T_2 Measurements in Tooth Enamel Using Electron Spin Resonance (ESR)

Participants: Daniel Katz, Emil Esrubilsky and David Costa

Mentors: Nir Dayan Ph.D candidate, Prof. Aharon Blank

Magnetic Resonance Lab, Schulich Faculty of Chemistry, Technion - Israel Institute of Technology

Motivation

In the case of a nuclear disaster such as an explosion or meltdown medical triage should include estimation of how much radiation the patient has absorbed.

Unfortunately current methods for estimating this are invasive and painful. With radiation deaths in the wake of such events often numbering in the tens of thousands, a cheap and portable method that can detect a person's radiation exposure would be invaluable.

When a tooth is irradiated, radicals are formed in the enamel layer that can be detected by electron spin resonance (ESR).

Background

ESR, sometimes denoted as electron paramagnetic spin resonance - (EPR) spectroscopy[1] is used in many fields of science for a variety of paramagnetic[2] samples, i.e. samples that contain one or more unpaired electrons in their valence shell otherwise called radicals.

ESR takes advantage of the magnetic resonance phenomenon. When a paramagnetic sample is introduced into a magnetic field, you can measure it using microwave radiation (9GHz ~ 100GHz) in the sample's magnetic resonance frequency: the frequency at which the radicals vibrate. This is like pushing a swing at the perfect time to amplify its movement or singing to break a glass.

The relaxation mechanism for T_1 is defined as spin-lattice relaxation where energy dissipates from the spins into the environment whilst T_2 is defined as spin-spin relaxation where energy dissipates from the spins to other spins. Figs 1+2.

Objective

The objective of the project is to explore the use of advanced ESR techniques in order to measure irradiated paramagnetic samples in specific dosages.

Methods

Teeth preparation - Teeth were irradiated by Cobalt 60 and Cesium 137 sources with doses from 1 to 1000 greys. Subsequently teeth were etched using acid while heated and sonicated for 200 minutes In order to achieve isolated enamel layer. Because only this layer contains the radicals.

A Constant wave spectrometer (CW) was used to determine the correlation between spin density and the radiation dose and source.

In order to identify the number of spins present in our tooth samples, the teeth were measured by themselves and then together with a quartz reference with a known number of spins. The weight of the samples was also measured in order to calculate their spin density. Fig 3.

Pulsed ESR - The relaxation time of T_2 was measured as a function of radiation dose in order to characterise the relationship between the dose and the resulting T_2.

In order to compare the results, T_1 was also measured to determine which method would best allow us to calculate the radiation level in an unknown sample.

In the equations below to gain the T_1 and T_2 relaxation times:

M = Magnetisation and M_0 = Initial Magnetisation

Experimental data was fitted to the equation in order to find the resulting T_1 and T_2 values.

Definitions

Spectroscopy - the study of how light and electromagnetic radiation interacts with matter

Paramagnetic - Having one or more unpaired electrons (radicals).

Resonance - The ability of a substance to absorb energy at a particular frequency.

