SENSOR PROPERTIES OF CADMIUM SULPHIDE (CDS) THIN FILMS IN SURFACE ACOUSTIC WAVE SYSTEM - PRELIMINARY RESULTS

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Presented here are the preliminary results concerning a cadmium sulfide(CdS) thin films investigations in a Surface Acoustic Wave dual-delay line systems. The CdS films has been prepared by an open-boat, physical vapor deposition (PVD) process using chemically prepared CdS powder as starting material. The thicknesses of the CdS films was about 115nm and 268nm. These CdS films have been investigated from the point of view their sensitivity towards: nitrogen dioxide, sulphur dioxide, ammonia and H_2S gases with different concentrations in dry air.

Keywords: cadmium sulfide film , surface acoustic wave, sensor properties

1. INTRODUCTION

Conducting polymers are a new class of materials with a potent application in a number of growing new technologies, such as energy storage [1,2], molecular recognition [3,4] and opto-electronic devices [5,6]. All conducting polymers exhibit highly reversible redox behaviour with a distinguishable chemical memory and hence have been considered as prominent new materials for the fabrication of chemical sensors [7,8].

Cadmium sulfide, the mineral *Greenockite*, is an hexagonal, orange crystal with specific gravity of ~4.8g/cm^3 and Mohs hardness of 3.8. Synthetic Cadmium pigments based on Cadmium sulfide are valued for their good thermal stability in many polymers, for example in engineering plastics. Cadmium sulfide has useful properties for optoelectronics, being used in both photosensitive and photovoltaic devices. Cadmium sulfide is an important II–VI semiconductor with a direct band-gap of 2.4 eV at room temperature, and it receives a wide range of research interest because of their unique properties and their wide variety of potential applications. For instance, for laser light-emitting diodes, solar cells, non-linear optical,

optoelectronic and electronic devices. The most important properties of CdS are shown in Table.1.

Table.1 Properties of CdS

Application fields:	IR optics, polarizers, beamsplitters, λ /2 and λ/4 waveplates; substrates;
Structure	Wurtzite (Hexagonal)
Density:	4.825 g/cm^3
Young's Modulus:	45 GPa
Coef. of Thermal Expansion (500 K):	α_1=6.26×10^{-6}/K; α_3=3.5×10^{-6}/K
Specific Heat:	0.47 J/gK
Thermal conductivity (at 25 ^{o}C):	0.2 W/cmK
Max. Transmittance (λ =2.5-15 μm):	≥ 71 %
Absorption Coef. (λ =10.6 μm):	≤ 0.007 cm^{-1} (including 2 surfaces)
Refractive index (λ =10.6 μm):	2.2
Max. crystal diameter/length:	∅ 40×30 mm

During the past decades, various methods have been applied to fabricate cadmium sulfide nanocrystallines, such as electrochemically induced deposition , thermal decomposition , laser-assisted catalytic growth method , ultrasound irradiation, solvothermal method, and hydrothermal method [9].

In Institute of Physics SUT – vacuum evaporation technology have been applied for manufacturing of CdS thin films 115nm and 268nm (with yellow colour) in a SAW method.

In this work, we report on sensor properties of as-deposited thin films of cadmium sulfide (CdS) by PVD technique at about 700^{0}C from synthesized CdS powder. The investigations have been performed by SAW method from the point of view ofr sensitivity towards: nitrogen dioxide, sulphur dioxide, ammonia and H_2S gases with different concentrations in dry air.

2. EXPERIMENTAL

Surface Acoustic Waves (SAW) are very attractive due to their remarkable sensitivity in a specific configuration of the sensor structure, as well as their small size, low power consumption and frequency measurements [10-12]. The sensor structure in SAW method is shown in Fig.1. In such a sensor structure we can use both the acoustoelectric interaction (between the electric potential associated with surface wave and the charge carrier in the CdS film) and the mass effects [13-15]. For rather high resistance CdS samples (even above 200 G Ω) we expect mainly the mass interactions.

