The Diagnostics of the Reaction Zone of Condensed High Explosives at the Detonation

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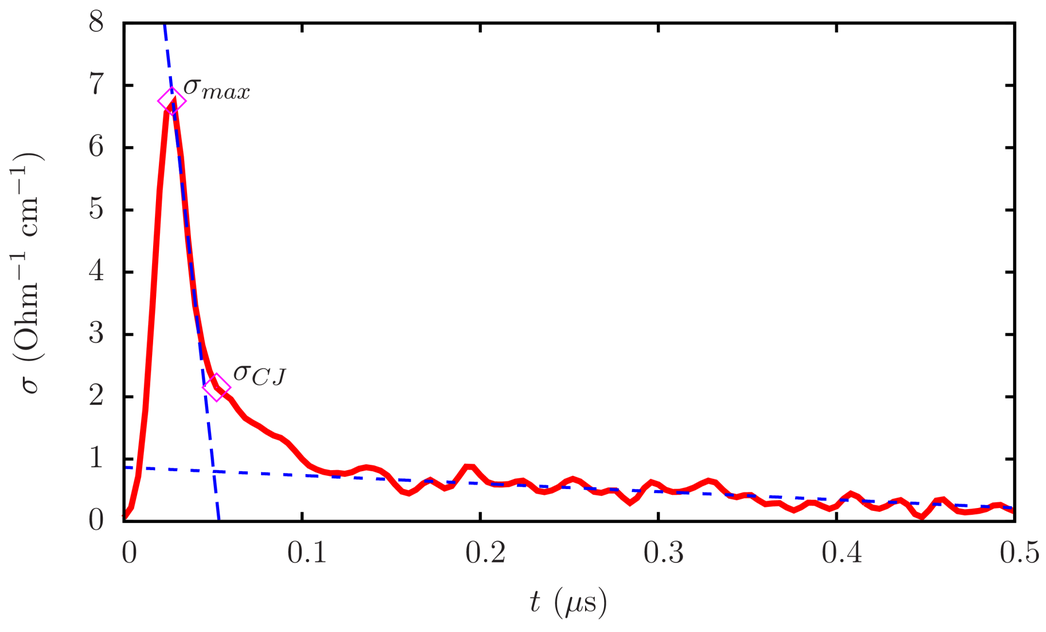
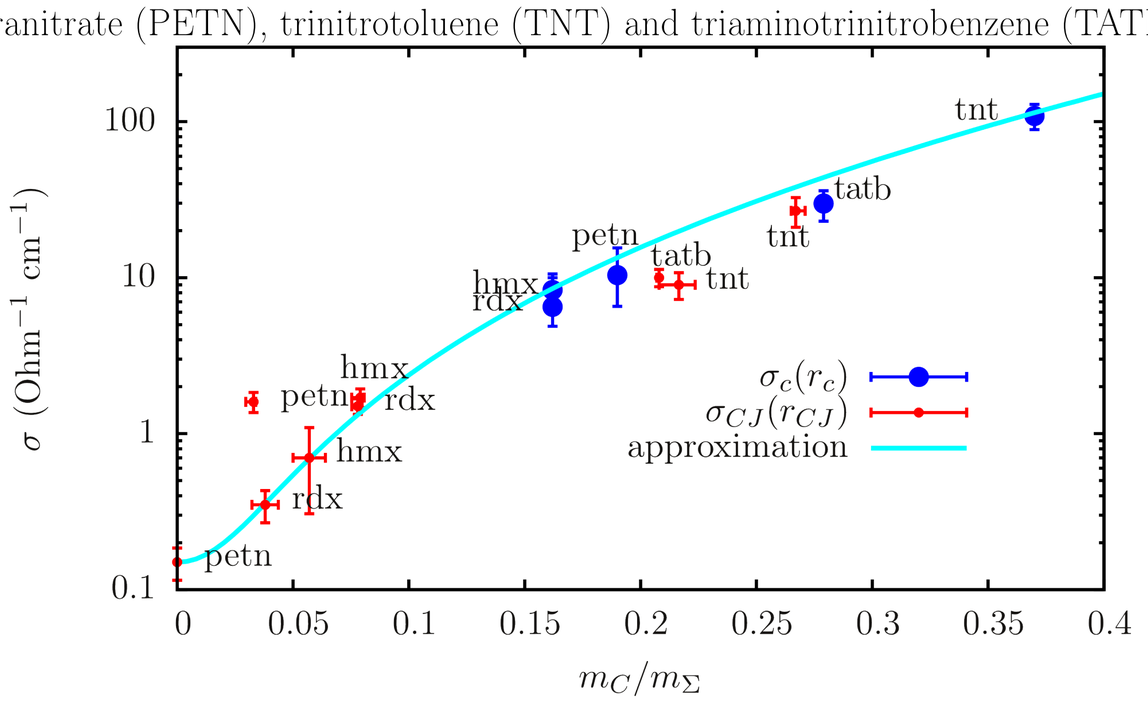
The highly-sensitive method is proposed for the real-time diagnostics of the chemical peak (von Neumann peak) at detonation of brisant high explosives. The absence of the direct link between the pressure and the course of chemical reactions was shown.

The typical graph of conductivity at the detonation of condensed HE is shown in Fig. 1. The value of conductivity increases up to the maximum σ_{max} during several tens of nanoseconds, then it rapidly decreases to the point marked as σ_{CJ}, which corresponds to Chapman – Jouguet point (CJP), and the region of slowly varying conductivity in the Taylor wave. The figure shows the end of the chemical reaction zone defined by a crossing of straight lines.



