Wave-matter coupling mechanisms in cellular-pulsating burning of energetic materials

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Cellular-pulsating burning in energetic materials remains unexplained after six decades of research. Classical continuum theories face three fundamental inadequacies: they cannot explain spontaneous emergence of organized patterns on smooth surfaces (logical circularity requiring initial disturbances), material universality where cellular dimensions maintain constant ratios ($L/\delta_h \approx 10$–15) and identical pressure scaling ($L \propto P^{-\beta}$, $\beta = 0.5$–0.7) across vastly different materials, and rapid coordination where cells synchronize within 20–40 ms over 10–20 mm distances while thermal diffusion requires ∼670 s.

We reveal energetic materials as quantum mechanical information processors through wave-matter coupling spanning ten orders of magnitude. The framework connects macroscopic pressure dynamics with molecular activation via cascaded energy transfer in crystalline structures.

Predictions match observations without adjustable parameters: cell-to-heated-layer ratios (10–15 vs. classical 2–3), synchronization timescales (7–20 ms vs. thermal 670 s), and pressure-scaling exponents (0.5–0.7). Material independence follows from universal wave properties; spontaneous organization emerges through interference patterns; rapid coordination occurs via wave propagation at ∼1000–2000 m/s.

Mechanistic foundations enable electrically-controlled solid propellants, nanocarbon-engineered combustion architectures, and smart materials combining solid reliability with liquid controllability. This demonstrates quantum transport phenomena governing macroscopic combustion at high energy densities.