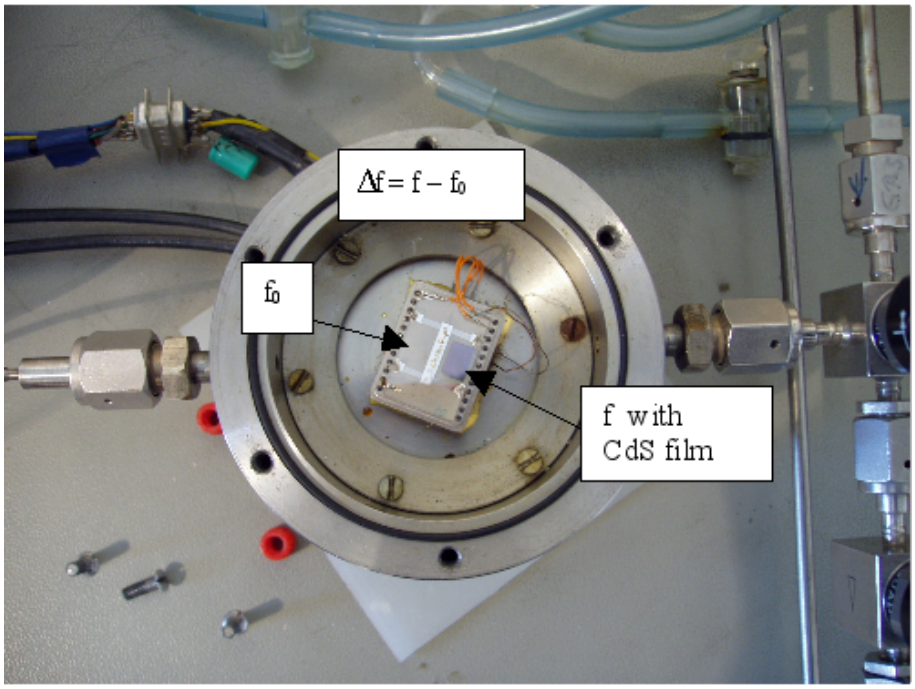

Fig.1. The sensor structure with CdS thin film in a dual delay line configuration on piezoelectric lithium niobate substrate placed in a measuring chamber

The experimental set-up for acoustic sensor is based on frequency changes in a surface acoustic wave dual delay line system, which is nowadays well known – Fig.2. On a piezoelectric $LiNbO_3$ substrate, two identical acoustic paths are formed, using interdigital transducers. Next, a CdS thin film structure is formed in the measuring line in vacuum deposition processes. The second path serves as a reference and can compensate small variations of temperature and pressure. Both delay lines are placed in the feedback loop of oscillator circuits and the response to the particular gas of the active is detected as a change of the differential frequency Δf, i.e. the difference between the two oscillator frequencies f and f_0.

