Strategies for avoiding FIB artefacts in small scale fracture

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Motivation

- Focused ion beam (FIB) milling is widely used to fabricate nanometer-sized notches for small scale fracture testing.
- Artefacts such as finite notch radius, crystalline defects, residual stresses due to ion implantion, and chemical interactions / segregation are introduced to the notch front due to the use of high energy gallium ions.
- These FIB artefacts lead to measuring system dependent properties when a material fractures in a brittle manner.

How to avoid Ga+ artefacts?

1) Stable crack growth

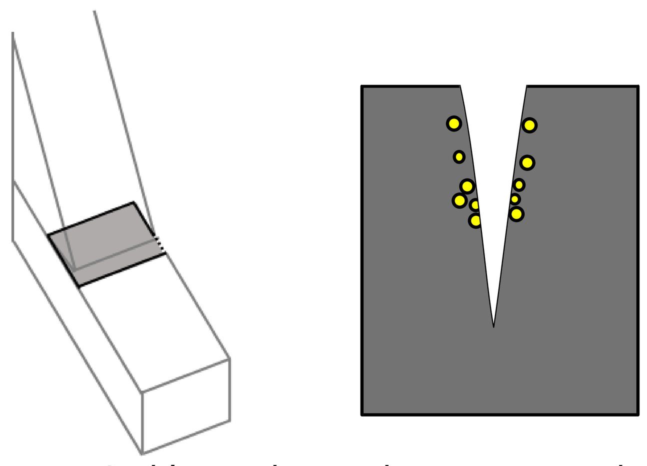

Fig. 1 – Stable crack growth geometry and notch cross section

2) Neon ion species

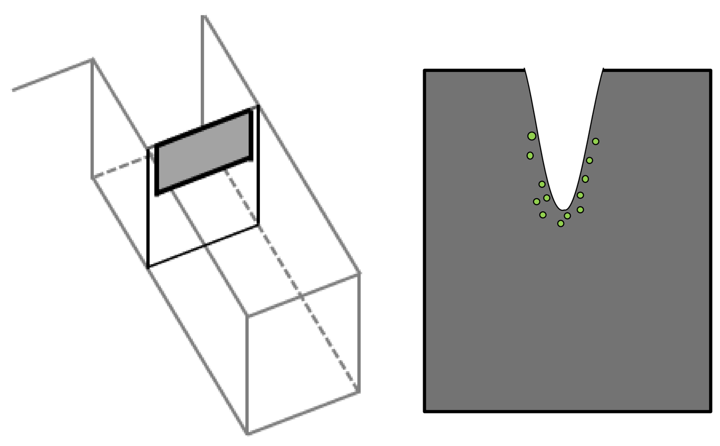

Fig. 2 – Single cantilever and neon notch cross section

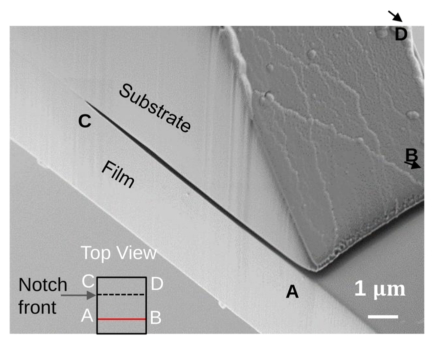

Fig. 3 – SEM image of through thickness notch

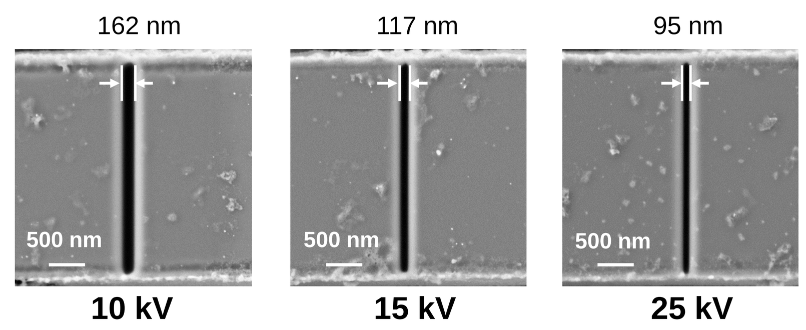

Fig. 4 – SEM image of bridge notch fabricated using different voltages

Results

Stable crack growth geometry

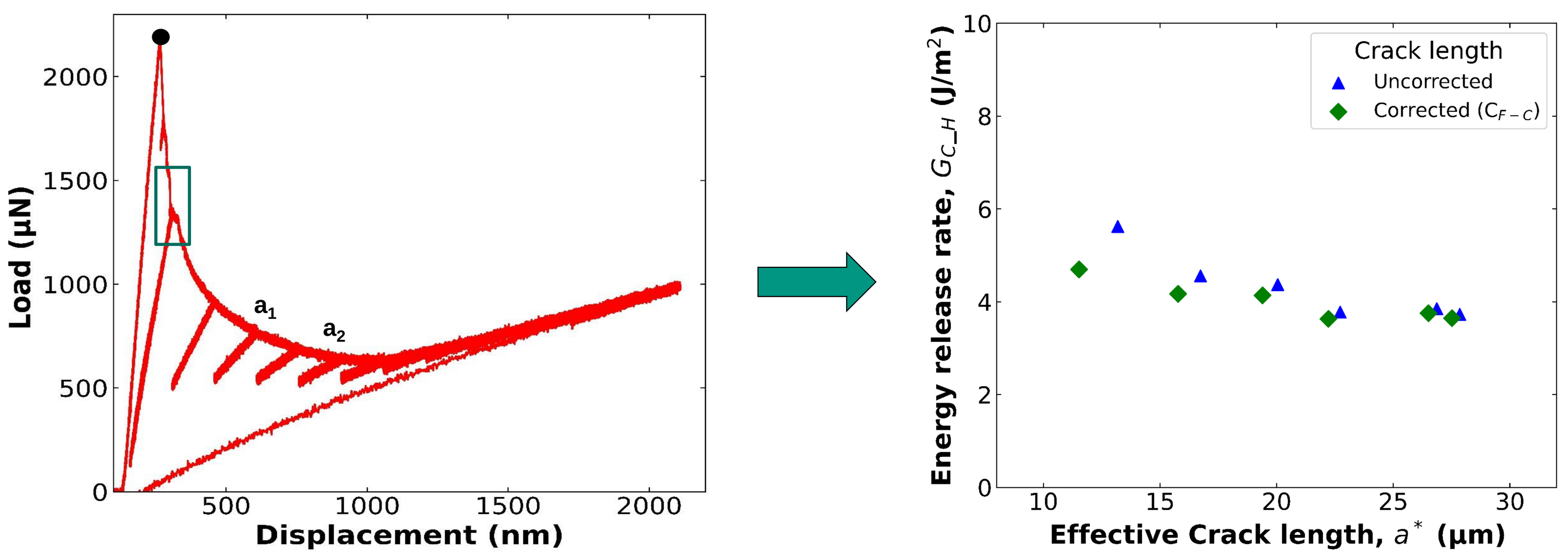

Fig. 5 – Load-displacement data from experiments, and the interface toughness values calculated from the data

