Development of Failure Tolerant Multi-layer Silicon Nitride Ceramics: From Macro to Micro Layered Structures

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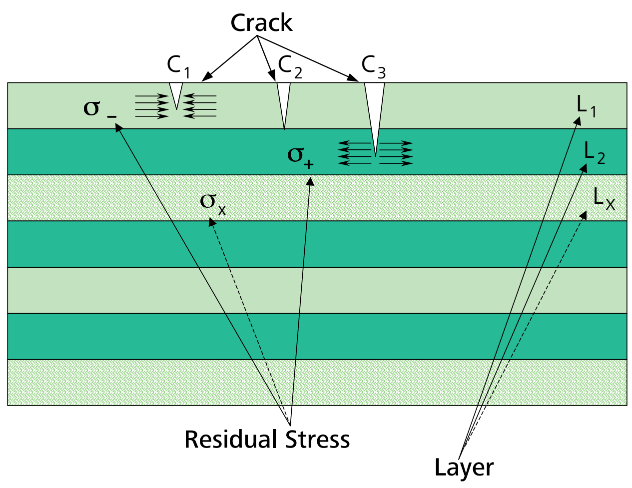
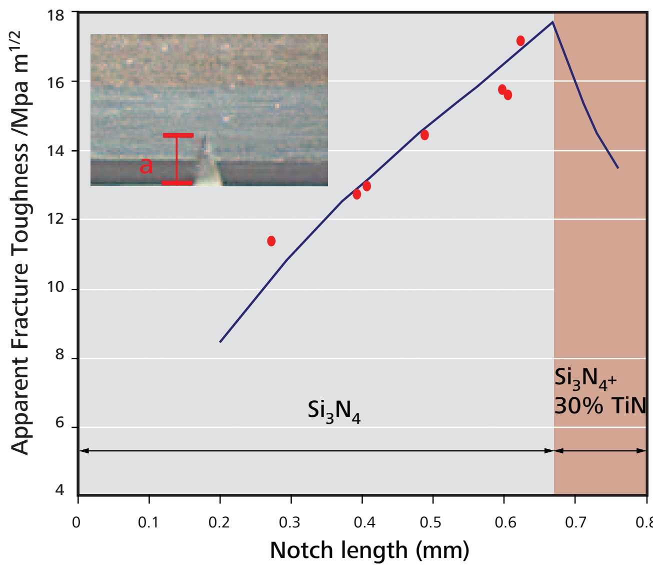
Recent developments have shown multi-layer ceramic laminates with alternative layers under compressive and tensile stress can lead to significant improvements in toughness. Macro-layered laminates with layers greater than 150 µm thickness were fabricated with a $K_{Ic\ app.}$ of >17 MPa $m^{1/2}$. However, detrimental surface "edge cracks" in the compressive layers are often observed in these laminates.

