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OPTIMIZING THE SIZE AND COMPOSITION OF SOLID STATE/EPR DOSIMETERS

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Intrudaction:

In the last three decades Electron Paramagnetic Resonance (EPR) spectroscopy has expanded significantly in the field of practical applications. In case of high energy radiation accidents or regular inspections, it is important to determine the exact dose absorbed at given position in the space. In every laboratory and work places that ionizing radiation is used, is very important to have dosimeters for current control of the irradiator. Solid State/Electron Paramagnetic Resonance (SS/EPR) dosimeters with different shapes are used. The most popular and widely used are cylindrical dosimeters. The diameter of the cylindrical samples is very important in quantitative EPR estimations and it is one of the most critical dimensions because its increase is connected with the penetration of the studied material in the electric component of the microwave field in the EPR cavity and leads to loss of EPR spectrometer sensitivity.

The aim:

Invention of solid state/EPR dosimeters allowing the highest possible sensitivity at determination of the absorbed dose ionizing radiation .

Cylindrical solid state/EPR dosimeters

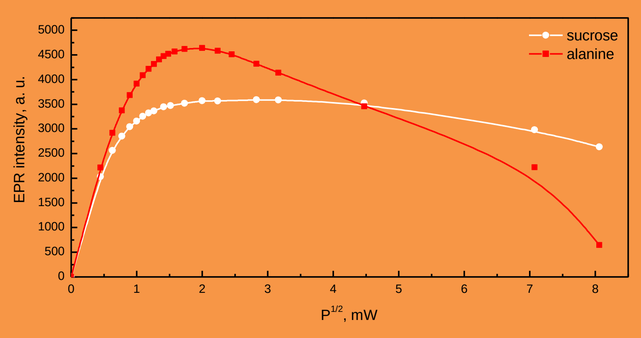
Experimental:

Two type of dosimeters were prepared:
1. Alanine (sucrose)/paraffin (60 : 40 %)
2. Alanine (sucrose)/paraffin/Mn-MgO_2 - (60 : 38 : 2 %)

From these mixtures cylindrical dosimeters with diameters 1, 2, 3 and 4 mm and high 10 mm were extruded.
The dosimeters were irradiated with gamma rays in dose range 3 – 80 kGy. The irradiation was performed in air at room temperature. After irradiation all samples were kept in closed plastic bags at room temperature and were stored in dark.

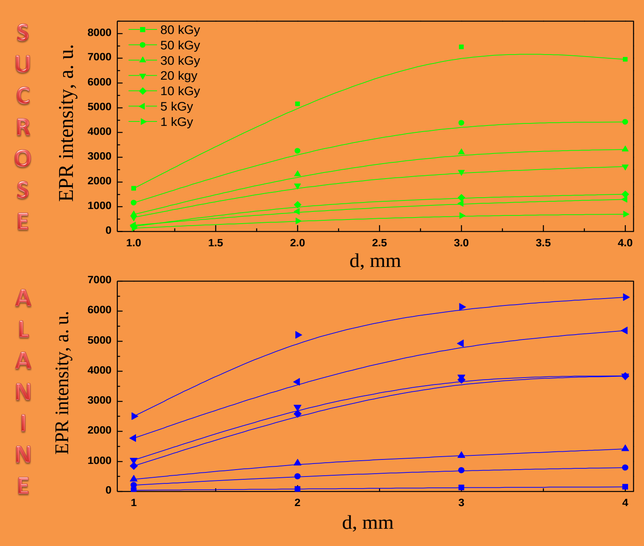
Dependence of the EPR response of sucrose and alanine dosimeters on the applied microwave power.

It is well known that a quantitatively correct analysis of EPR spectrum requires adjustment of some parameters on EPR spectrometer such as microwave power (P) and modulation amplitude (MA). The dependence of the EPR response on the applied microwave power was studied with sucrose and alanine dosimeters with diameter 3 mm irradiated with 10 kGy gamma rays. The results clearly show that whereas sucrose dosimeter is saturated at ca. 1 mW, the magnitude of the microwave power for the alanine is still increasing saturating it up to ca. 2.5 mW. The averaged peak-to-peak intensity of the third (g=2.0330) and fourth (g=1.9810) Mn^{2+} lines remains unchanged up to about P = 1mW and then significantly increases. This effect was explained by the fact that at P ≥1 mW the EPR spectrum of Mn^{2+} is under saturation and thus it is no longer linearly dependent on $P^{1/2}$. Therefore, for self-calibrated dosimeters the microwave power must be less than 1 mW. In regard to modulation amplitude 0.5 mT was chosen.