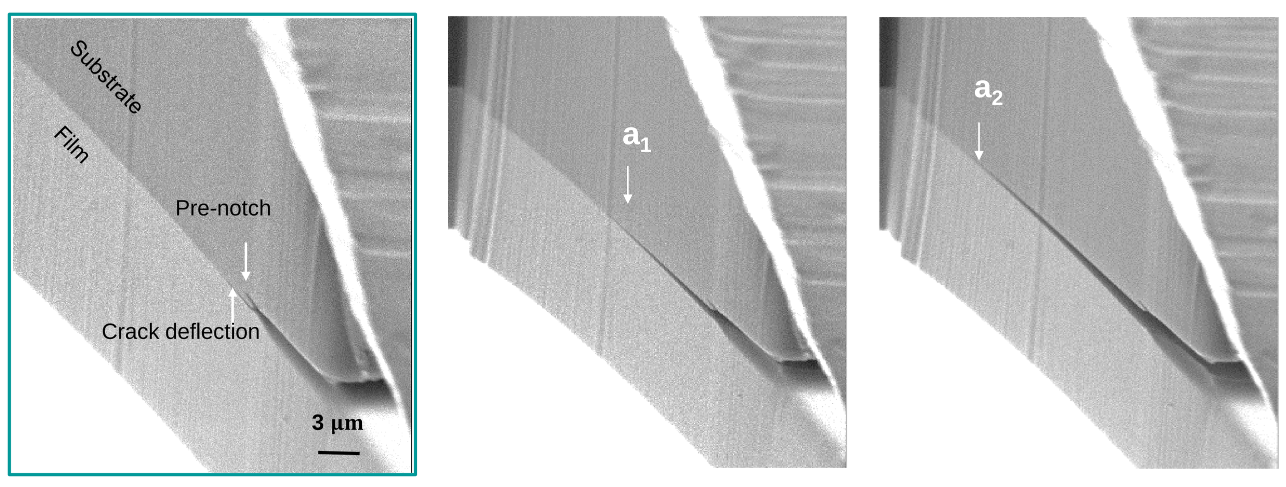

Fig. 6 – Crack deflection and extension along the interface during testing

- Formation of natural crack from FIB notch
- Stable crack growth observed
- Final fracture far from FIB damage zone

Neon notched single cantilever beam

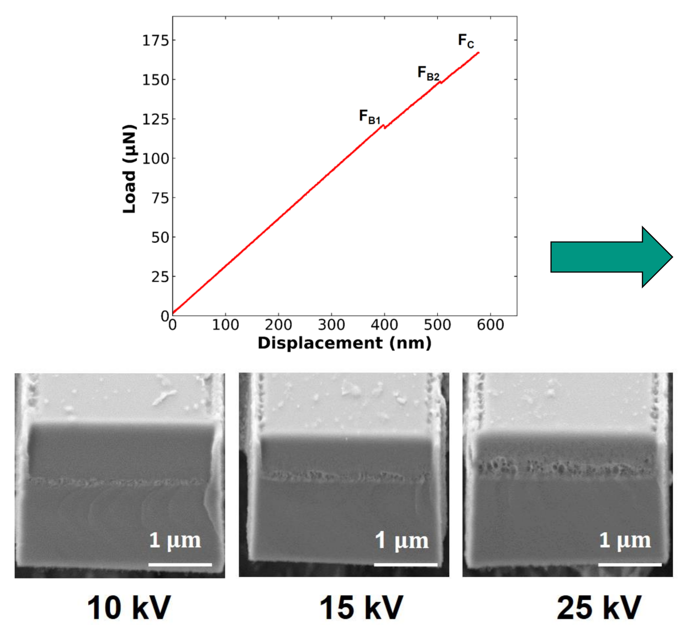

Fig. 7 – Load-displacement data and fractured surfaces of neon notched cantilevers

