

# Study of Acoustical-spectral Parameters in Alkali Halides Crystals

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*In this paper, the authors aim to determine some acoustical-spectral parameters in the time-frequency domain for alkali halides crystals. The sample consisted of a potassium chloride crystal (KCl) having the form of a parallelepiped with known dimensions. The purpose is to find out the sample behaviour after applying the method of growth of alkali crystals (pull-axis). Pulse-echo technique is used here and the instrumentation is supplied from Physical Acoustical Corporation. By applying an original program for determining acoustical-spectral parameters named “Ultrasonic computerized system for evaluation of materials” – (UCSEM), the determinations were made from the time domain into the frequency domain.*

**Keywords:** *ultrasounds, alkali halides, pulse-echo technique, acoustical-spectral parameters*

In the past, a considerable amount of work, both theoretical and experimental, has been done in evaluating the frequency dependence of ultrasonic attenuation in alkali halides crystals [1, 2].

Experimental studies reveal that the dislocation mechanism yields a negligible contribution to the ultrasonic absorption in well-annealed alkali halides crystals and also the contribution of thermo elastic losses is exceedingly small [3].

A computer program recently developed by us named “Ultrasonic computerized system for evaluation of materials” (UCSEM) facilitates the calculation of acoustical-spectral parameters. The motivation and aim of developing this program was that such a program would facilitate a theoretical investigation of different models in different solids on one hand and it could have the flexibility of incorporating new refinements in these models at any stage, on the other hand. In this work we apply our program in order to evaluate ultrasonic attenuation and longitudinal velocity in KCl.

## Experimental part

The sample consisted of a potassium chloride crystal (KCl) having the form of a parallelepiped with 10 mm ( $L_{10}$ ), 17 mm ( $L_{17}$ ) and 22 mm ( $L_{22}$ ) sides dimensions.

The sides are well polished which allows ultrasounds propagation to take place properly. KCl was chosen partly because of its relatively large refraction angle and because of its stability in various media. The method of growth of alkali crystals allowed us to determine the pull-axis that is parallel to  $L_{22}$ . Glycerin was used as a couplant in order to ensure a high transmission coefficient. Pulse-echo technique that uses a single E-R transducer was used to examine KCl sample by direct contact method. The transducer is a 5 MHz piezoelectric one of 15 mm diameter from Nortec Company (fig. 1). There were determined some acoustic parameters such as ultrasonic attenuation and longitudinal velocity of ultrasounds propagation in 4 points on each dimension ( $L_{10}$ ,  $L_{17}$ ,  $L_{22}$ ). The determinations were made in the time domain from RF signal using IPR-100, A/D-90 and SMC-4 from Physical Acoustic Corporation (PAC). By applying an original program for determining spectral parameters named “Ultrasonic computerized system for evaluation of materials – UCSEM”, the determinations were made from the time domain into the

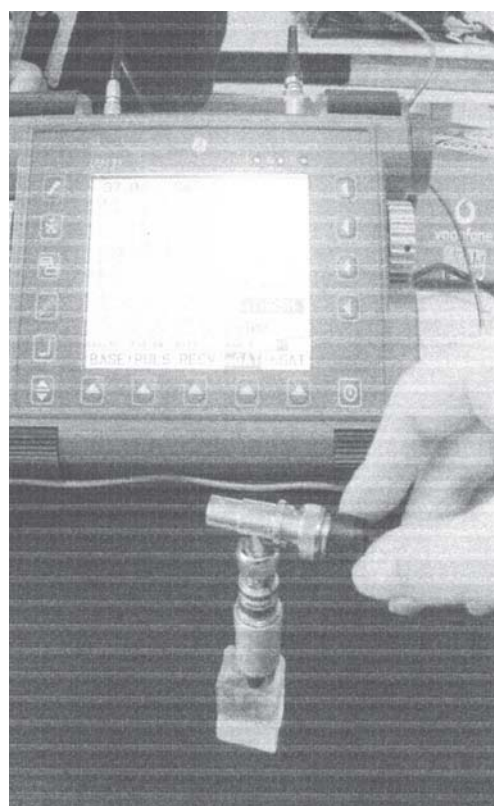


Fig. 1 Experimental system

frequency domain. The program saves RF signals and all parameters specific to the examined sample: density, dimension, coupling medium, probable velocity and operating frequency. The software of this system (UCSEM) can be used to determine the following parameters of the investigated sample: the attenuation measured from the two echoes amplitudes, the longitudinal waves velocity and the attenuation versus frequency determined from the spectral analysis in real time.