Graphs

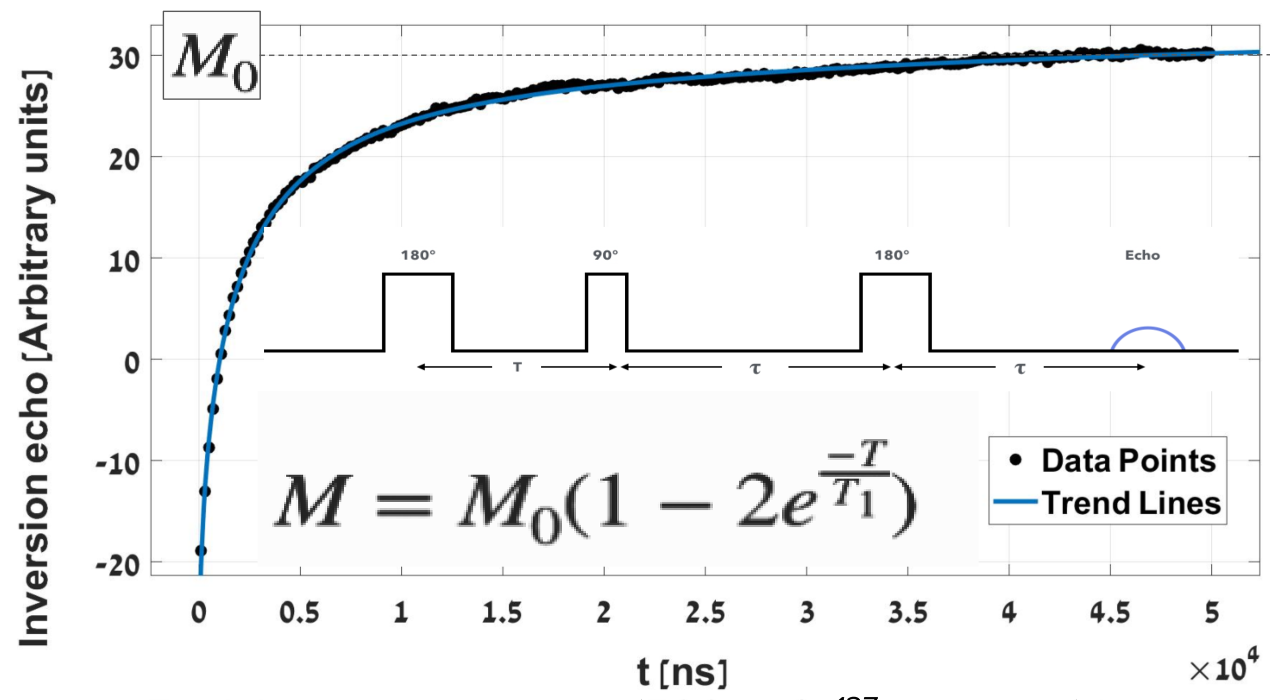

Fig 1: Inversion recovery (500gy Cs^{137} exposure) by a Pulsed ESR fitted to the T_1 equation. T_1 = 43 ± 32 µs

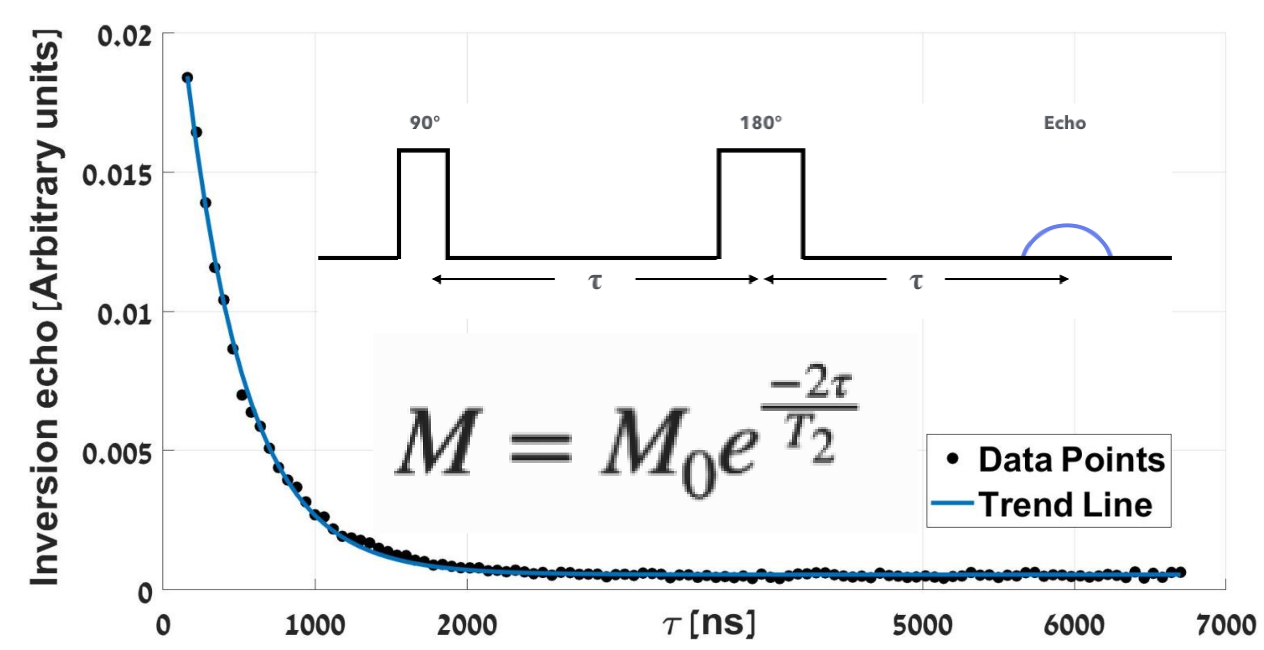

Fig 2: Echo decay (500gy Cs^{137} exposure) by a Pulsed ESR fitted to the T_2 equation. T_2 = 788.7667 ns.

