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High-Speed Observations of Dynamic Fracture Propagation in Solids and Their Implications in Earthquake Rupture Dynamics

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This contribution outlines our experimental observations of seismicity-related fast fracture (rupture) propagation in solids utilising high-speed analog and digital photography (maximum frame rate 1,000,000 frames per second) over the last two decades. Dynamic fracture may be triggered or initiated in the monolithic or layered seismic models by detonation of micro explosives, a projectile launched by a gun, laser pulses and electric discharge impulses, etc. First, we have investigated strike-slip rupture along planes of weakness in transparent photoelastic (birefringent) materials at a laboratory scale and shown (at that time) extraordinarily fast rupture propagation in a bi-material system and its possible effect on the generation of large strong motion in the limited narrow areas in the Kobe region on the occasion of the 1995 Hyogo-ken Nanbu, Japan, earthquake (Uenishi Ph.D. thesis 1997, Uenishi et al. BSSA 1999). In this series of experiments, we have also modelled shallow dip-slip earthquakes and indicated a possible origin of the asymmetric ground motion in the hanging and foot-walls. In the photoelastic photographs, we have found the unique dynamic wave interaction and generation of specific shear and interface waves numerically predicted by Uenishi and Madariaga (Eos 2005), and considered as a case study the seismic motion associated with the 2014 Nagano-ken Hokubu (Kamishiro Fault), Japan, dip-slip earthquake (Uenishi EFA 2015). Second, we have experimentally shown that even in a monolithic material, rupture speed may exceed the local shear wave speed if we employ hyperelasically behaving materials like natural rubber (balloons) (Uenishi Eos 2006, Uenishi ICF 2009, Uenishi Trans. JSME A 2012) but fracture in typical monolithic thin fluid films (e.g. soap bubbles, which may be treated as a solid material) propagates at an ordinary subsonic (sub-Rayleigh) speed (Uenishi et al. SSJ 2006). More recent investigation handling three-dimensional rupture propagation in monolithic brittle materials (e.g. ice spheres, concrete blocks in the field) has repeatedly indicated some specific (rather simple and smooth) fracture patterns even without the existence of distinct planes of weakness, which may help in understanding how the dynamic fracture propagation is controlled in three-dimensional brittle solids like Earth's crust (Uenishi et al. Con. Buld. Mat. 2010, 2014, JSME 2013).