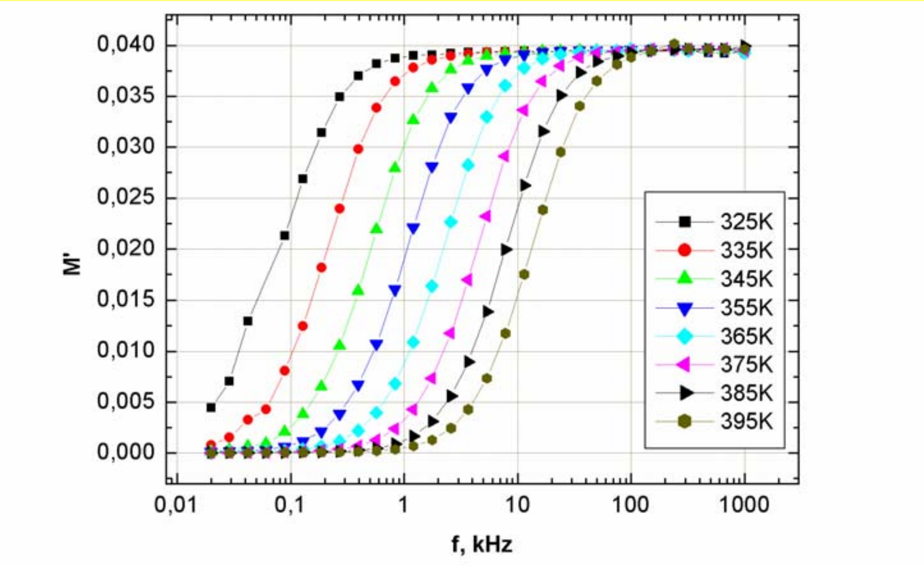
$\sigma = \sigma_0 \exp(E_A/kT)$.

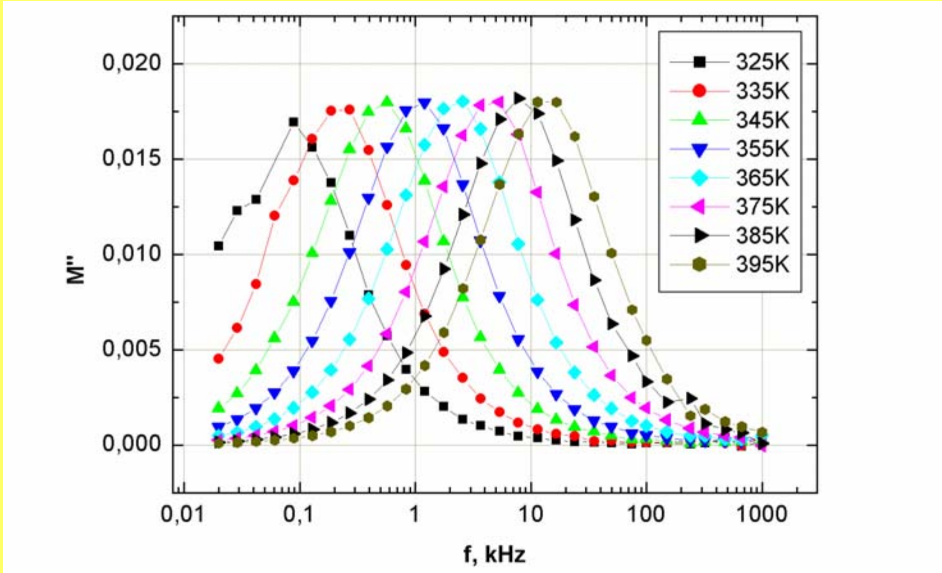
$E_A = 0.8$ eV,

$\sigma_0 = 6{,}7 \times 10^{-15}$ S/m.

Conductivity are caused by Tl ions, which can move in the crystal lattice.

# Electric modulus




Frequency dependence of the **real part** and the **imaginary part** of electrical modulus at different temperatures.