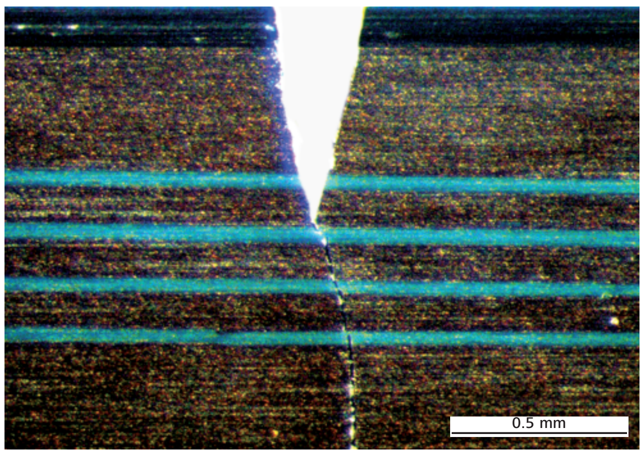


Residual stresses due to CTE mismatch

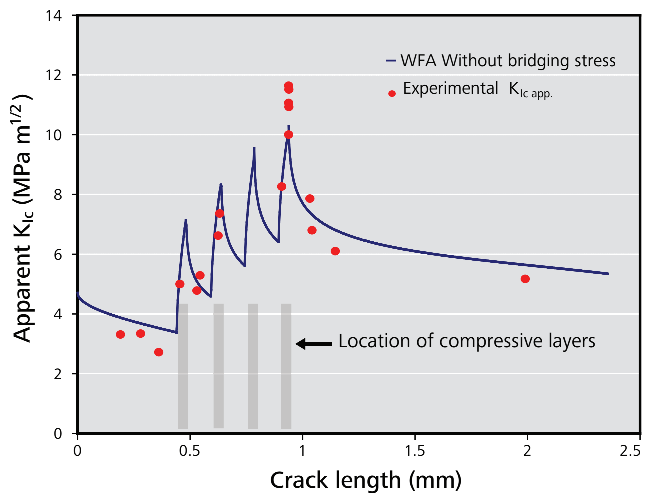


External layer under compression

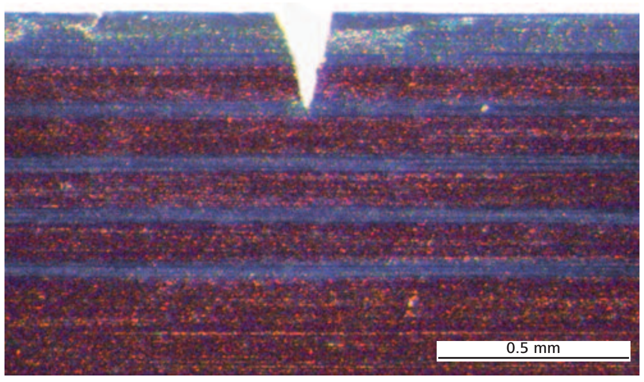
The structural and processing limitations of the macro-layered laminates lead to the development of a weight function analysis as an effective design tool for developing micro-layered laminates with compressive layers of approximately 50 µm thickness. The micro-laminates showed a failure tolerant behaviour and high fracture toughness. A laminate with outer layer under tension is shown with a notch in the second tensile layer.



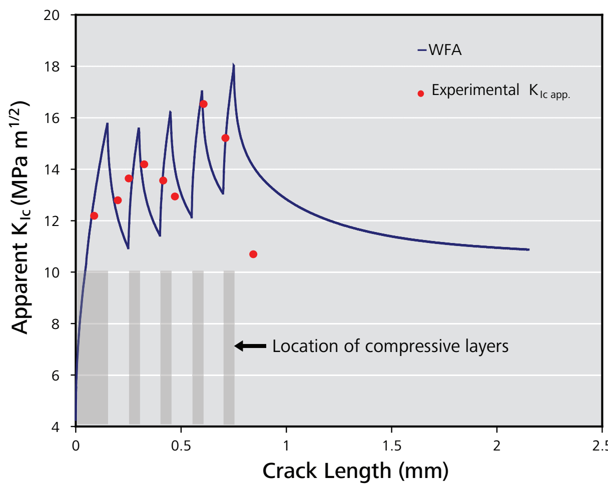
Outer layer under tension

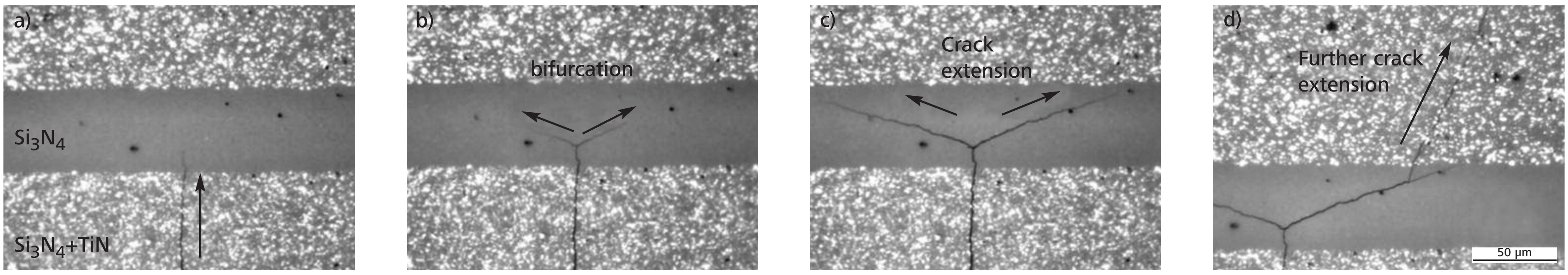


When a micro-laminate with a compressive outer layer is used, this introduces further bridging stresses and increases the effective K_{Ic} further whilst maintaining graceful failure. In the design shown a maximum increase in the $K_{Ic\ app.}$ of >18 MPa $m^{1/2}$ is achievable (4.5 times that of monolithic Si_3N_4).



Outer layer under compression





Crack propagation / bifurcation in micro-laminates measured on an extremely stiff test machine.

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