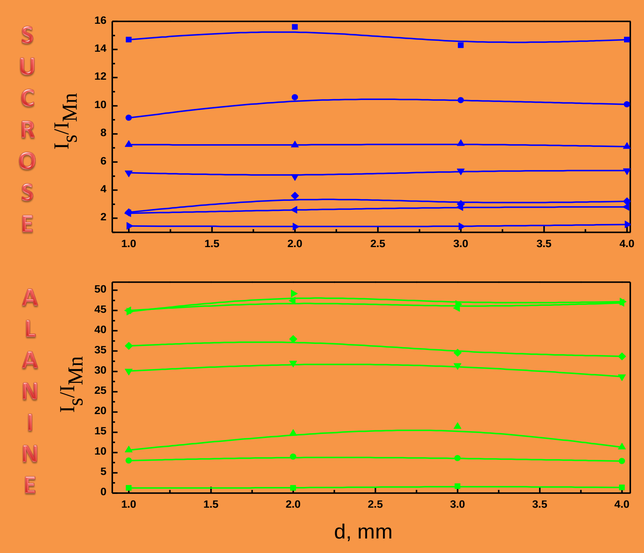


Influence of the diameter of the cylindrical SS/EPR dosimeters on their response.

Quantitative EPR is very difficult approach.
For the aim of dosimetry, it is a relative method in which is not necessary determination of absolutely concentration of radiation induced free radicals.
The number of these paramagnetic centers is proportional of absorbed dose ionizing radiation and it is in touch with EPR signal intensity after irradiation.
The influence of the diameter of cylindrical dosimeters on the EPR response was studied at 1 mW microwave power and 0.2 mT modulation amplitude in other to avoid some interference of the instrumental parameters.

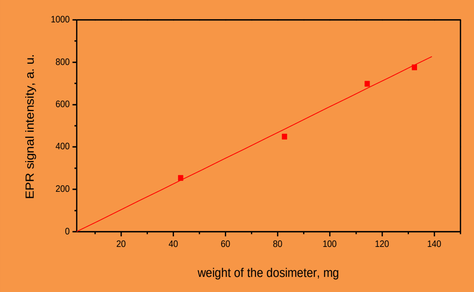


At absents of Mn in MgO_2 the EPR signal intensity (I_s) increase with increasing of the diameter of the dosimeters for the equal doses. It is logical because the quantity of the RSM increases. The intensity of the EPR signal of the dosimeters with 4 mm diameter is almost the same as these of 3 mm diameter especially for higher doses where even slowly decreased. For self-calibrated type dosimeter the ratio I_s/I_{Mn} is used instead of Is where I_s and I_{Mn} are the intensities of the RSM and standard respectively. It is seen that in this case the EPR response not depends on the diameter of the samples.

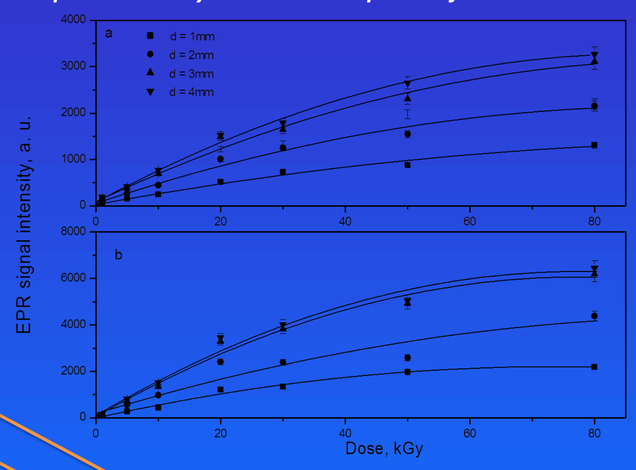


The EPR signal intensity function of the weight of the dosimeters.

