Quartz resonator based low-energy ionizing radiation detection

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Objectives
• Analyze the influence of soft X-rays & electrons on quartz acoustic resonators
• Analyze the usability of quartz oscillators for quantitative ionizing radiation dose measurements

Cold-cathode X-ray generator
• a high voltage generator (0-12 kV, 0-10 mA) accelerates electrons and creates a plasma (pressure=5.10^{-2} mbars)
• the accelerated electrons hit a grounded 11 μm Al electrode
• Bremsstrahlung/ ionization X-rays leak through the Al sheet (spectrum= Bremsstrahlung+absorption of low energy Xrays)
• peak energy defined by the energy of the incoming electrons (=voltage)
• these electrons propagate either in vacuum (5.10^{-2} mbars) or air, but strong absorption in air due to low energy
• calibration of the X-ray generated dose using an ionization chamber (requires the area above the target to be at room pressure)
• alternative to X-rays: accelerated electrons as ionizing radiations (requires the area above the target to be at primary vacuum pressure \( \simeq 3 - 5 \times 10^{-2} \) torrs).

Ionizing radiation detection

• monitoring of the phase of a Love-mode SAW (2.2 μm SiO_2 on AT-cut quartz), \( \lambda = 40 \mu m \), center frequency \( \simeq 125 \) MHz, as well as a thin (180 nm-think) Al strip on the quartz substrate acting as thermistor (3.5 Ω/K, 2280 Ω at room temperature).
• no visible effect of soft X-rays on the behaviour of acoustic sensors: insufficient dose ?
• strong temperature increase of our sensor (in-situ measurement), up to 90 K, upon irradiation by accelerated electrons
• threshold voltage below which no effect of electron irradiation is observed (first ↓): absorption of electrons by remaining air in chamber ?
• heating correlated with strong phase shift during electron irradiation (2nd and 4th ↓)
• little effect of pressure on the behaviour of the delay line (3rd ↓)
• observation compatible with STW (505 MHz) and BAW (12 MHz) resonators

Conclusion and perspectives
• substrate heating has been identified as the cause of phase/frequency shift of our delay line/resonator used as radiation detector
• quartz based resonators/delay lines are thus used as sensitive calorimeters (heating associated with energy transfer from ionizing radiation)
• this mechanism can be enhanced to improve the sensivity by using Z-cut quartz as substrate (strong temperature coefficient)
• accurate calibration temperature dependence of the phase/frequency is needed to separate heating from other possible disturbances associated with ionizing radiations
• wireless interrogation is to be enhanced to be compatible with range/medium required fortherapeutic uses of ionizing radiations

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