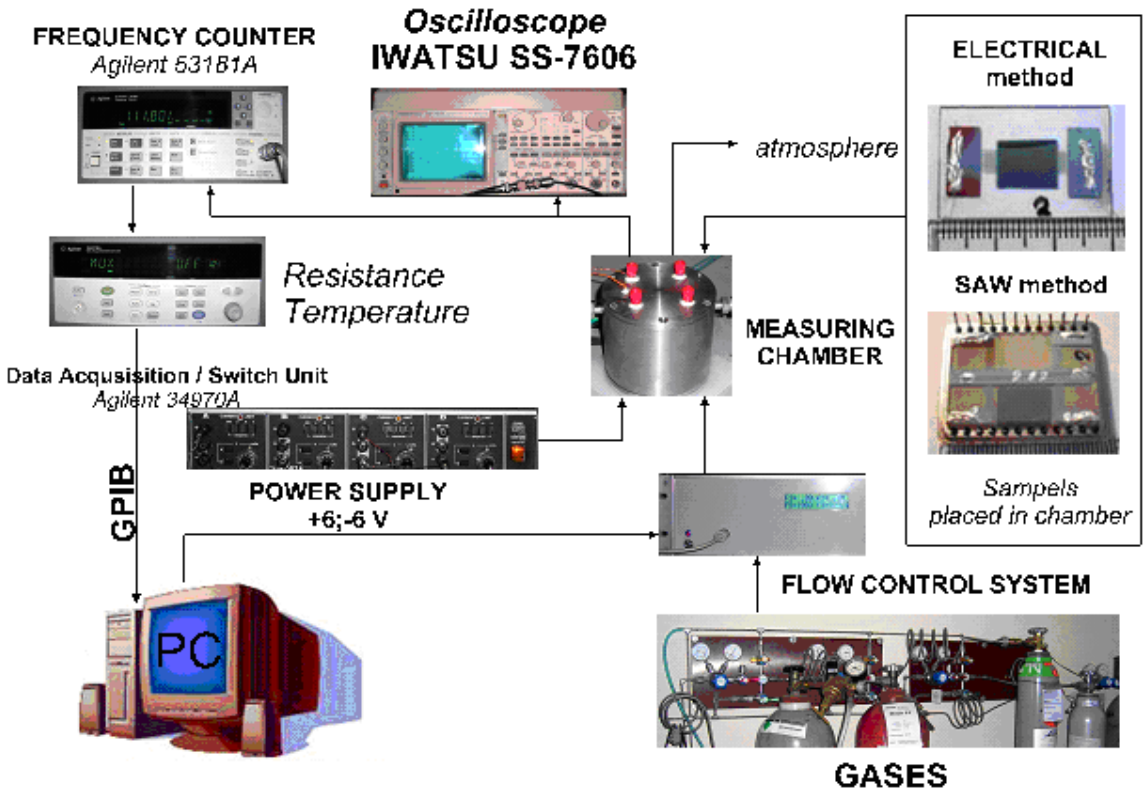

Fig.2. Schematic diagram of the experimental set-up

The investigated CdS films with thicknesses of about 115 and 268 nm, were made by means of the vacuum-sublimation method, using a special aluminium mask and molybdenum boat. The source temperature was about 700 ^{o}C and the thickness was measured by the interference method. A copper-constantan thermocouple was used to control the temperature. The total flow rate of 1000ml/min was used during all the measurements. The volume of the measuring chamber was about 30cm^3. The sensor was tested in a computer-controlled system. Gases of 99.999% pure hydrogen and 99.998% pure NO_2, SO_2, NH_3 in dry air were mixed using mass flow controllers (Bronkhorst Hi-Tech). The temperature was measured using a thermocouple adjacent to the structure.

3. RESULTS

Examples of interaction of the obtained CdS film with 115nm in SAW system in sulphur dioxide are shown in Fig.3, with NO_2 in Fig. 4, with NH_3 in Fig.5 and with H_2S in Fig.6.

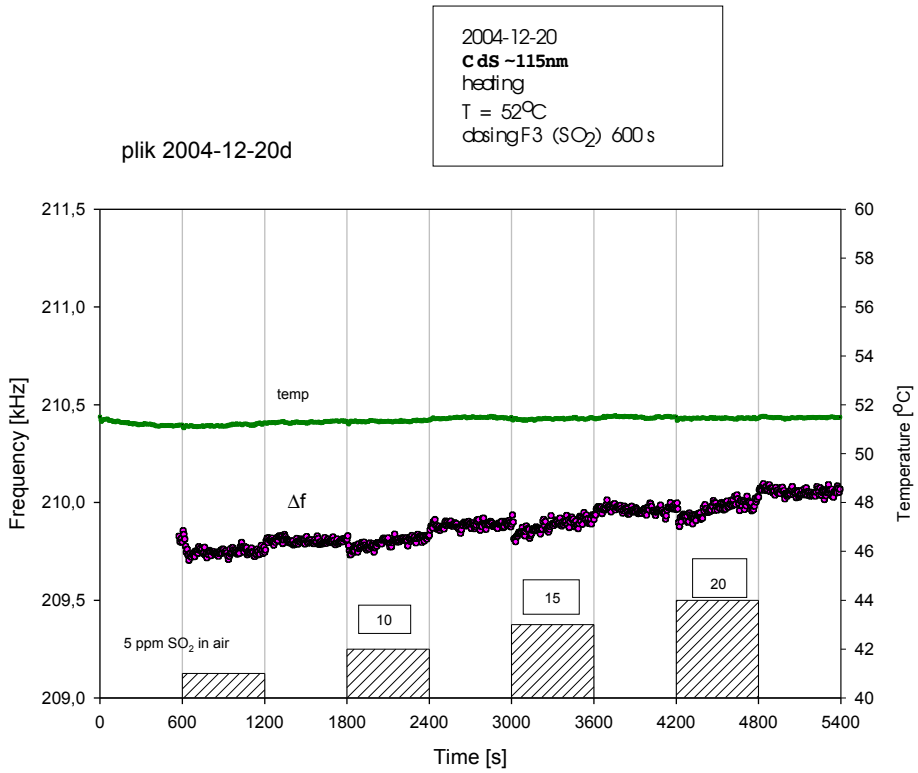

Fig.3. Interaction of CdS film (~115nm on $LiNbO_3$ Y-Z substrate) with different concentrations of sulphur dioxide (SO_2) in synthetic air at temperature (~52^{0}C)

