UNIVERSITÀ DEGLI STUDI DI MILANO
DIPARTIMENTO DI FISICA

CHARACTERIZATION OF PHENOLIC SOLID STATE PELLETS FOR ESR DOSIMETRY WITH RADIOTHERAPEUTIC PHOTON AND ELECTRON BEAMS

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INTRODUCTION

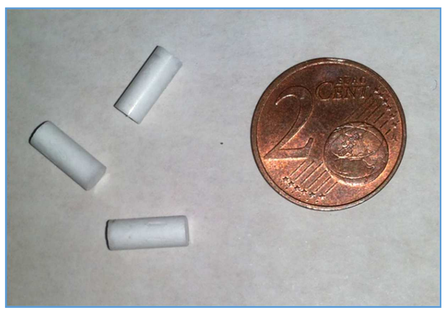
There is considerable literature on the use of alanine as material for dosimetric application by using the Electron Spin Resonance (ESR) spectroscopy. The main application of alanine/ESR dosimetry are related to high-dose standardization and dose control in radiation processing. In case of medical dosimetry, the main drawback of this material is the limited sensitivity below 2.5 Gy. Therefore, more sensitive materials than alanine are needed to make the ESR dosimetry competitive with other dosimetry systems, especially for radiation therapy applications [1]. Our research group has started an investigation of the ESR response of some phenols compounds for possible ESR dosimetric applications with suitable features, such as high efficiency of radiation-matter energy transfer and radical stability at room temperature [2,3]. In this work we report the ESR investigation of phenol pellets exposed to clinical photon and electron radiotherapy beams [4,5].
This research activity was carried out in collaboration with Physics Department of University of Palermo, the RadChemLab of the University of Pavia and Radiotherapy Department of the Hospital "Maggiore della Carità" in Novara.

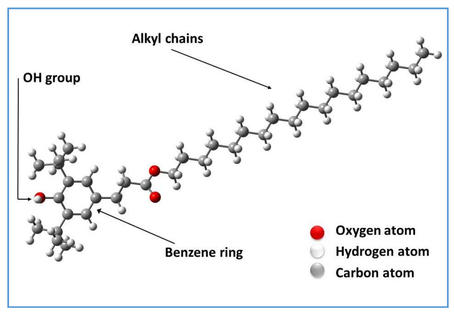
MATERIALS AND METHODS

PHENOL PELLETS

(Left) Phenol pellets (*d ~4.0 mm, h ~7.0 mm, mass ~110 mg*) were produced at the RadChemLab using a blend of paraffin (10% by weight) as binder, and IRGANOX® 1076.

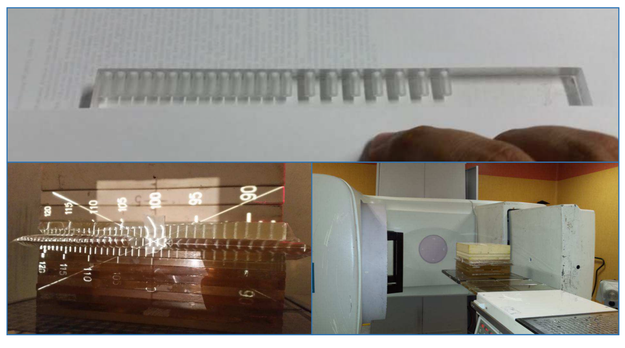
(Right) IRGANOX 1076 structure formula shows a OH group of the phenol that is protected by ramified alkyl chains. The phenol ring is linked also to a long linear chain. Following irradiation, an unstable radical cation is formed first. The unstable radical cation subsequently decomposes to give a proton and a stable phenoxy radical.





IRRADIATIONS

Photon and electron irradiations at various energies were performed with clinical LINAC at the radiotherapy department of the A. O. Maggiore della Carità, Novara (Italy).
The energies used are respectively 7, 10 and 14 MeV for electrons and 6 MV for photons. Doses delivered to the samples are from 1 to 13 Gy.

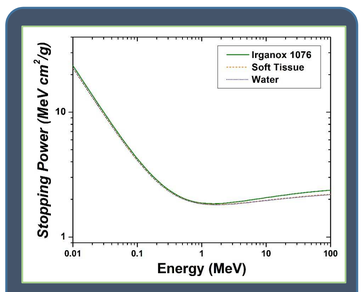


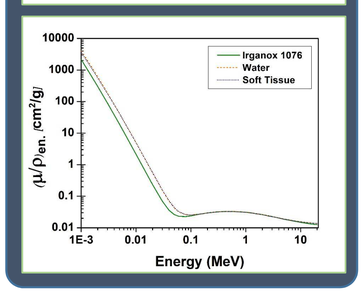
ESR MEASUREMENTS

The ESR measurements were made with a Bruker ELEXSYS E580 spectrometer acting in the X-band (~ 9.80 GHz) . The first derivative of the ESR absorption spectrum was measured at room temperature.

