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Comparison of electromagnetic emission from cracking of piezoelectric and magnetite plates

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Electromagnetic emission (EME) caused by the fracturing of piezoelectric or piezomagnetic crystals in rocks has been studied theoretically. We have considered a piezocrystal of a finite size with an uniformly moving crack, its linear front is parallel to the optical axis of the crystal. The tip of the crack has instantly begun the uniform motion at a moment t = 0 and analogously has stopped at a moment t = T. It has been revealed that time-dependent mechanical stresses, which exist in the vicinity of the apex of the crack, are a source of the electromagnetic waves. The EME has been investigated for the piezoelectric crystals of point symmetry group 32 and for the piezomagnetic crystals of Fd3m space group symmetry in the first approximation for piezocoefficients and in a zero approximation for deviations of the elastic tensor of the crystal from one for the isotropic medium. It is supposed that a piezocrystal is environed by rocks having close mechanical and dielectric properties; therefore it is possible not to take into account the boundary conditions for the electromagnetic field and mechanical strains and to consider such a medium as unbounded but assume that the piezoactive region has the finite sizes.

The Maxwell equations have been solved by using the Fourier transform on spatial coordinates in the infinite limits and the Laplace transform on the time. The approximations for mechanical stresses both around the crack and for the wave of unloading have been used. We have obtained that the non-stationary mechanical stresses in the vicinity of the moving crack have caused non-stationary polarization currents, which include potential and vortical components in a piezoelectric crystal and only the vortical component in the piezomagnetic one. The potential currents generate electric polarization currents, but the vortical ones are magnetization currents only. Therefore, in the both cases, we have obtained that namely the non-stationary magnetic dipole is the source of radiation. Such a dipole is created due to the motion of the apex of the crack and depends on the specific crystalline symmetry that determines its piezoproperties. The intensity of the emission has several maxima as a function of the frequency. These maxima are determined by the crystal size and the velocity of the crack and are located in the low frequency (LF) region of spectrum. The values of the magnetization vector and the corresponding magnetization current have been estimated. It was found that in both piezocrystals the intensity of the electromagnetic emission is proportional to product of the tree values, namely, the energy deposited into mechanical stresses, the coefficient of electromechanical coupling for the piezocrystal, and a non-dimensional constant that depends on the problem conditions.