A very small interactions of the investigated film of CdS can be observed for the measurements with SO_2 gas even at higher temperatures (~52^{0}C). The interaction is on the level of ~100Hz . The resistance of the sample is above of the range of the Electrometer Keithley 614 (200GΩ). So monitoring of the resistance cannot be performed.

In Fig.4 we can observe an increase of differential frequency of the sample under the influence of various concentrations of NO_2 in synthetic air (between 1000 and 5000 ppm). The regeneration of the sample at measurement temperature ~56^{0}C is quite good.

The decrease of differential frequency of the sample (but for lower frequency mode) is observed for interaction with ammonia – Fig.5. The changes in frequency are between 250Hz for 1000ppm to 500Hz for 3000ppm NH_3 in dry air.

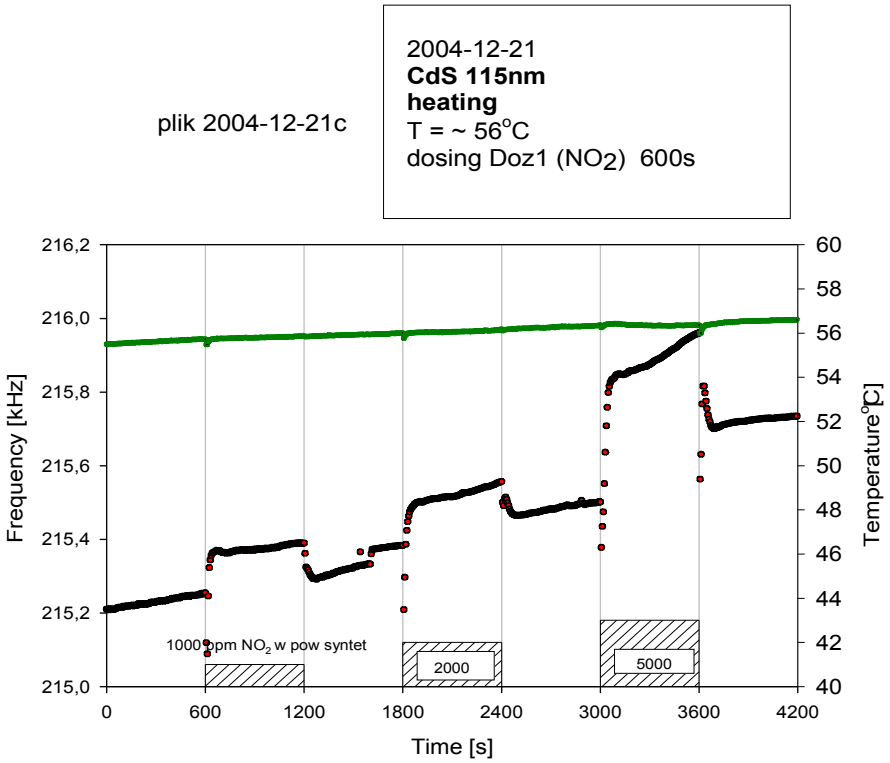

Fig.4. Interaction of CdS film (~115nm on $LiNbO_3$ Y-Z substrate) with different concentrations of NO_2 in synthetic air at temperature (~56^{0}C)