Use of Ultrasonic computerized system for evaluation of materials (UCSEM) software is presented for two domains.

### *Time domains:*

- determination of propagation velocity: from the RF signal window, the position of the maximum, the width, number of points and the thickness are read.

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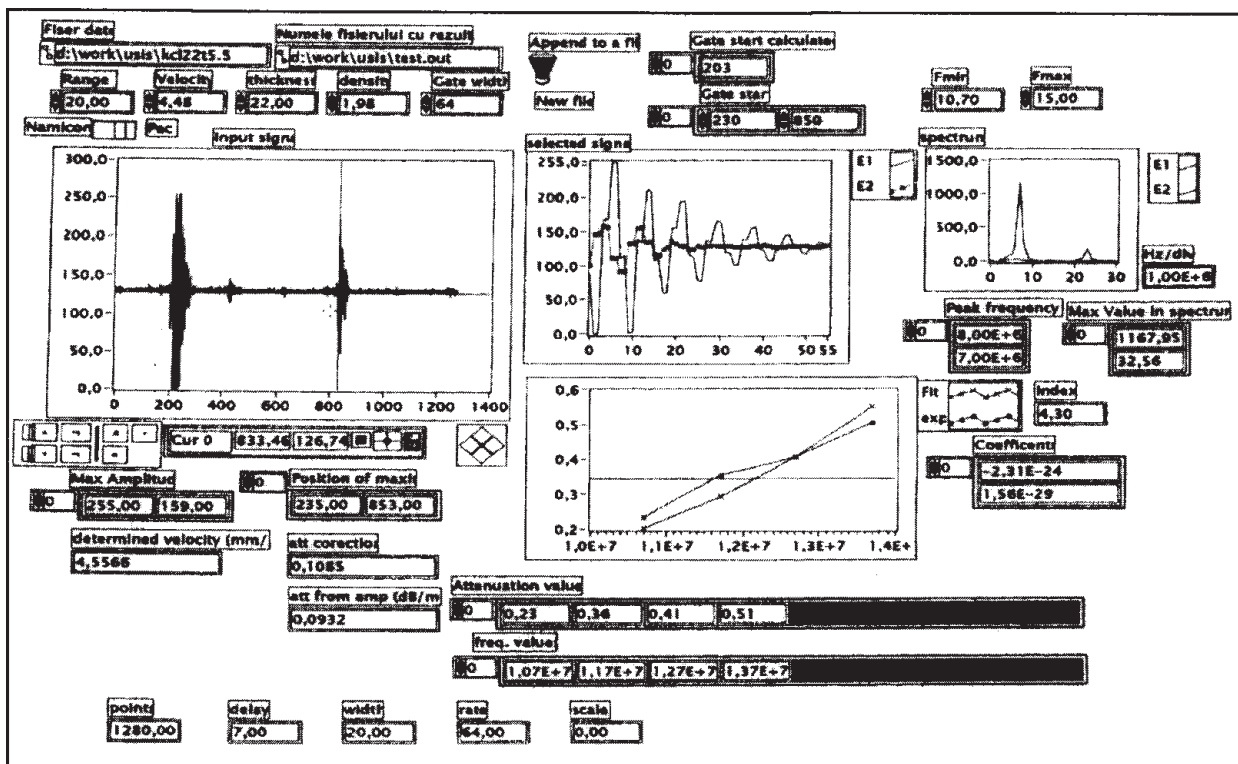


Fig. 2 Ultrasonic computerized system for evaluation of materials- "UCSEM"

The following relation is applied:

$$\frac{(\text{Position of the maximum}) \times \text{width}}{\text{number of points}} = A \quad (1)$$

$$\frac{2 \cdot \text{thickness}}{A} = \text{velocity} \quad [\text{mm}/\mu\text{sec}] \quad (2)$$

- determination of attenuation from the amplitude

$$\alpha_1 = \frac{10}{L} \cdot \left( \log \frac{A_2}{A_1} \right) \quad (3)$$

Frequency domain:

$$\alpha_2 = \frac{10}{L} \cdot \log \left| \frac{H(\omega)}{R^2} \right| \quad (4)$$

where  $H(\omega)$  is the maximum values ratio from the spectrum and  $R=0.58$  is the reflection coefficient between the coupling medium (glycerin) and the sample (KCl).