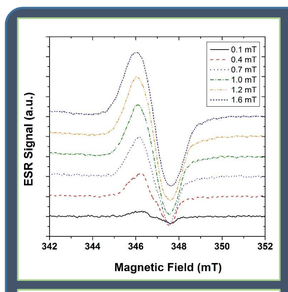
RESULTS

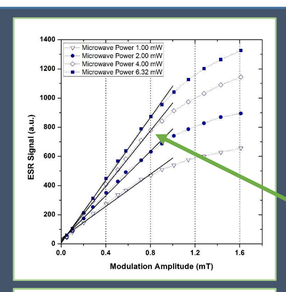
TISSUE EQUIVALENCE

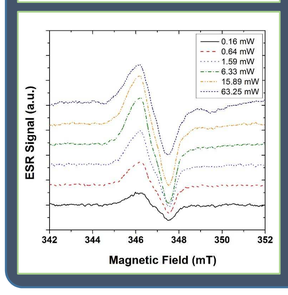


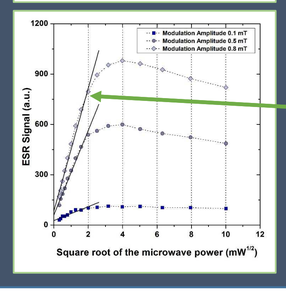


PRELIMINARY STUDIES FOR ESR PARAMETERS



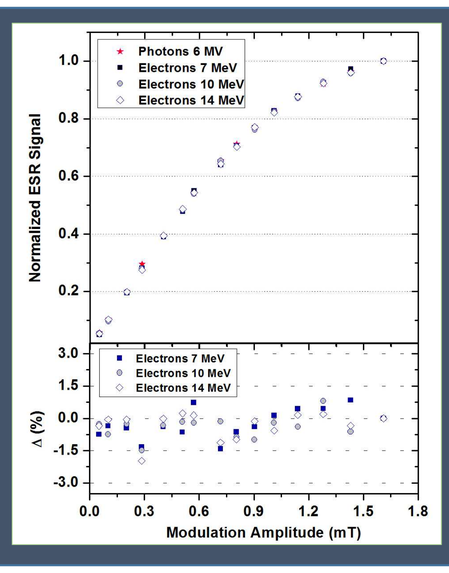


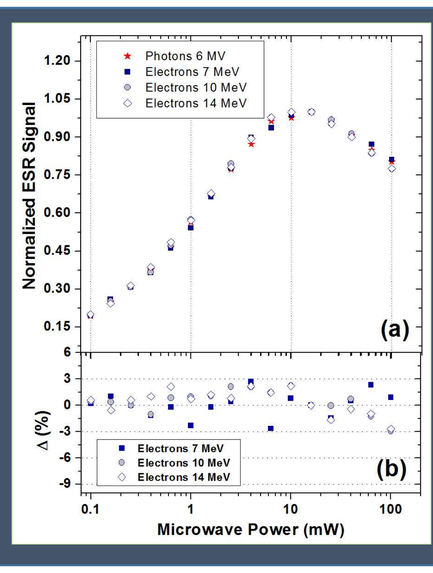




A Modulation Amplitude of 0.8 mT and a Microwave Power of 4.00 mW were chosen as best values

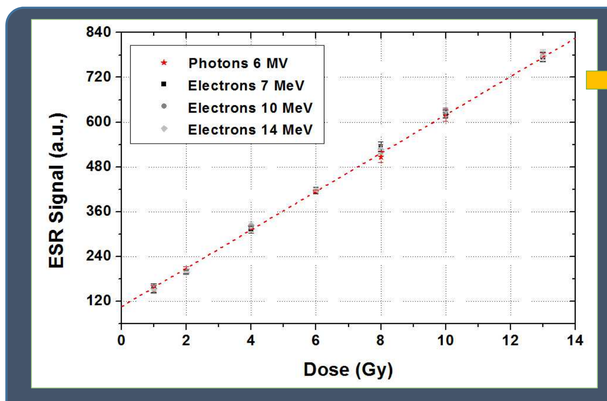
ESR RESPONSE TO VARIUOS BEAMS





The ESR signal features for photon and electron exposure are independent of radiation beam and energy

