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Chemically induced fracturing in alkali feldspar

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Several millimetre sized cubes of gem-quality alkali feldspars with X_{Or} = 0.85 and X_{Or} = 0.72 and with polished (010) or (001) surfaces were reacted with NaCl – KCl salt melt in quartz glass tubes at close to ambient pressure and 850 ˚C for 7 to 32 days. The X_{KCl} of the salt melt was varied based on the Na/K fractionation factors for feldspar – salt equilibria to shift the feldspar to more sodium-rich compositions. Exchange between the salt melt and the feldspar occurred by Na^+/K^+ interdiffusion while the tetrahedral framework remained intact.

When the composition shift exceeds about 3 mole%, a system of cracks forms due to the composition dependence of the lattice parameters of the feldspar. The most noticeable set of sub-parallel cracks extends in a [h0l] direction enclosing an angle of about 83˚ with the [100] direction (measured from positive [100] to positive [001]). Locally a second set of cracks forms, which follows the (010) cleavage planes. The crack pattern reflects the strong anisotropy of the chemically induced change in lattice parameters; shortening in the [100] direction is larger by a factor of five than in the [010] and the [001] directions (Kroll et al. 1986).

The cracks emanating from the polished surfaces show very regular spacing. The crack spacing decreases with increasing extent of the composition shift. E.g., after annealing for 8 days and a 15 mole% composition shift the crack length a is 100 μm and the crack spacing $2h$ is 50 μm. Applying the elastic constants compiled by Bass (Bass 1995) the maximum in-plane elastic tensile stress on a (010) surface associated with a 15 mole% composition shift is calculated as 600 MPa. The crack spacing factor (Tada et al. 1985) $s = a / (a + h) = 0.8$. In this regime fracturing is subject to stress shielding by neighbouring cracks and the corresponding stress intensity factor for mode 1 (tensile) cracks is given by (Tada et al. 1985) as $K_1 = \sigma\, h^{1/2}$.

The validity of this relation is corroborated by the fact that the crack spacing indeed decreases with increasing composition shift, i.e. with increasing coherency stress. Inserting σ = 600 MPa and $h =$ 0.025 mm we obtain K_I = 90 MPa mm$^{1/2}$. The stress intensity factor is the key material parameter describing the material behaviour during brittle fracturing. Our estimate for K_I of alkali feldspar is within the range of glass and ceramics.

References

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