Flexible multilayer interconnections based on Flex-to-Rigid (F2R) technology for intravascular ultrasound (IVUS) applications

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Introduction

Diagnostics of coronary artery disease can employ minimally invasive catheters (d = 1.2 mm) with ultrasound imaging. An IVUS imaging device consists of rigid silicon islands with ultrasound transducers. The device is wrapped around the catheter and thus needs to be flexible. F2R technology forms flexible foil connections between the islands. The foil consists of thin aluminium-copper (AlCu) between two polyimide (PI) layers (Fig. 1a/b). A test device successfully showed repeated bending down to 30 µm radius (Fig. 1c).

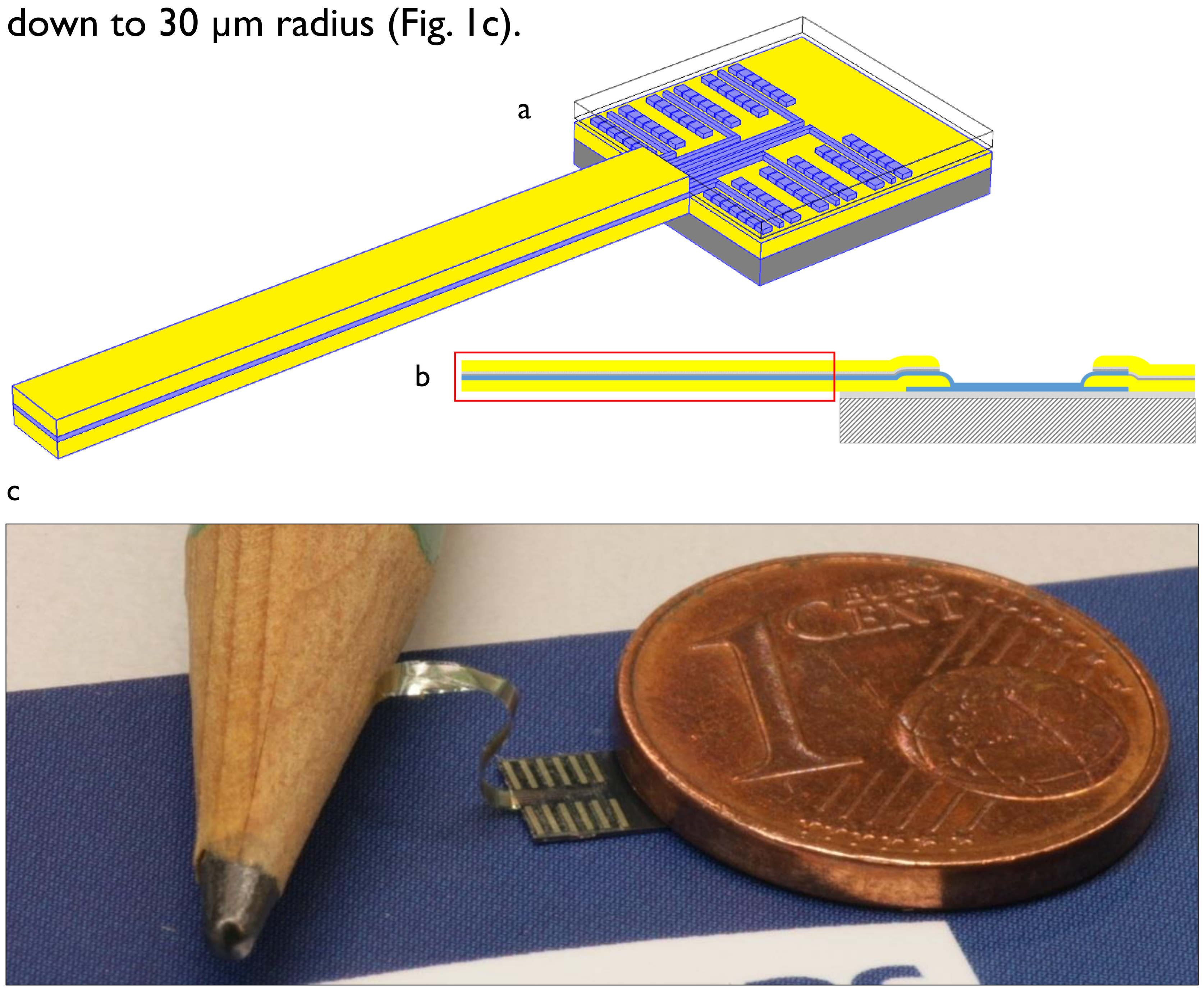

Figure 1: (a) Isometric view of a simplified model of the test device with one layer of AlCu (blue) between layers of PI (yellow). (b) Cross section view with the flexible foil highlighted in red. (c) Manufactured one-layered test device with bent flexible interconnection foil.

Next generation IVUS devices require more transducers and hence, higher density interconnects. Multilayer interconnects provide an effective solution. The goal of this work is to design, develop, manufacture and test a flexible interconnection foil with two layers of AlCu interconnects between layers of PI. Simulation models with boundary conditions for pure bending were used to gain insight in the expected increase of stress loads in the AlCu layers.

