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ELECTRODE DEPENDENT SHOCK POLARIZATION SIGNALS IN WATER

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ABSTRACT

Shock polarization data is presented for water with both dural and copper working electrodes from 20 kbar (2 GPa) to 100 kbar. It is concluded for low enough pre-shock electrical conductivity water, that one can neglect electrochemical (electrode material) effects below 50 kbar allowing molecular modeling based upon shock polarization data.

INTRODUCTION

There has been considerable discussion[1-5] in the literature concerning electrochemical effects associated with electrolyte-electrode interaction in the presence of a shock wave. As the nature of such electrochemical phenomena is related to charge transport between an electrolyte and an electrode, that phenomena is generally present in energetic as well as inert electrolyte systems.

Electrical ("shock polarization") signals generated when a medium contained between electrodes is shock loaded can serve as

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the foundation data for modeling molecular behavior in the presence of a mass density shock wave[6-8]. The interelectrode medium, however, may depart from perfect dielectric behavior by exhibiting, among other things, electrochemical effects. Electrochemical contributions to shock polarization signals must then either be shown to be negligible or such contributions must be considered when utilizing shock polarization data for model construction.

EXPERIMENT AND DATA

In an attempt to better understand the electrochemical contributions to shock polarization a series of carefully controlled experiments have been carried out with water as the shock medium and with "working" electrodes of either dural (3.9% Cu, 0.7% Mg, 0.7% Mn, 0.6% Si, and the remainder pure aluminum) or copper (see Fig. 1). Aluminum and copper are characterized by electronegitivities of opposite sign and thus should have direct bearing on the electrochemical question. The experiments were performed at the Univ. of Poitiers as part of an overall program to study shock front phenomena in liquids on a molecular level, that program already having extensively studied the shock polarization of water[8] with a working electrode of dural, and the optical reflectivity of a shock front in water[9] and water and liquid nitromethane[10].

Figure 2 illustrates the data collected by using the experimental arrangement of Fig. 1. Water with a pre-shock electrical conductivity of $8 \times 10^{-6}\ \Omega^{-1}\ cm^{-1}$ was used, and only

the prompt pulse (corresponding to the voltage vs time insert of Fig. 2) signal maximum was employed in generating the data. Each of the Fig. 2 data points represents a different explosive (shock wave generator). The (100 mV, 75 kbar, dural electrode) point is the result of only one shot, while all other points are the result of averaging at least two shots. The water sample thickness was 1 mm.

The Tektronics 7800 oscilloscope had a 3 nanosecond rise time. The experimental error, based upon both repeatability and the noise level at the top of the prompt pulse signal, is judged to be less than 10% at 100 kbar (100 kbar = 10 GPa) and less than 25% for the remaining lower pressure data.

Within experimental error and if the (54 kbar, 23 mV, dural electrode) point is neglected, there is no experimentally discernible electrode dependence below 50 kbar. From Hamann and Linton[11] it may be noted that the water post-shock electrical conductivity at 50 kbar is approximately $5 \times 10^{-4}\ \Omega^{-1}\ cm^{-1}$, or approximately two orders of magnitude larger than the pre-shock conductivity. Clearly electrochemical effects can be neglected for reasonably pure water in molecular modeling of the prompt pulse data below 50 kbar, but except for crude models (e.g. utilizing an average value of 100 mV at 100 kbar) electrochemical effects must be included in the 100 kbar range.

DISCUSSION

The data presented here differs from that of previous workers in (a) the concentration on the prompt pulse signals, and (b) on the concentration with below 50 kbar data.

The post prompt shock (i.e. later time) signals exhibit a much more complicated behavior than the data of Fig. 2 in that an electrode dependence is discernible well below 50 kbar. Not only is the presence of charge available for transfer to the working electrode of importance, but the time available for such transport must play a role.

If the prompt pulse signal is taken as being generated by a 10^{-12} sec shock front rise time in water, as has already been argued[8] by these authors, it is very understandable that a small amount of charge availability has insufficient time to effect the prompt pulse data. The later time signals ($\sim 10^{-7}$ sec), however, must represent sufficient time for a small amount of transportable charge to become important.

These authors believe that the same analysis as presented here for water is applicable to explosives such as liquid nitromethane. After finding the pressure range of electrode independence the prompt pulse voltage shock polarization signals for that range can be utilized in modeling the shock front within the explosive in terms of molecular processes (e.g. shock induced modecular rotation) as has been done with water[8].