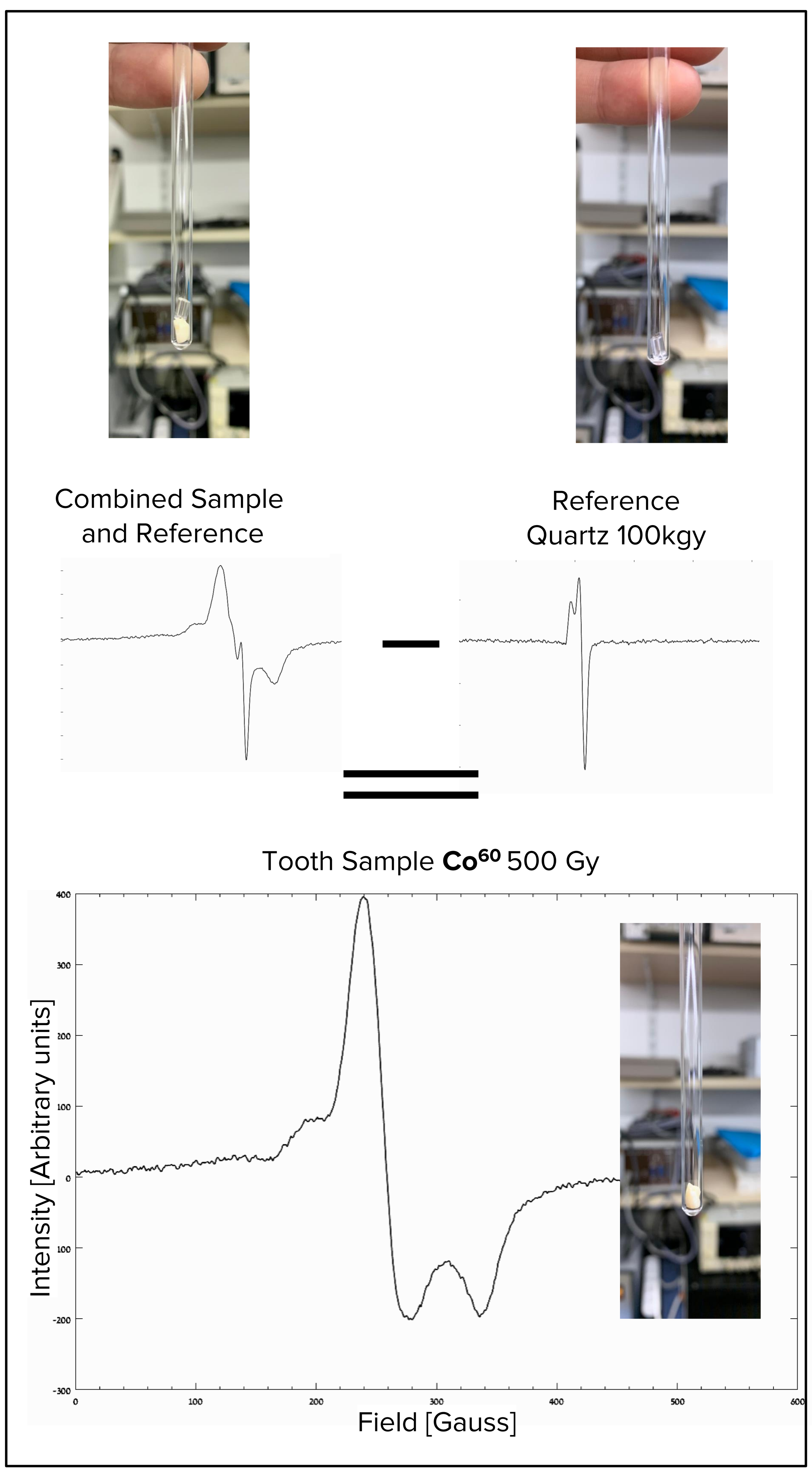

Fig 3. Upper - Pictures of the samples above their respective spectra. Lower - Continuous wave spectra along with pictures of the samples inside a tube. Double integral of the combined sample and reference on the top left minus the reference on the top right will give the double integral of the tooth sample. Comparing the tooth to the a reference quartz with a known number of spins gives the tooth's number of spins.