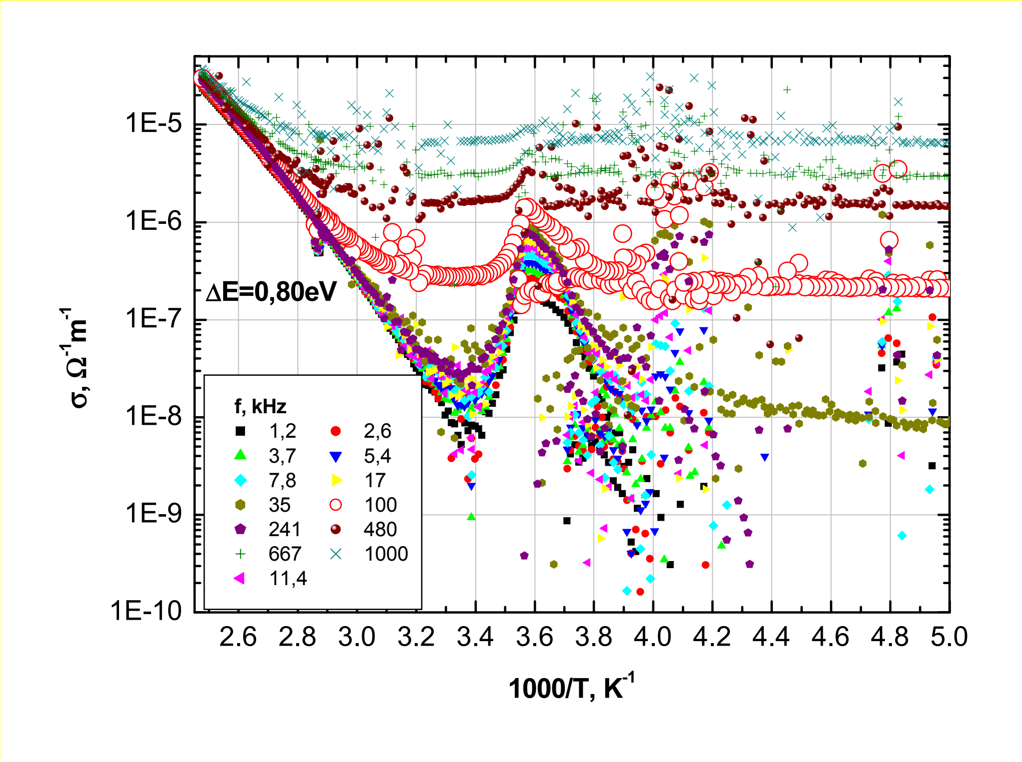
The conductivity of mobile ions can be related to the electrical modulus: $M^*(\omega) = 1/\varepsilon^*(\omega) = M'(\omega) + M''(\omega)$.

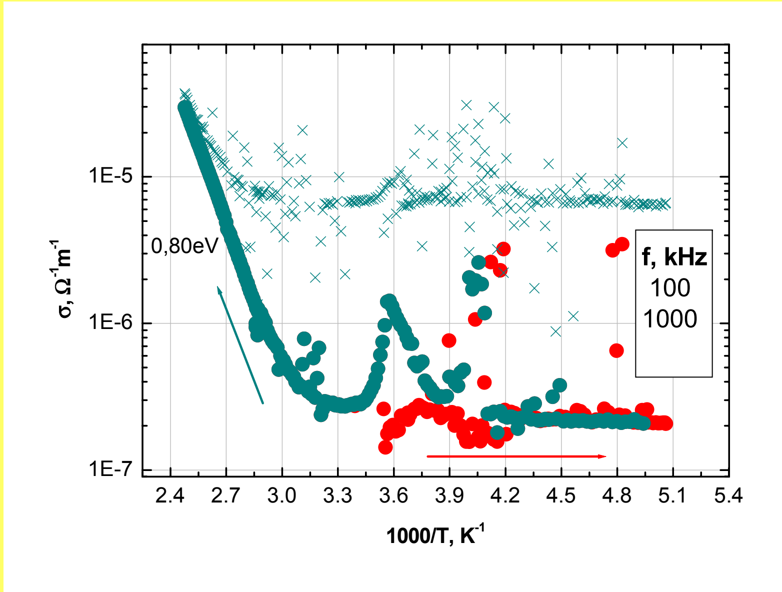
The low frequency value of $M'$ is zero and represents a lack of the restoring force for the electric field induced mobile Tl ions. As frequency increases, each ion moves a shorter and shorter distance until finally the electric field changes so rapidly that the ions only oscillate within the confinements of their potential energy wells. As a result, $M'$ increases to a maximum asymptotic value $M(\infty) = 1/\varepsilon(\infty)$.

*The spectra of* $M''$ show a slightly asymmetric peak centered in the dispersion region of M'.

The region where the peak occurs $(\omega\tau_\sigma = 1)$ is indicative of the transition from **long-range** (left) to **short-range** (right) ion mobility and the peak frequency corresponds to the average electric field (or conductivity) relaxation time, $1/\tau_\sigma$. The broadening in the modulus spectra indicates a cooperative motion of mobile ions, especially in the higher frequency range.