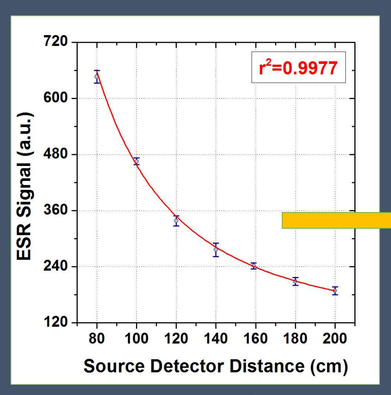
ESR DOSE RESPONSE

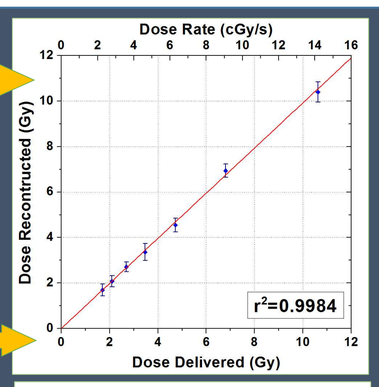


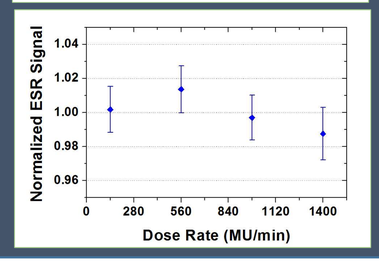
$$ESR_{SIGNAL} = m \times Dose + q$$

Beam	Energy	q±Δq	m±Δm	R^2
Photons	6 MV	100±4	52.6±0.6	0.9992
Electrons	7 MeV	99±4	52.7±0.7	0.9990
Electrons	10 MeV	100±4	52.6±0.7	0.9990
Electrons	14 MeV	99±5	53.3±1.0	0.9983

ESR DOSE RATE RESPONSE

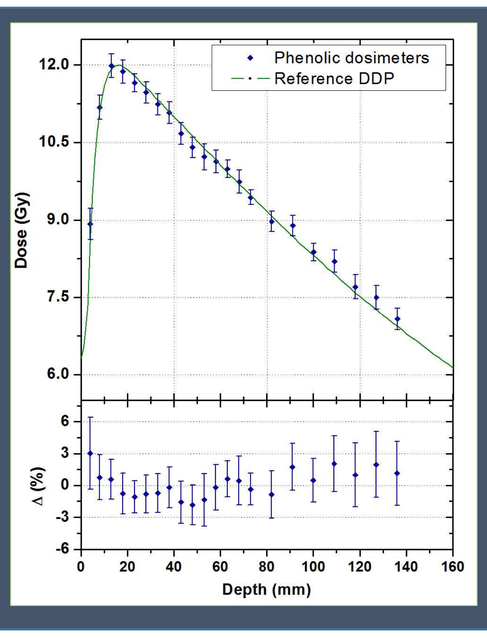




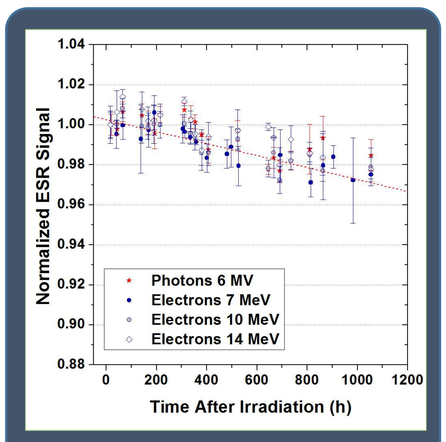


$$ESR_{SIGNAL} \propto {}^{1}/_{R^2} + q$$

DEPTH DOSE PROFILE (DDP)



SIGNAL STABILITY



Signal loss about 4% in the first 1000 hours after irradiation

SUMMARY AND CONCLUSIONS

- ✓ The ESR signal proved to increase linearly with increasing the dose in the investigated interval 1-13 Gy for each type of beams.
- ✓ The presence of an intrinsic background signal limits the minimum detectable dose to a value of approximately 0.7 Gy.
- ✓ Reliable and accurate dose assessments were achieved, independently of the dose rate.
- ✓ The signal is stable in the first 1000 hours after irradiation: signal loss about 4%.
- ✓ The possibility of obtaining depth dose profile was investigated: good agreement between measured dose and the reference one.
- ✓ The phenols shows radiometric features that designate them as new materials for ESR dosimetry.

REFERENCES

1) O. Baffa and A. Kinoshita, *Clinical applications of alanine/electron spin resonance dosimetry*, Radiation and Environmental Biophysics, (2014) DOI:10.1007/s00411-013-0509-2.
2) M. Marrale, et al., *ESR response of phenol compounds for dosimetry of gamma photon beams*, Nuclear Instruments and Methods in physics research B (2014). DOI: 10.1016/j.nimb.2014.08.015.
3) S. Gallo, et al., *Testing and calibration of films of phenol compounds exposed to neutron field for EPR dosimetry.* Applied Radiation and Isotopes (2015). DOI: 10.1016/j.apradiso.2015.07.043.
4) S. Gallo el al., *ESR dosimeter material properties of phenols compound exposed to radio-therapeutic electron beams,* Nuclear Instruments and Methods in physics research B (2017) DOI: 10.1016/j.nimb.2017.06.004.
5) S. Gallo et al., *Characterization of phenolic pellets for ESR dosimetry in photon beam radiotherapy.* SUBMITTED on Radiation and Environmental Biophysics (2017).

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