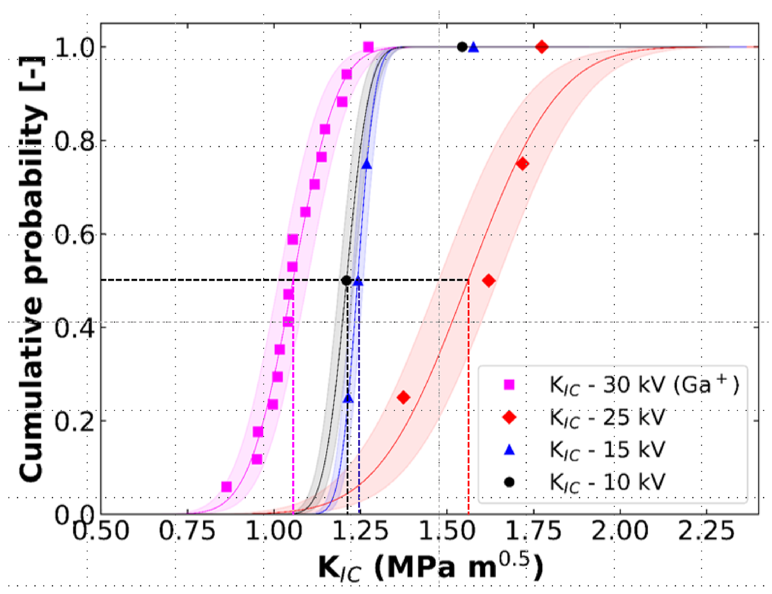

Fig. 8 – Cumulative distribution of fracture toughness of gallium and neon notches

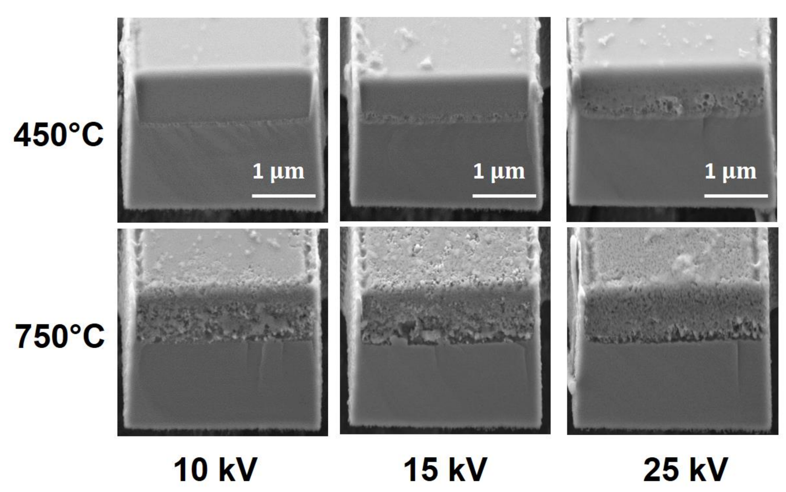

Fig. 9 – Fractured surfaces of cantilevers annealed at 450°C and 750°C

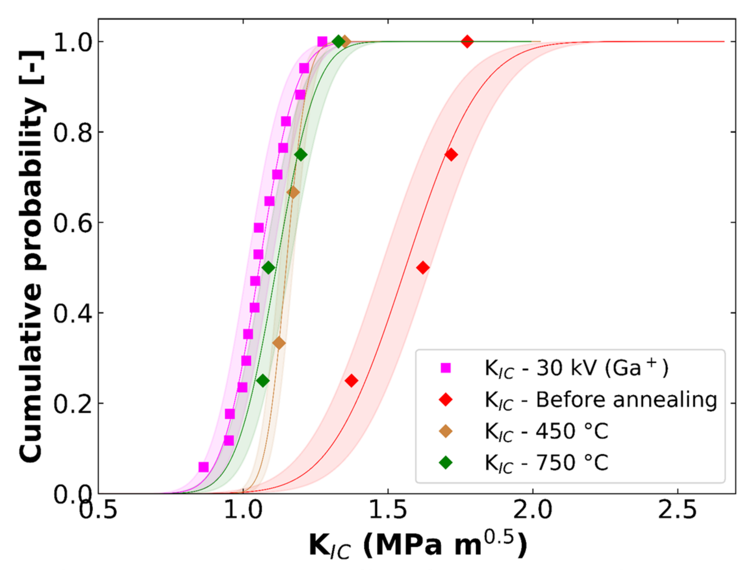

Fig. 10 – Post annealing fracture toughness of 25 kV notched samples

- Small notch width at high voltage
- Subsurface damage observed in deep notches
- Annealing reduced FIB artefacts

Summary

FIB based small scale fracture experiments are optimised to reduce artefacts at the notch using two approaches:

- Stable crack growth geometry for interface toughness measurements of films after a natural crack is formed and deflected along the interface.
- Chemically inert neon notching ions gives small notch width and valid fracture toughness after annealing.

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