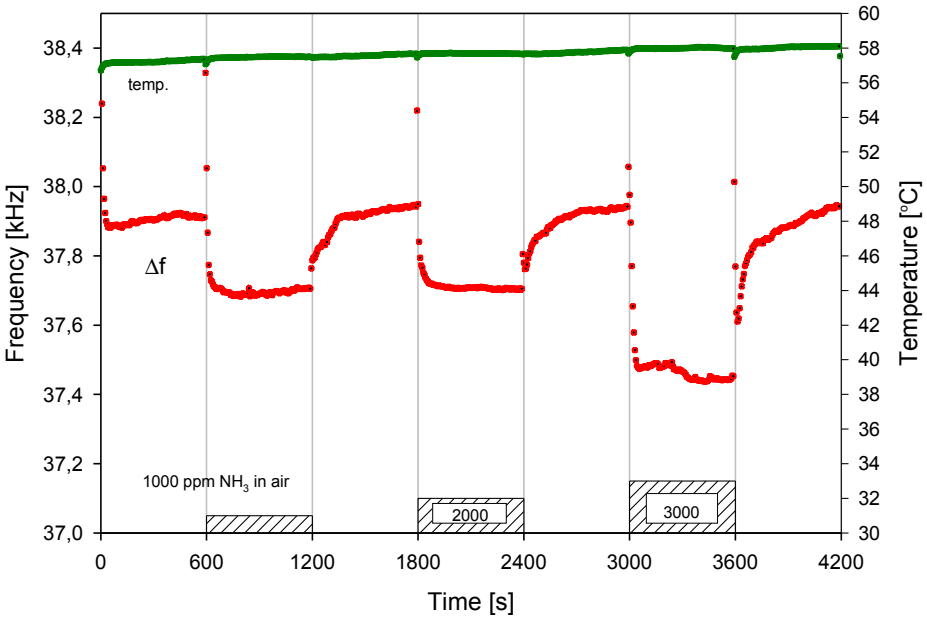

Fig.5. Interaction of CdS film (~115nm on $LiNbO_3$ Y-Z substrate) with different concentrations of NH_3 in synthetic air at temperature (~58^{0}C)

For interaction with H_2S a lack of regeneration at lower temperatures and good regeneration but small interactions at higher temperatures is clearly observed – Fig.6.

In Fig.7 an example of interaction of the second film of CdS (~268nm) with sulphur dioxide is shown. The changes in frequency Δf are not great even for rather high gas concentrations – between 1000 – 5000 ppm in dry air.

