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LETTERS TO THE EDITOR

Mechanism of sound generation in a solid by a spark discharge near the surface

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The generation of surface and bulk acoustic waves in metals by electrical breakdown of the gas between a discharge electrode and the investigated sample has stimulated considerable interest in recent years as a noncontacting method for the excitation of sound in solids (see, e.g., Refs. 1 and 2). Spark generation has several controversial, primarily simplicity of implementation and compactness, over other noncontacting generation methods such as, in particular, the laser technique. 3

Whereas the spark generation of sound in liquids has been investigated in great detail,1 the case of solids has scarcely been touched. Only some preliminary experiments have been carried out, demonstrating the capabilities of the method,3,4 and it has been compared with laser generation under conditions corresponding to destruction of the metal surface.2 Detailed experimental studies, let alone theoretical investigations of the spark technique, have not been conducted to date. Neither have its inherent sound-generation mechanisms been established.

Here, we report the results of experiments on the generation of surface and bulk acoustic waves by a spark discharge for the purpose of determining the predominant generation mechanism.

A spark discharge was created by a standard circuit (see Fig. 1), where the capacitive energy accumulator C was charged from the high-voltage dc source U through the resistance R with subsequent breakdown of the gas-discharge gap. In contrast with (e.g.) Ref. 2, however, the resistance R of the charging circuit was made relatively small (R = 1 MΩ), so that a periodically recurring discharge could be implemented in the operation of the discharge device in the relaxation self-excitation regime (the discharge gap served as the nonlinear element in this case). The repetition period of the discharge-current pulses was determined by the charging time constant τ = RC of the capacitor and the breakdown voltage U₀, which depends on the electrode tip radius a and the width d of the discharge gap. The voltage from the high-voltage source was equal to 2.7 kV in the experiments, the radius a = 0.3 mm, the quantity d was varied by means of a micrometer screw from 0.05 to 2 mm, and the capacitance C, which consisted of a bank of parallel-connected capacitors, was varied in the interval 60–10,000 pF. Accordingly, the discharge repetition period was 0.05–10 ms, which permitted an ordinary (nonstorage-type) oscilloscope to be used to record the generated acoustic waves; its sweep was triggered by the discharge pulse from a capacitive divider. Longitudinal-mode piezoceramic wafers of diameter 1.5 cm with resonance frequencies of 2.04 MHz were used as receivers of the generated waves; they were deposited on a Plexiglas wedge to record Rayleigh surface waves and on a Plexiglas plate to receive longitudinal bulk waves. The transducers were bonded mechanically to the sample through epoxy resin. Rf pulses of the generated waves were observed reliably on the oscilloscope screen with carrier frequencies ~2 MHz and amplitudes ~1–3 mV (after hundredfold amplification).

Figure 2 shows the amplitudes of surface (curves 1) and bulk (curves 2) acoustic waves generated in aluminum samples of dimensions 17 × 4 × 5 cm² and 7 × 2 × 1.5 cm³, respectively, as a function of the capacitance C and with width d of the discharge gap (bulk waves were excited along the long side of the sample and were recorded in the direction normal to the surface). The statistical scatter attained ~20% in a number of cases as a result of the instability of the discharge for certain values of C and d; the graphical data therefore represent averages. The measured graphs are seen to have a complex nonlinear behavior for both surface and bulk waves and do not provide an unequivocal answer to the question of

FIG. 1. Experimental arrangement. 1) High-voltage dc source; 2) investigated sample; 3) surface-wave receiver; 4) bulk-wave receiver; 5) amplifier; 6) oscilloscope.

FIG. 2. Amplitudes of generated waves vs: a) capacitance C (d = 0.1 mm); b) gap width d (C = 2350 pF). 1) Bulk waves in Al; 2) surface waves in Al; 3) surface waves in glass.
which of the possible generation mechanisms in the case of a metal surface is predominant: thermal expansion, bombardment by charged particles, magnetic pressure, plasma pressure, etc. To ascertain the principal generation of surface waves in a more porous medium—a dielectric (a glass plate of dimensions $12 \times 3 \times 0.5$ cm$^2$). A spark was created between the discharge electrode tip, which was curved parallel to the surface, and a flat grounded metal electrode, which was placed to one side and was insulated acoustically from the surface of the glass sample. As in the case of a metal surface, the amplitudes of the received acoustic signals was measured as a function of the capacitance $C$ and the width $d$ of the discharge gap. The measurements showed that the signal levels changed insignificantly in transition to the glass sample, and the behavior of the curves remained the same as before (see curves 3 in Fig. 2).

The indicated similarities can be explained if we assume that the same generation mechanism prevails in both cases, specifically the action of the shock wave created in the surrounding air by the expanding discharge plasma on the surface of the solid. To test this hypothesis, we measured the delay time $t_d$ of a recorded Rayleigh wave and its amplitude $u$ as a function of the height $h$ of the discharge gap above the glass surface. The mean propagation velocity $v$ of the shock wave in air in the corresponding intervals of variation of $h$ was calculated from the measured values of the delay time. The results are summarized in Table I. It is seen at once that the values and delay law of the velocity $v$ with distance very def-

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<th>$u$, mV</th>
<th>$v$, m/s</th>
<th>$N$</th>
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Translated by J. S. Wood