Based on the data of Tanaka [1] the mass fraction of carbon in the CJ point r_{CJ} at different initial density was calculated by the interpolation. Fig. 2 shows some data of Ershov [2-8] on the dependence of σ_{CJ} on the mass fraction of the condensed carbon $\sigma_{CJ}(r_{CJ})$ and the values of maximum of conductivity at crystal density $\sigma_c(r_c)$ (extrapolation results). Adopted the following notation: cyclotrimethylene-trinitramine (RDX), cyclotetramethylene-tetranitramine (HMX), pentaerythritol tetranitrate (PETN), trinitrotoluene (TNT) and triaminotrinitrobenzene (TATB).



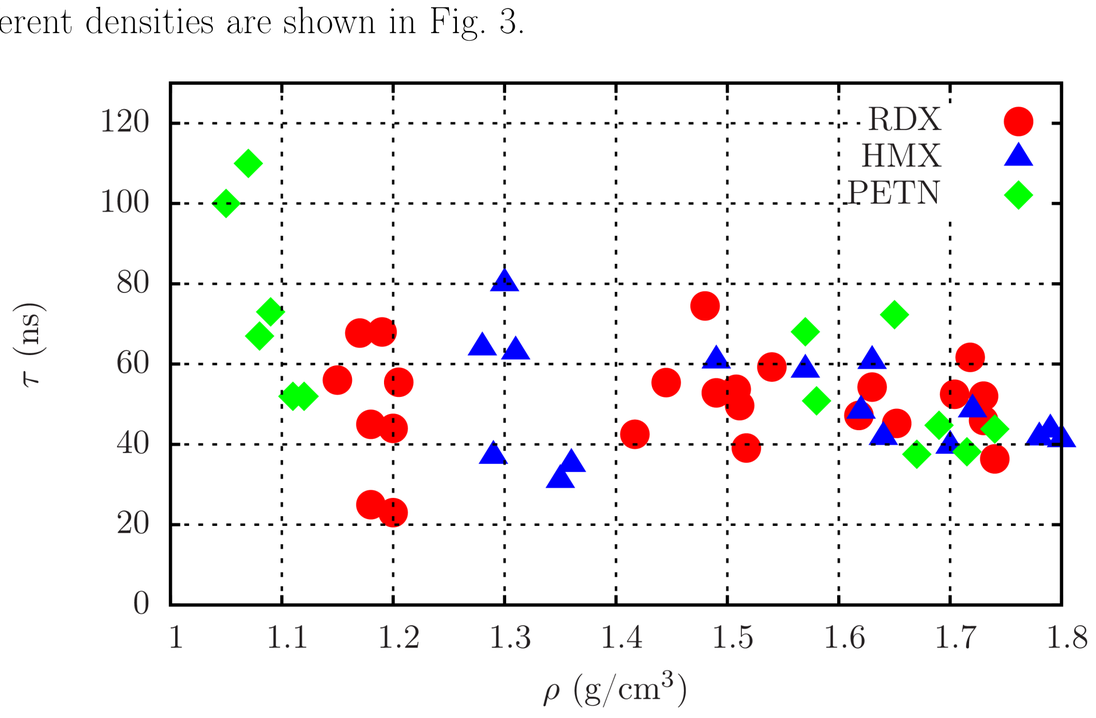
Condutivity depends on the carbon content [9,10], the dependence can be approximated as $\sigma(r) = a + \sum b_n r^n$, where r is the mass fraction of carbon, $a > 0$, $b_n > 0$ are constant coefficients. The correlation obtained from the experimental data allows us to claim that the conductivity in the whole detonation wave is provided by the carbon nets in conductive phase except the cases with low volume fraction of carbon (less than 0.07 [11]). Thus, the dynamics of conductivity tracks the evolution of carbon nanostructures. Before the arrival of the detonation front, HE is dielectric, and all carbon is bound in molecules. On the Fig. 1 the conductivity increase to the maximum corresponds to the decay of initial HE molecules accompanied by the growth of carbon structures. The oxidation of carbon occurs between the points σ_{max} and σ_{CJ} leading to the thinning and partial breaking of conductive structures which results in the decrease of the conductivity. The transition region between 0.05 and 0.1 s could be caused by the decrease of the intensity of oxidation reactions due to the decrease of concentrations of reactive components. The region of t $>$ 0.1 μs corresponds to the Taylor wave. We define the ending of the chemical peak as the place within the detonation wave where the decay of initial HE molecules is finished, and the synthesis of main products which constitute more than 97 % of the detonation products (C, CO, CO_2, N_2, H_2O) already occurs. This point corresponds to the place of σ_{CJ} in Fig. 1.

We propose a new method for the diagnostics of the state of the matter in the von Neumann peak based on the electric conductiovity profile.
Results of the investigation of the duration of the pressure peak are summarized in the Table. The values obtained for the same density by different methods differ by several times. Maximum and minimum values for PETN differ by the factor 16.

Таблица : Data on the duration of the chemical peak

HE	ρ, g/cm^3	Δt, ns	ref
TNT press.1	1.53	190	[12]
TNT press.2	1.62	330	[12]
TNT cast	1.56	290	[12]
TNT	1.62	305	[13]
TNT	1.62	260÷360	[14]
RDX	1.44	200	[14]
RDX	1.68	50÷70	[12]
RDX	1.72	≤100	[14]
PETN	1.73	80	[12]
PETN	1.74	<5	[12]
PETN		25	[15]
HMX	1.86	60	[15]
HMX	1.90	40	[12]
HMX		30	[15]

The data on the duration of the conductivity peak for RDX, PETN and HMX at different densities are shown in Fig. 3.



There is no noticeable density dependence of the conductivity peak duration.
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References

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