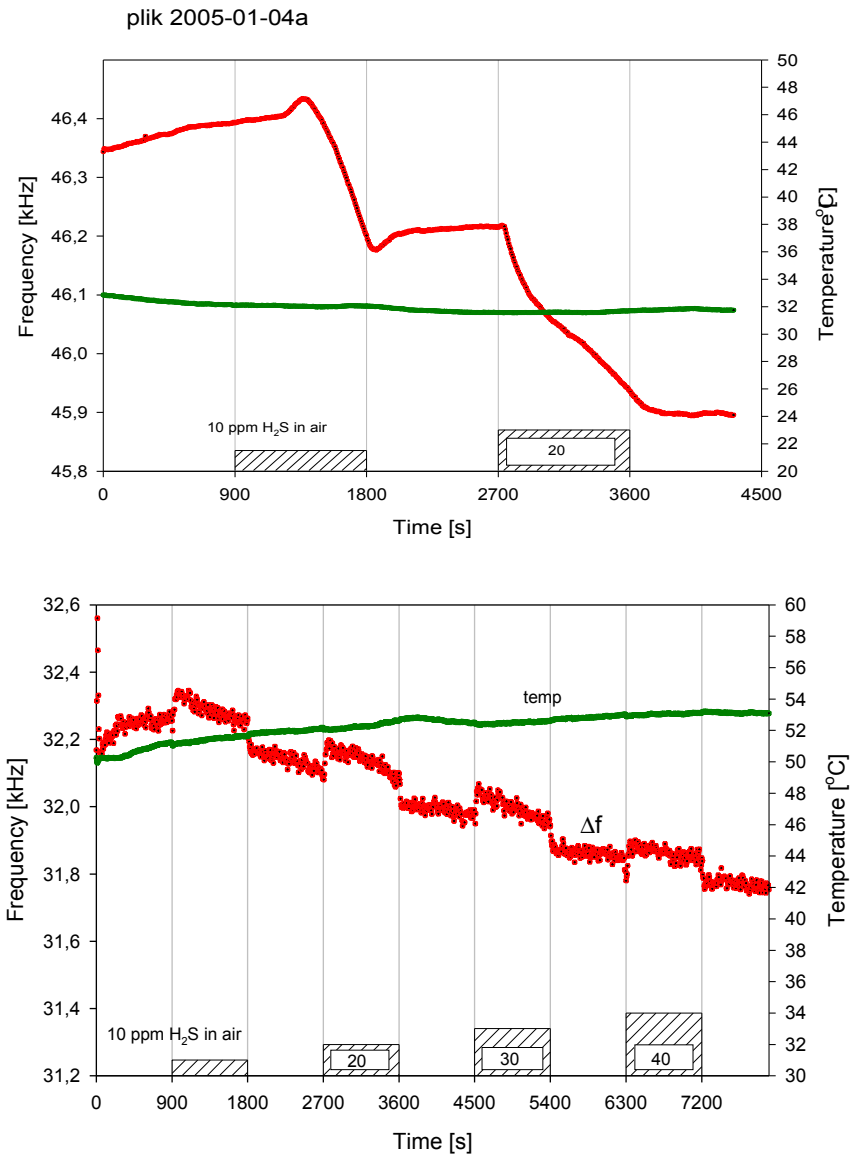

Fig.6. An examples of preliminary acoustic measurements for CdS 115nm with different concentrations of H_2S at ~32^{0}C (upper) and ~53^{0}C (lower graph).

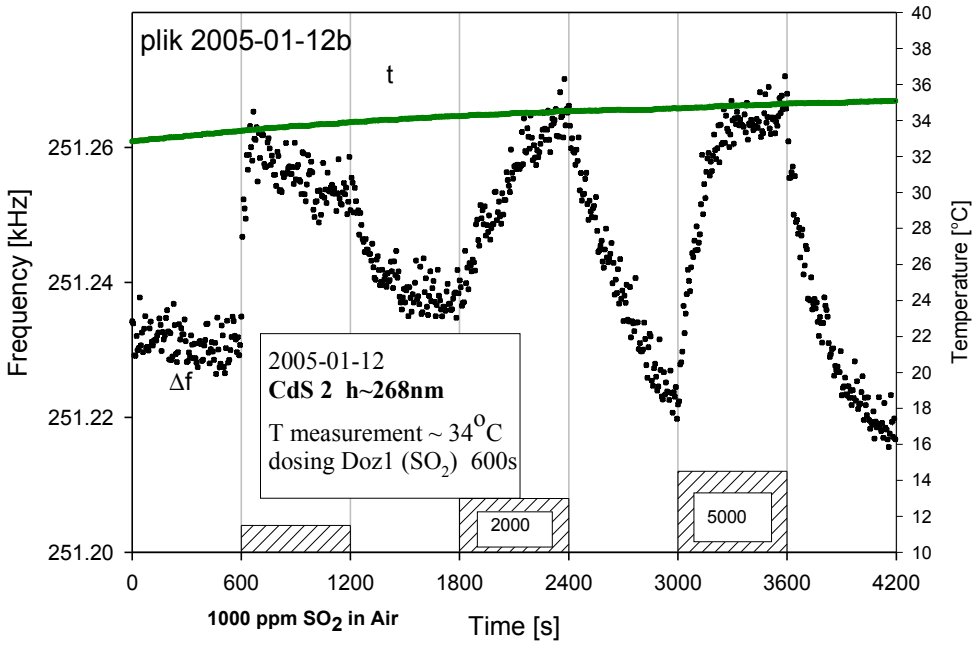

Fig.7. Interaction of CdS film (~268nm on $LiNbO_3$ Y-Z substrate) with different concentrations of sulphur dioxide (SO_2) in synthetic air at temperature (~34^{0}C)

4. CONCLUSIONS

The cadmium sulfide films has been prepared by an open-boat, physical vapor deposition (PVD) process using chemically prepared powder as starting material. The thicknesses of the CdS films was about 115 and 268 nm. These CdS films have been investigated from the point of view their sensitivity towards: nitrogen dioxide, sulphur dioxide, ammonia and H_2S gases with different concentrations in dry air. Preliminary measurements of this two CdS films have been performed using an acoustic method with Surface Acoustic Waves. This method can be successfully used even when the resistance of the sample is very high – above 200GΩ.

For CdS 115nm film, good and very *repeatable* interaction with NH_3 at higher temperatures (above 50^{0}C) has been observed.

Whereas for interaction with H_2S lack of regeneration at lower temperatures and good regeneration but small interactions at higher temperatures is clearly observed.

For the sample with a CdS thickness of 268nm an interaction with SO_2 on the level 50Hz is observed but only for higher concentrations.

The best results were achieved after many cycles of interaction and at higher temperatures.

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