IMPURITIES AND THEIR RADIATION EFFECTS ON THE PERFORMANCE OF QUARTZ OSCILLATOR CRYSTALS FOR ONBOARD SATELLITE COMMUNICATION

Harish Bahadur and S.C. Garg
National Physical Laboratory
Dr. K.S. Krishnan Road,
New Delhi-110012, INDIA.

BecauseBecause of their high Q (~ 2-3Because of their high Q (~ 2-3 million) andBecause of their high Q
integralintegral part of allintegral part of all the frequencyintegral part of all the frequency control appliances. The
typetype and concentration of the impurities present in thetype and concentration of the impurities present in the qu
inin quartz is trivalent aluminum which occupies the substitutional sites of tetravin quartz is trivalent aluminu
aluminumaluminum center therefore becomes an electron excess daluminum center therefore becomes
ccompensacompensation.compensation. These charge compensators are usually monovalent ionic impurities lo
aluminumaluminumcentersat interstitial sites. Sincequartzaluminum centers at interstitial sites. Since quartz is grown
becomesbecomes an ubiquitous impurbecomes an ubiquitous impurity in qubecomes an ubiquitous impurity i
defectsdefects and somedefects and some in the form of interstitial protons around aluminum as charge compensato
ofof the other charge compensators at aluminum sites include impurities such asof the other charge compensat
derivedderived from the mineralizer solution andderived from the mineralizer solution and get incorporated in the
give rise to the internal losses in the crystalline material. When exposed togive rise to the internal losses in the cry
oscillatorsoscillators exhibit both transient and steady state frequency shifts and Q losses. Depending upon the
typetype and concentration of impurities, the lostype and concentration of impurities, the losses type and conc
crystalcrystal from vibrating following acrystal from vibrating following a strong burst of radiation that may occur d
oror magnetic storms . After the irradiation is over, it is only or magnetic storms . After the irradiation is ove
assumes a reasonable value of Q, the crystal resumes its oscillations.

ThisThis paper describes the resultsThis paper describes the results of ourThis paper describes the results of o
crystalscrystals and gives a currentcrystals and gives a current understanding on the radiation effectscrystals and give
onon theon the material selection and itson the material selection and its post-growth treatment for achieving the d
ofof quartz oscillators crystals. Such crystals would find application in satellite-borne frequency
standards.standards. Results of our studies on characterization of various grades of natural andstandards. Results of
crystalscrystals for their irradiation induced changes willcrystals for their irradiation induced changes will becrystal
K before andK before and after a 300 K-irradiation.K before and after a 300 K-irradiation. Irradiation at 77 K allo
duringduring theduring the 300 K-irradiation both protons as well as the alkali move away fromduring the 300 K-irra
under the influence of radiation. Thus, irradiation at 300under the influence of radiation. Thus, irradiation at 300 K
mixturemixture of Al-hole and Al-OH centers. These centersmixture of Al-hole and Al-OH centers. These centers
forfor monitofor monitorinfor monitoring the radiation-induced changes. Our characterization methods include m
ofof transient and steady-state frequency andof transient and steady-state frequency and Q losses, infrared absorptio
sweeping). sweeping). The irradiation sequence has been sweeping). The irradiation sequence has been carried
Al-OHAl-OH and Al-alkali centers forAl-OH and Al-alkali centers for their contribution to radiation inducedAl-OH
gradesgrades of natural and cultured quartz crystals.grades of natural and cultured quartz crystals. The current under
Al,Al, and high mechanical Q crystalsAl, and high mechanical Q crystals should be the preferred material forAl, and
crystals for use in satellite-borne frequency standards.