Results

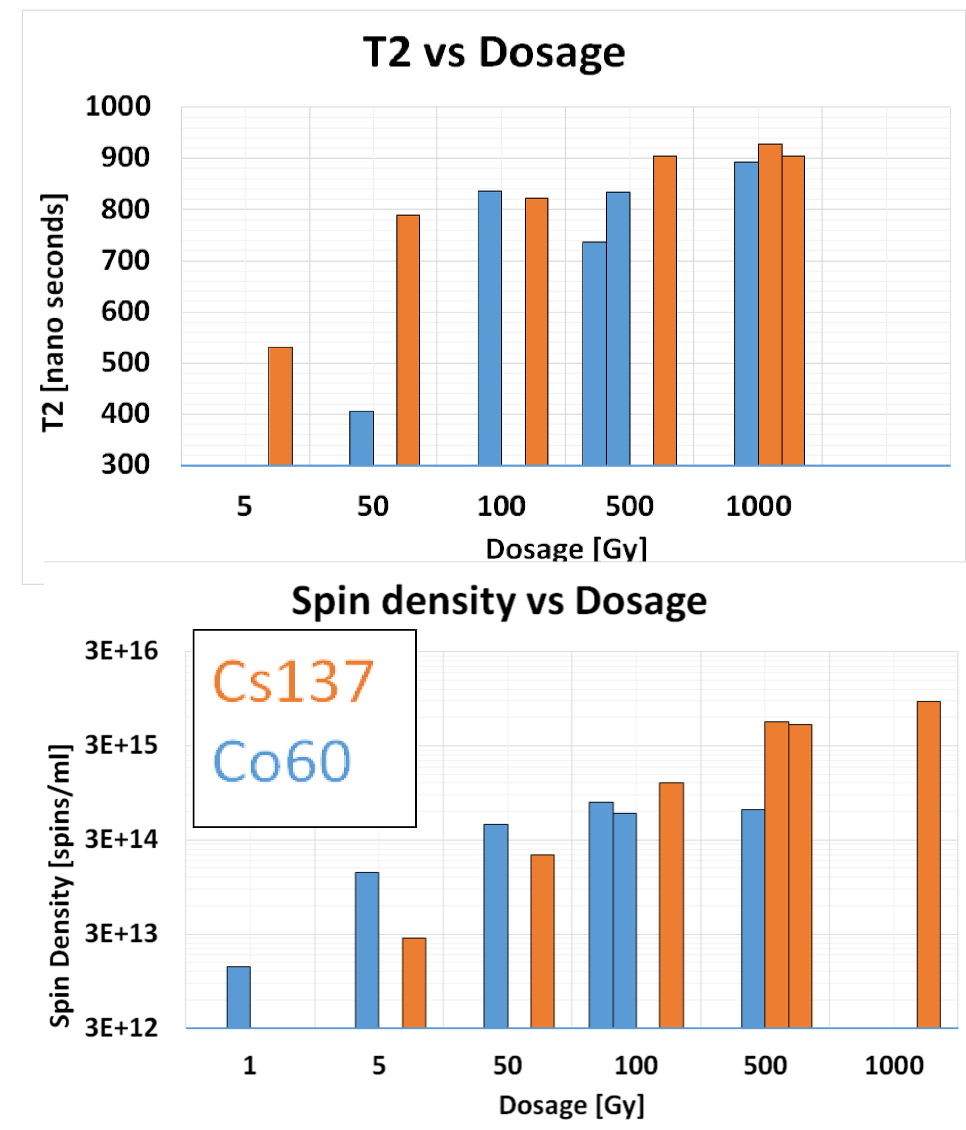

Fig 4. T_2 and Spin density vs radiation dosage results. Each bar represents a different tooth with the colors representing different radiation sources.

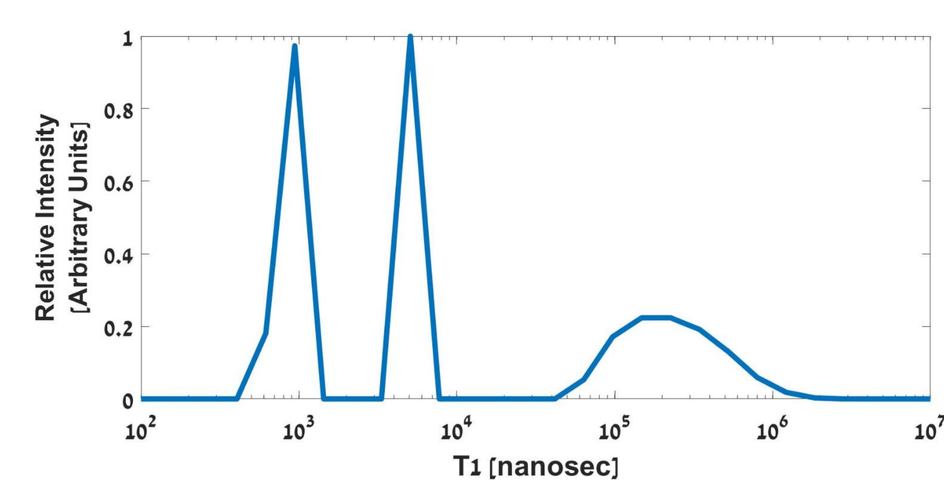

Fig 5. Normalized T_1 distribution from Upen Software

Discussion and Conclusions

Spin density increase with dose, enamel show different energy response to Cs^{137} and Co^{60}. T_2 increase with the dose in both radiation sources. This is contradicting the basic theory. Fig 4.

T_1 distribution show that the enamel layer contains different contributions for the spin environment. Fig 5.

However, more analysis is needed to understand these phenomena.

Our project shows the complexity of dose response in teeth enamel and the use of advanced ESR techniques of T_1 and T_2 give us a different aspect of the irradiated teeth samples.

Acknowledgements

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References

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