# Dark current frequency dependence

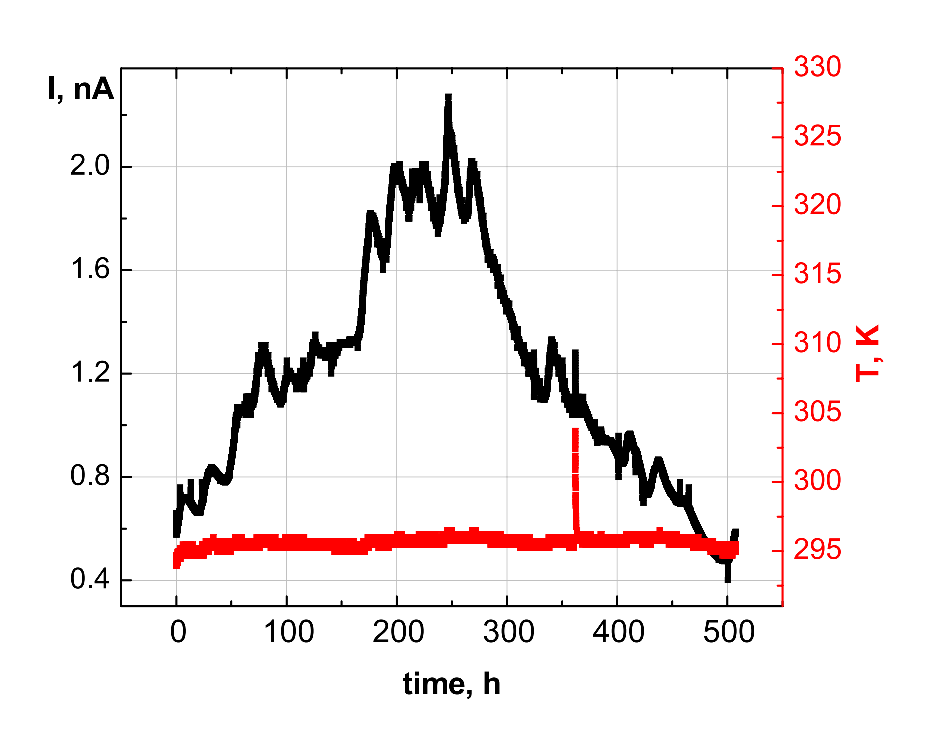


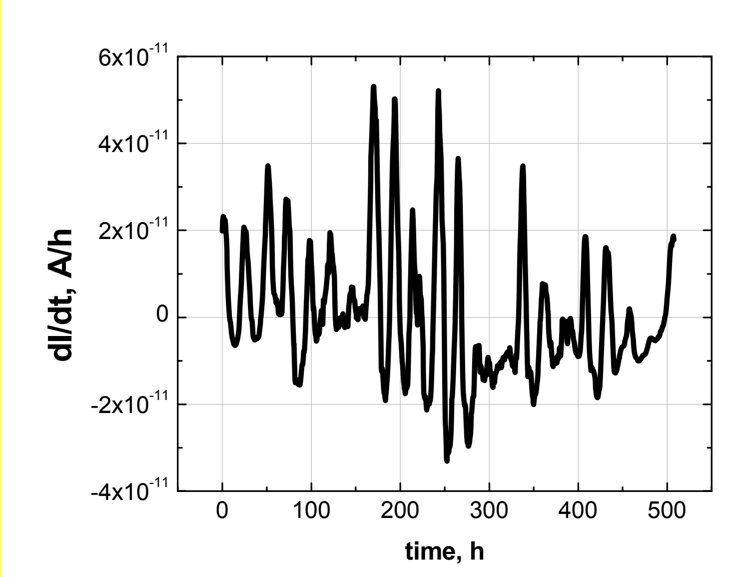

**Dark current vs temperature and vs frequency.**

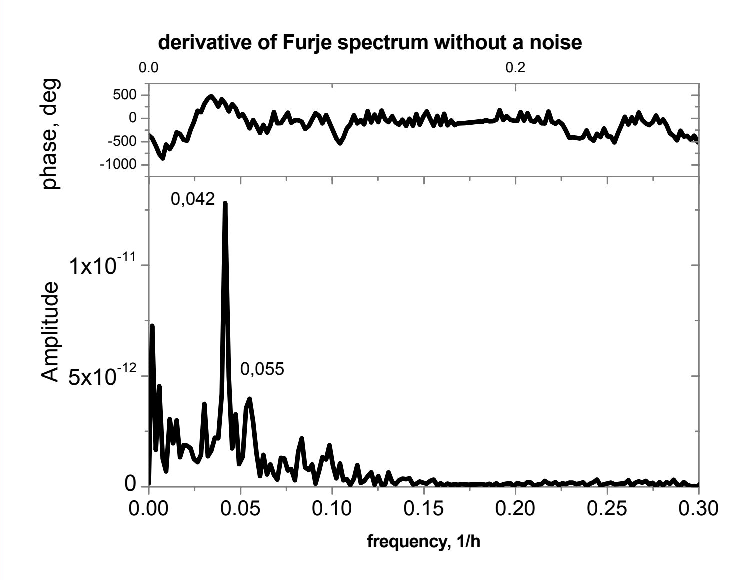
Peculiarities related to the percolation character of ion drift and, probably, the specific features related to ion oscillations and space charge effects.

# Tl-TlBr-Au




Electric current time dependence in TlBr in system Al-Tl-TlBr-Al and applied 30V DC voltage. Total charge 2,33mC ($1,45 \cdot 10^{16}$ particles).

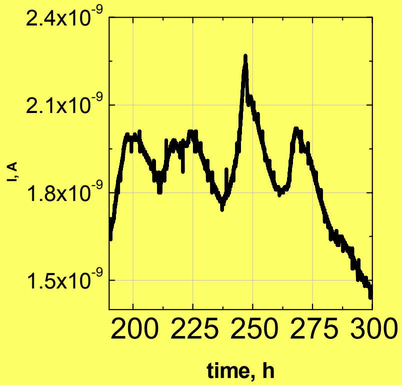



A deposited Tl contact disappears due to ionic conductivity and characteristic instabilities (spikes) are observed.

**A new result was found by direct $Tl^+$ ions transport:**
**diffusion – limited aggregation** is responsible for a **dendritic structures** which could be grown by $Tl^+$ or electrode ion electrodiffusion.

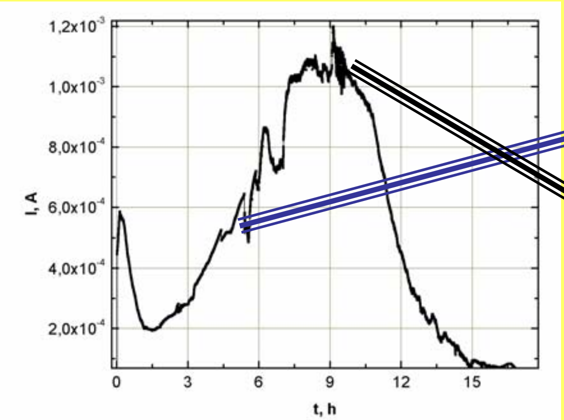
