The use of atomic force microscopy to study crack tips in glass

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Sub critical crack growth is the primary cause of failure in glasses, brittle ceramics and minerals when these materials are forced to sustain mechanical loads for long periods of time. Recently, a number of investigators have turned to the use of atomic force microscopy to characterize crack motion in glass. The technique has been used to study crack motion to velocities as low as $1x10^{-13}$ m/s. It has also been used to characterize the roughness and fractal dimensions of fracture surfaces. By comparing opposing fracture surfaces, permanent displacements are shown to develop between fracture surfaces as a consequence of corrosion during the fracture process. In this talk we examine fracture surfaces of glass specimens that have been subjected to stresses at or below the static fatigue limit. Opposing fracture surfaces matched to an accuracy of better than 0.3 nm normal to the fracture plane and 5 nm within the fracture plane. Displacements between the upper and lower fracture surfaces that developed after a critical holding time were independent of distance from the crack tip, but increased with holding time, approaching an upper limit of about 25 nm for very long times. Despite the surface displacement, cracks tips appeared to be sharp. No evidence of plastic deformation near the crack tip was found. Results are discussed in terms of a hydronium ion - alkali ion exchange along the crack surfaces and corrosion of the glass surface near the crack tip by hydroxyl ions.

Hydrogen anomalies at seismogenic depths of the San Andreas Fault

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During drilling of the SAFOD Main Hole (San Andreas Fault Observatory at Depth), up to several percent of hydrogen were identified in drill mud gas. Hydrogen enters the well particularly in two fractured zones around the fault center, whereas apparently no hydrogen is present in the fault core in ~3100-3425 m bore hole depth.

In the fractured zone on the Pacific plate (~2700-2900 m bore hole depth), hydrogen correlates mainly with CO_2 and radon, whereas in the fracture zone on the North American plate (below ~3550 m bore hole depth), hydrogen concurrenty appears also with hydrocarbons.

The H/D values of hydrogen in drill mud gas range from –618‰ to –708‰ SMOW. Deuterium fractionation between water and hydrogen would imply hydrogen genesis at relatively low temperatures that makes a deep hydrogen source unlikely. Moreover, we can widely rule out artificial hydrogen from drilling, hydrogen from serpentenization reaction, as well as radiolytic and organic hydrogen.

Several laboratory studies have shown in the past that freshly generated silicate mineral and quarz surfaces can catalyse the synthesis of hydrogen from water. Such reactive mineral surfaces could be generated in the rupture zone around a fault core, however, no experiments on fault zone rocks from seismogenic depths have been carried out yet. Thus, we have performed experiments on the mechano-chemical gas synthesis on SAFOD drill cuttings from seismogenic depth of the SAF, which mainly consist of clay, shale and sandstone. First results reveal an increase in gas after ball-milling the rock samples in a vaccum-tight mill. We will furthermore show results from experiments at varying conditions to verify if indeed mechano-chemical processes could account for hydrogen occurrences at the SAF.