The slope of the EPR response for cylindrical dosimeters with diameter 3 and 4 mm is higher than those for diameter 1 and 2 mm. It can be explained with higher quantity RSM in these dosimeters prove for which is the fact that the dependence EPR intensity/weight of the samples is linear. Increasing the diameter over 4 mm will be connected with decreasing of the EPR response, calculated per sample weight. This effect is related by the penetration of the dosimeter into the electric component of the microwave field in the EPR cavity. From the other side, using a small sample diameter as 1 and 2 mm is unfavorable because it is connected with a loss of sensitivity.

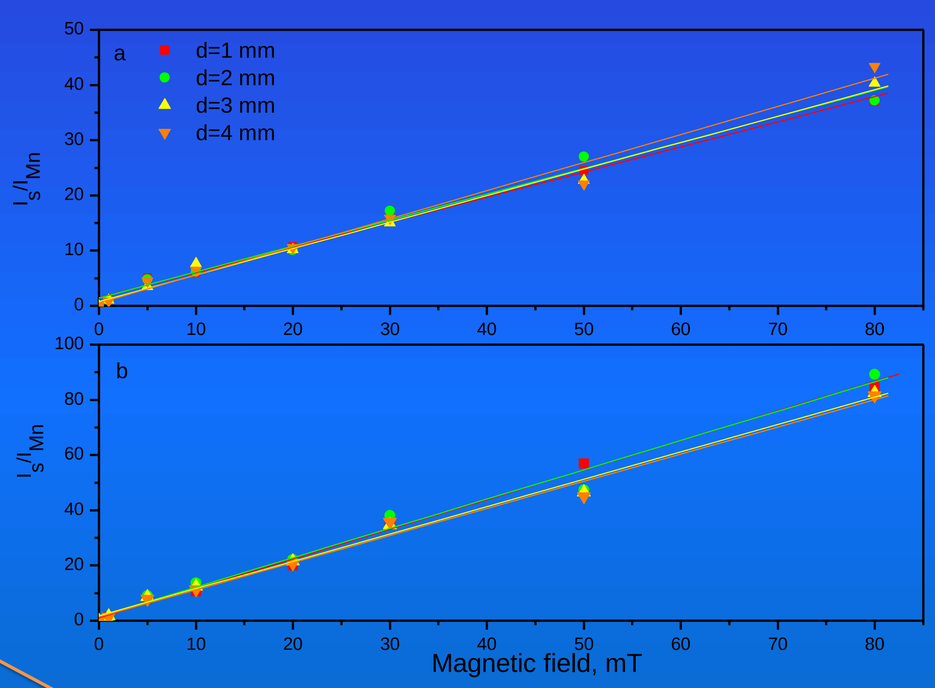


Comparative study on the EPR response of the dosimeters with different diameters, in presence and absence of internal standard Mn^{2+}/MgO_2.



It was found that the slope of the EPR response for cylindrical dosimeters with various diameters is different and it is linear to 20 kGy.

For self-calibrated dosimeters Mn^{2+}/MgO_2 is used as an internal standard because its EPR properties remains constant after irradiation with gamma rays up to 100 kGy and the diamagnetic matrix is EPR silent. In the alanine and sucrose dosimeters Mn^{2+} lines can be easily and unambiguously distinguished from those of the RSM. The simultaneous recording of the spectrum of the RSM and standard under the same experimental conditions strongly reduces the uncertainties in the dose estimations with the prepared dosimeters. The ratio I_s/I_{Mn} is independent of the spectrometer at given spectrometric settings and depends only on the absorbed dose.



In this case, the ratio I_s/I_{Mn} is not influenced by the positioning of the dosimeter along the z (sample) axis of the EPR cavity caused by the non-linear distribution of the microwave energy. The presence of internal standard lead to linear EPR response over the investigation region of absorbed dose (3-80 kGy) as opposed to data for non-calibrated dosimeters.

CONCLUSIONS:

I In the sucrose (alanine) solid state/EPR dosimeters the intensity of the EPR signal increased linearly with the absorbed dose up to 20 kGy and depends on the diameters of the dosimeters.

II In the self-calibrated dosimeters, the EPR signal intensity increased linearly with the dose in the all investigation region of dose and the EPR response is independent of the diameters of the dosimeters.

III The optimal diameter of cylindrical type solid state/EPR dosimeters from the type RSM/ binder material is 3 to 4 mm.

IV The optimal composition is RSM/ binder material/Internal standard independent from the diameter of the dosimeter.

The EPR response of self-calibrated dosimeters is independent on the diameter of the samples.

Acknowledgments:

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