**Proposed: spikes appear during a growth of a dendrit or creation of cluster**

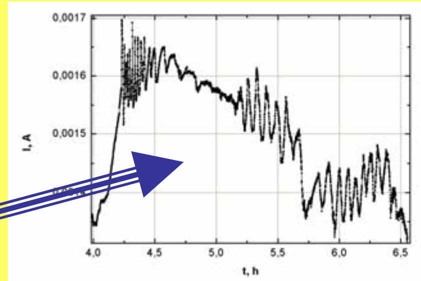


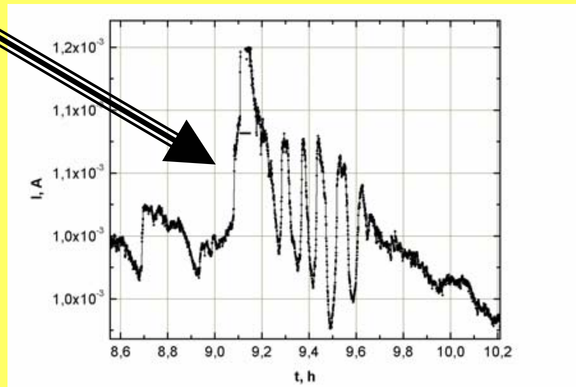
A part from the current time dependence

**A fractal analysis approach seems very promising.**

Typical fractal system:
Cu electrode and mineral water




The current vs time dependence

# Conclusions:

1. Photoconductivity spectra demonstrates the electric field redistribution in the sample and an existence of the deep centres.

2. Frequence dependence of conductivity allows to measure the ionic conductivity and demonstrates the regions of ionic instabilities. T < 250 K is promising for improve a stability of detectors.

3. $Tl^{+}$ ion current time dependence shows the fractal behaviour of ion migration.

Fractal in the natural colours

# *Thank you for your attention !*