The theoretical and experimental graph of attenuation versus frequency is shown in the lower window and the values of attenuation and the afferent frequency are shown in the table.

## Results and discussion

The graph of ultrasonic attenuation on each dimension and in all 4 positions on the sample is shown in figure 3.

One can notice a minimum in attenuation for all dimensions in position 2. Comparative, for the 3 D(dimensions), the attenuation has the smallest value for  $L_{22}$ .

The 3D graph, attenuation-velocity-dimension showed in figure 4 was made by calculating the mean value of attenuation and velocity values on each dimension. The graph analysis shows that after  $L_{22}$  the attenuation has the

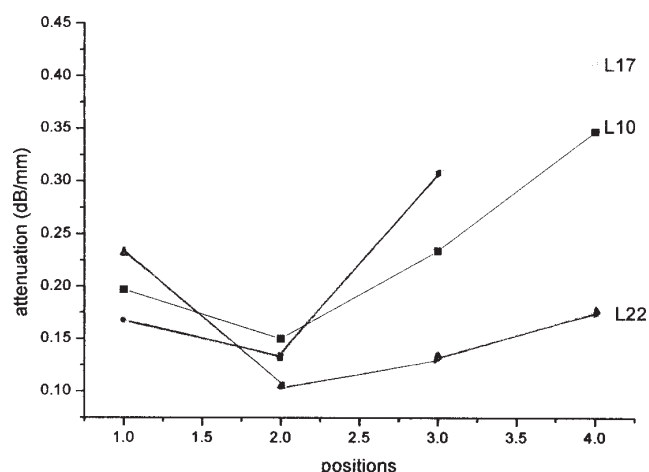


Fig. 3 Ultrasonic attenuation on each dimension

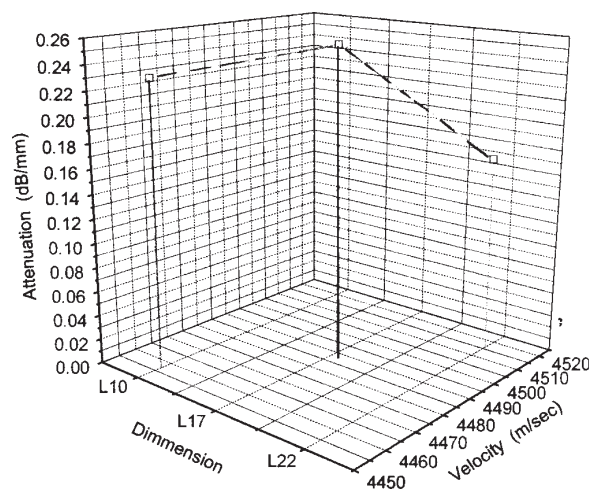


Fig. 4 3D graphs, attenuation-velocity-dimension

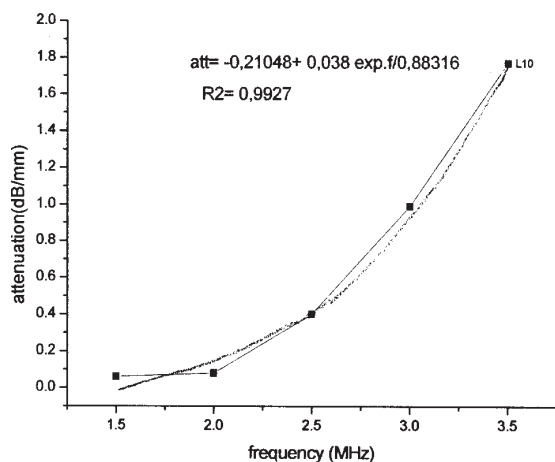


Fig. 5 Attenuation vs. frequency for  $L_{10}$

smallest value (0.162 dB/mm) and the velocity has the biggest value (4516.25 m/s), followed by  $L_{10}$  with attenuation 0.252 dB/mm and velocity 4457 m/s and  $L_{17}$  with attenuation 0.254 dB/mm and velocity 4490 m/s.