Approach

Both AlCu layers will be outside of the neutral axis, which results in a not trivial situation for bending. The σ_{11} stress states parallel to the neutral axis are studied computationally with finite element analysis in Comsol. The results from a pure bending 2D plane strain model of a single-layered device are compared to the stresses in the two-layered interconnection foil. Bending the flexible foil to small radii requires an analysis for large deformations. Failure of the interconnects is defined as reaching the elastic limit of the AlCu.

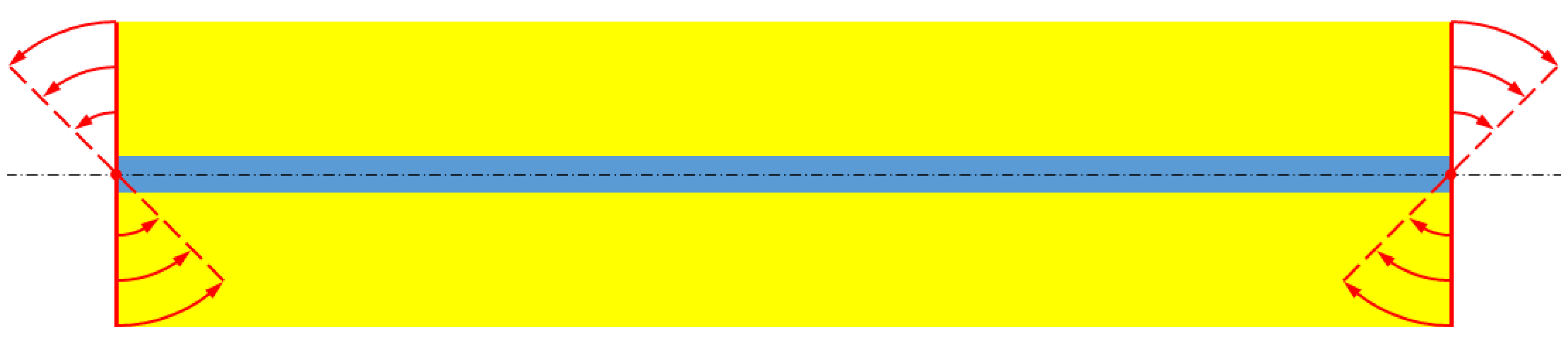

Figure 2: Cross section view of the flexible foil with one layer of AlCu interconnects. Rotational displacements of the edges in a circular way around the neutral axis (black dotted line) are highlighted in red.

Results

The simulation results for bending the one-layered device down to an equivalent radius of 30 µm show stress values several times greater than the yield limit suggesting plastic deformation. It can be observed that the boundary conditions for pure bending do not deform the geometry in a uniform way. However, this only happens at very large deformations in a study including non-linear behaviour.