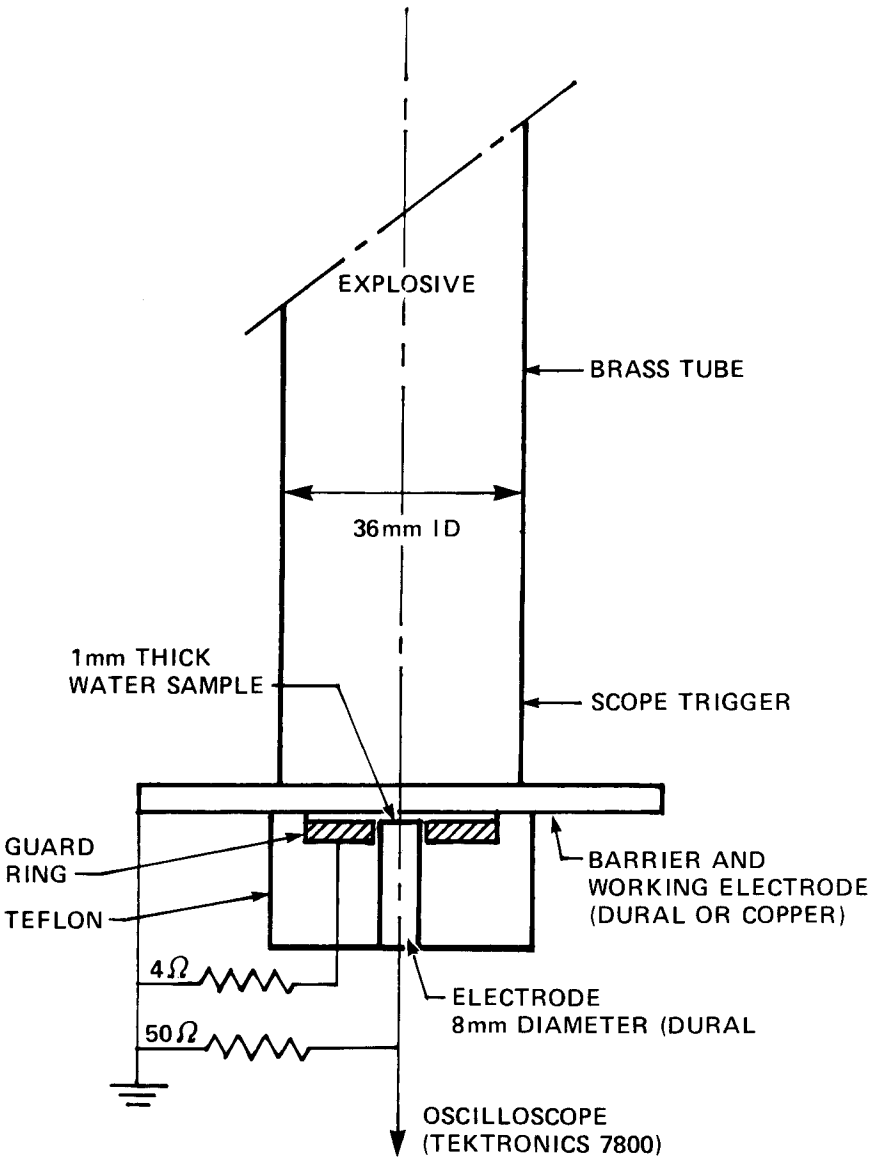

FIGURE 1

Experimental arrangement

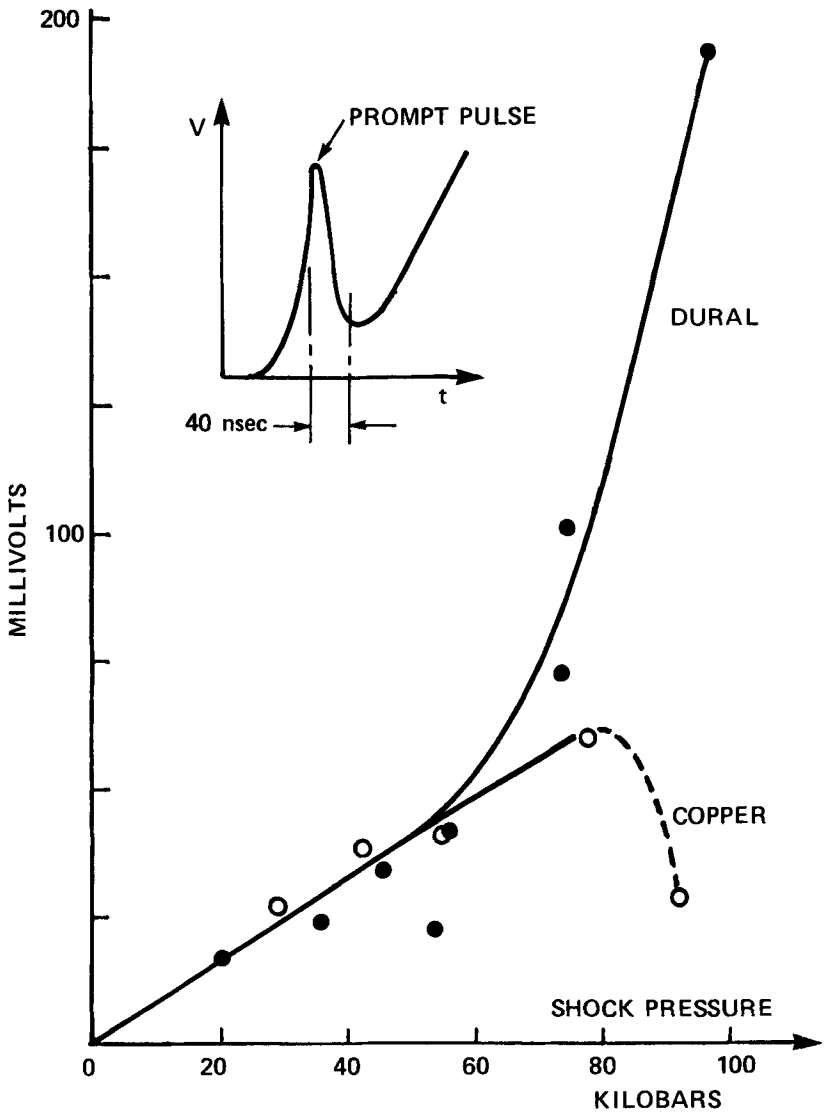

FIGURE 2

Prompt pulse shock polarization voltages (50 Ω load) for copper (open circles) and dural (closed circles) working electrodes.

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