Applying UCSEM, one determined the value of velocity using relations (1) and (2) and of attenuation using relation (3). In the frequency domain, by FFT and applying the relation (4), the graph  $\alpha=f(\text{frequency})$  was drawn for  $L_{10}$  in figure 5 and for  $L_{22}$  in figure 6.

The analysis of the graph  $\alpha=f(\text{frequency})$  from figure 5 for  $L_{10}$  shows a good concordance between theory and experiment being also confirmed by the equation  $R^2=0.9927$  having the relation

$$\alpha_{10} = -0.21048 + 0.038 \cdot e^{-f/0.88316} \quad (5)$$

If one analyzes the same graph for  $L_{22}$  (fig. 6) can be noticed a deviation from the theoretical curve in the range 7MHz- 9 MHz also confirmed by  $R^2=0.95$ .

The relation for the theoretical curve is the following:

$$\alpha_{22} = -0.01867 + 0.04527 \cdot e^{-f/5.5708} \quad (6)$$

The comparative analysis of the 2 graphs from figure 5 and 6 shows that for  $L_{10}$ , at small frequencies, the attenuation shows big values (for example,  $f=3.5$  MHz and  $\alpha = 1.77$  dB/mm) and for  $L_{22}$ , for a big frequencies range  $2.5 \times 10^6$ - $13.7 \times 10^6$ , the attenuation varies between 0.07-0.51 dB/mm.

## Conclusions

In this work, the authors study the behavior of a sample of alkali halides crystals (KCl) at the interaction with ultrasounds. There are determined the acoustical-spectral

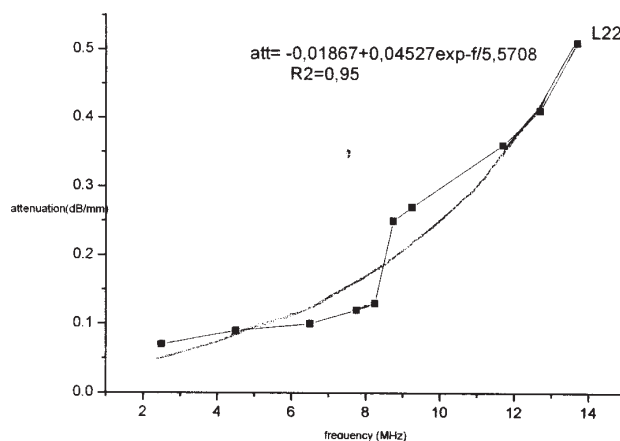


Fig. 6 Attenuation vs. frequency for  $L_{22}$

parameters in the time-frequency domains, after the 3 dimensions  $L_{10}$ ,  $L_{17}$ ,  $L_{22}$  of the sample. The ultrasonic equipment used here consisted of IPR-100, A/D-90 and SMC-4 from PAC (Physical Acoustic Corporation). The piezoelectric transducer has a 5 MHz resonant frequency. The experimental data that could be obtained by using the software UCSEM in real time, elaborated in the laboratory, show a minimum ultrasonic attenuation and a maximum propagation velocity of ultrasounds after the dimension  $L_{22}$ . The experimental researches regarding the growth of KCl crystal showed that the pull-axis is after  $L_{22}$ . The values of acoustical-spectral parameters that were obtained after the dimension  $L_{22}$ , show that the physical losses after this dimension are minimum which prove that ultrasounds propagation it is not affected by the scattering or absorption processes. For this reason, one assumed that the pull-axis is ultrasounds transparent. The validity of experimental data determined by the authors is confirmed by the theoretical relations (5) and (6) for the two dimensions  $L_{10}$  and  $L_{22}$  and also by the correlation coefficients  $R^2=0.9927$  for  $L_{10}$  and  $R^2=0.95$  for  $L_{22}$ . The interaction ultrasounds-KCl (alkali halides crystals) by the determined acoustical-spectral parameters, allow the discovery of new methods for evaluating internal loss mechanisms caused by microstructural modifications.

## References

1. GALT, I.K., Mechanical properties of alkali halides crystals, Technical report nr. 45, 1947
2. ARTMAN, R.A., Ultrasonic internal conical refraction in potassium chloride, JASA, pg. 493-498, 39 nr. 3, 1966
3. PAPADOKIS, P.E., The propagation of ultrasonic waves in alkali halide single crystals, JASA, 6, 1962

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