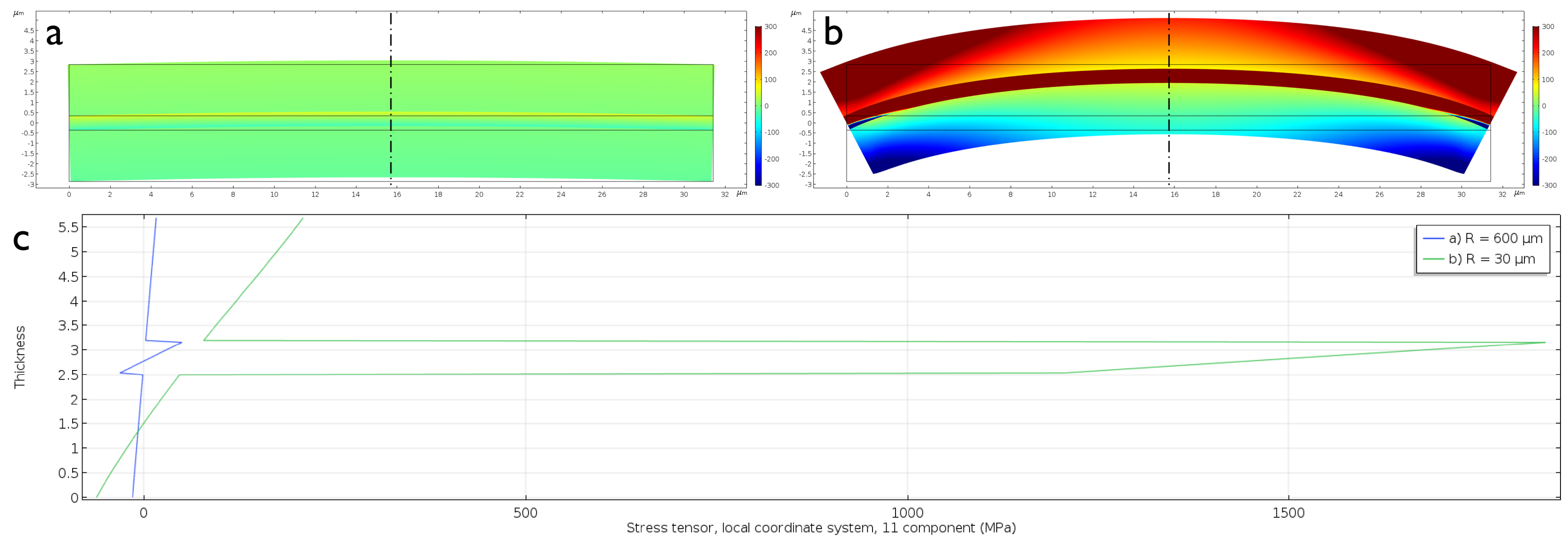

Figure 3: Stress distribution through the thickness of the single-layer interconnect model for bending radii of (a) 600 µm and (b) 30 µm. (c) σ_{11} values from the black dotted line through (a) and (b) show mostly symmetric tensile and compression distribution for radius 600 µm (blue), but highly asymmetric behaviour for radius 30 µm (green).

σ_{11} values of 50 MPa for bending radius 600 µm stay under the yield limit. For the small radius of 30 µm the σ_{11} distribution throughout the model shows non-uniformity and stress values over 1800 MPa. Large deformations make the model highly asymmetric. As a result the neutral axis shifts within the geometry and with it the distribution of tensile and compression loads.

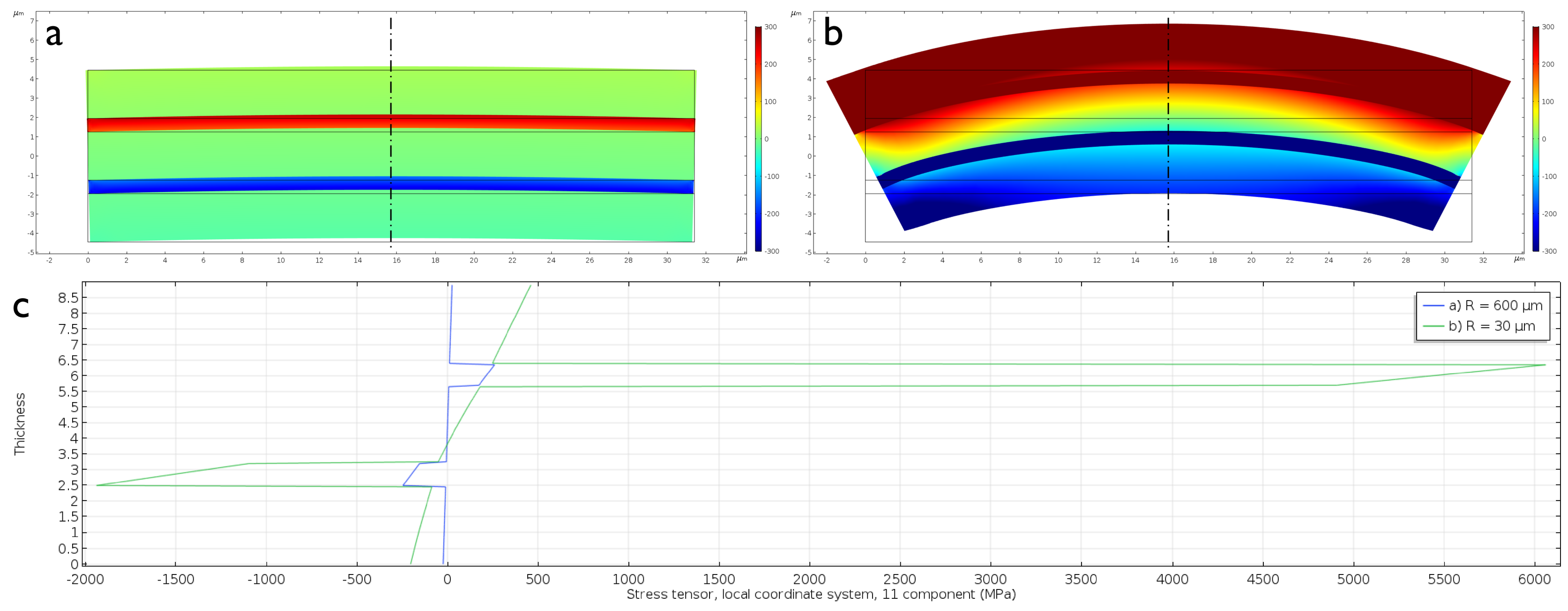

Figure 4: Stress distribution through the thickness of the double-layer interconnect model for bending radii of (a) 600 µm and (b) 30 µm. (c) σ_{11} values from the black dotted line through (a) and (b) show mostly symmetric tensile and compression distribution for radius 600 µm (blue), but highly asymmetric behaviour for radius 30 µm (green).

Adding a second layer of interconnects let the symmetric tensile and compression distribution remain for bending radius 600 µm. σ_{11} values increase to 260 MPa. For large deformation with radius 30 µm σ_{11} values went up to a maximum of 6060 MPa for tensile load.

Conclusion

Modeling two layers of AlCu interconnects with small deformations already show critical stress values at the edge of the yield limit. For large deformations the model is inadequate due to non-linear deformation. The model will be improved using moments symmetric to the neutral axis instead of rotational displacements.

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