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Mechanisms and models for SiC fiber strength changes after oxidation in air and steam

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The strengths of Hi-Nicalon™-S SiC fibers were measured after oxidation in wet air, dry air, and $Si(OH)_4$ saturated steam between 600° and 1400°C. Amorphous and crystalline SiO_2 scale thickness was measured by TEM. Deal-Grove kinetics for oxidation and Kolmogorov-Johnson-Mehl-Avrami kinetics for crystallization were determined. Fibers oxidized in steam much more rapidly than in dry or wet air. Hi-Nicalon™-S fibers were completely oxidized to crystalline SiO_2 after 100h at 1100°C. The corresponding scale thickness for dry air was 1.3 μm. Fiber strength changes after oxidation in dry and wet air were similar, but with some subtle distinctions. Fiber strength increased by approximately 10% for scale thickness up to ~100 nm, and decreased for thicker scales. Fibers oxidized in wet air were slightly weaker than those in dry air, and there were several outliers for fibers oxidized in wet air at 800 - 900°C with significantly lower strength. These outliers are attributed to intermediate temperature subcritical crack growth during oxidation. All other fibers with significantly degraded strength had crystallized or partially crystallized scales. The strength changes that occur during oxidation are modeled using oxidation and scale crystallization kinetics, growth stresses that develop in scales from volume expansion during oxidation, and thermal stresses that develop in scales from thermal expansion mismatch and phase transformations in crystalline scales. Strength modeling uses the superposition of stress intensity factors for the residual stress field on the stress intensity factors for a critical flaw without residual stress. The models are sensitive to the fraction of the scale that is crystallized. Modeling results are presented and discussed. Degradation and strength enhancement mechanisms in SiC fibers after oxidation are also discussed.