

Delamination micromechanics in stretchable electronics

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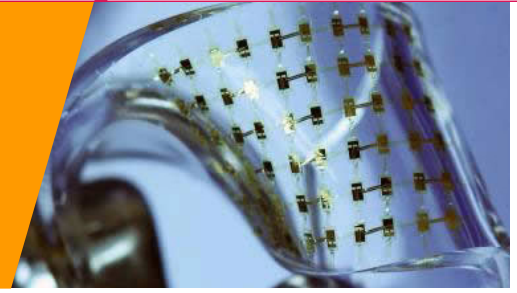
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Delamination micromechanics in stretchable electronics

Jan Neggers, Johan Hoefnagels and Marc Geers



Introduction

Stretchable electronics is a new field aiming to enable a range of **bio-compatible** futuristic devices (Fig. 1-2). The designs of these devices typically consist of regular electronic components interconnected with metal lines made stretchable by design, (Fig. 3a) embedded in a stretchable (rubber) matrix material.

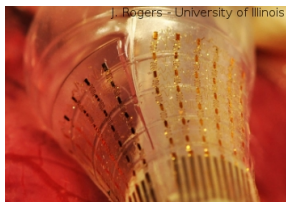


Figure 1: Hart ablation catheter



Figure 2: Health sensor tattoo

Many design solutions can be found in literature, one of which is the horseshoe shape interconnect. However, **interface delamination** is a common precursor to failure in all designs (Fig. 3c).

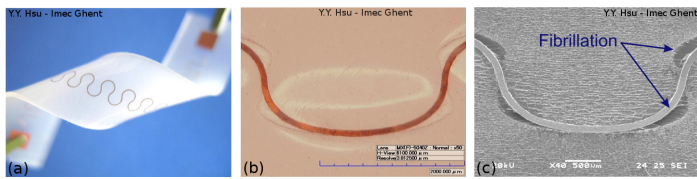


Figure 3: (a) Horseshoe shaped interconnect sample, (b) uni-axially stretched under a microscope, (c) showing fibrillation at the interface failure position, when imaging in-situ in an ESEM.

Goal

Understanding the **delamination micro-mechanics** responsible for the interface toughness. This knowledge can be applied to all interconnect designs to increase their stretchability.

Experiments

Four types of **peel-test** experiments are performed to investigate the characteristics of interfaces with two types of **roughness** in two **opening modes**. Moreover, the delamination front is visualized with **in-situ** ESEM imaging.

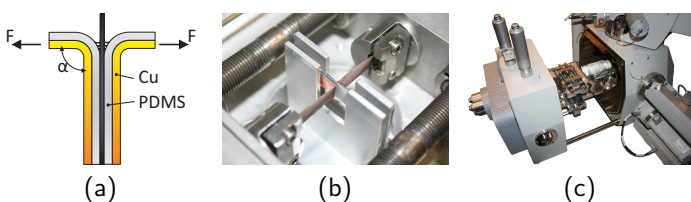


Figure 4: (a) Schematic of a 90° peel-test (b) 90° peel-test sample mounted in a tensile-stage, (c) which is mounted in the ESEM,

Figure 5 shows that the roughness morphology dictates the shape of the fibrils. Moreover, the interface of the **rougher** sample is

more tough, this is due to the **extra energy dissipation** in the **longer fibrils**.

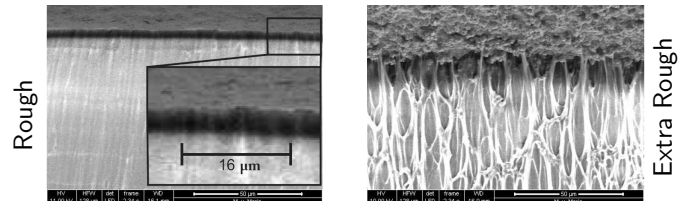


Figure 5: in-situ visualisation of the delamination micro-mechanics, i.e. the **forming, stretching** and ultimately **rupture** of fibrils.

Figure 6 shows that the **area fraction** of **rubber** on the new metal surface is **greater** for the **rougher** sample, this shows that more rubber fracture takes place instead of interface fracture, again dissipating more energy.

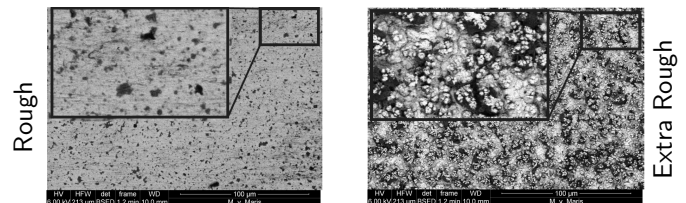


Figure 6: The new metal surfaces for both roughnesses, for a 90° peel test, i.e. crack **opening** mode.

Figure 7 shows an increase in rubber fracture for the “rough” sample, showing some **mode dependency**, yet, the “extra rough” sample is **insensitive** to the crack **opening** mode.

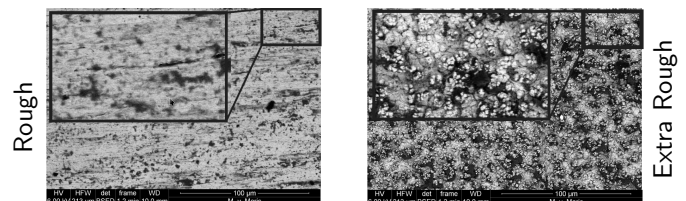


Figure 7: The new metal surfaces for both roughnesses, for a 0° peel test, i.e. crack **shearing** mode.

Conclusions

- In-situ ESEM imaging revealed a **complex mechanism**, which is the dominating **dissipation mechanism**
- The **roughness** initiates and controls the **fibrillation** process
- The **fibrils** and large surface **roughness** cause these interfaces to be **insensitive** to the crack **opening** mode, due to the “local” mode-mixity in the roughness morphology and the orientational freedom of the fibrils.
- **Future** designs of **stretchable electronic** devices should aim to initiate the fibril process, with an **artificial** “tailored” **roughness**.