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# Study of YBCO strip-line inductances connected to nano-Josephson junctions

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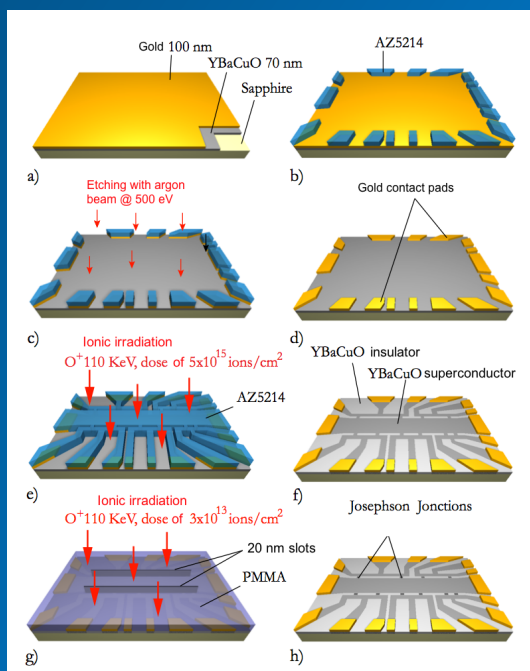


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## ABSTRACT

- The inductances of high-Tc YBCO striplines have been studied as a function of temperature and geometry with several SQUIDS defined on a mono superconducting layer.
- The devices are made with nanometre-sized Josephson junctions defined by ion irradiation in order to investigate the potential of the technology for digital applications in the 20-60 K temperature range.
- Different techniques have been used to model the inductances and compare these with experimental data:
  - one technique relies on analytical formulas associated with coplanar lines and coplanar waveguides based on conformal mapping
  - another uses InductEx and a modified version of FastHenry that takes into account the superconducting behaviour of the films and the distribution of the superconducting currents on the layers;
  - a third technique is based on 3D-MLSI software.
- Several geometries have been investigated in order to decrease the effect of manufacturing tolerances and provide a wider range of test values.
- Using the experimental measurements to verify the analytical formulas and simulation results, we have obtained reasonably accurate simulation models for the YBCO strip-line inductances – something not possible with conventional inductance extraction software such as LEMETER.

## TECHNOLOGICAL PROCESS



## MODELLING THE INDUCTANCE

### Conformal mapping

Based on the Telegraphist's equation with the quasi-static assumption valid for the range of frequencies involved in the study. Effective dimensions are used to take into account edge effects. The topology of the normal metal coplanar structure is taken into account through geometrical parameters derived from [1-2]. The superconducting behaviour is considered through the insertion in the expressions of the geometrical parameters of the kinetic inductance connected to the superconductor London penetration depth  $\lambda_L$ . A detailed description of the formalism can be found in [3].

- [1] K.C. Gupta, R. Garg, I.J. Bahl, Microstrip lines and slotlines, Chapter 7, Artech House, Inc., 1979.
- [2] J.F. Whitacker, R. Sobolewski, D.R. Dykaar, T.Y. Hsiang and G.A. Mourou, "Propagation Model for Ultrafast Signals on Superconducting Dispersive Striplines," IEEE Trans. Microwave Theory Tech., vol. MTT-36, no. 2, pp. 277-285, Feb. 1988.
- [3] Febvre, P., C. Boutez, S. George, and G. Beaudin, Models of superconducting microstrip and coplanar elements for submillimeter applications, Proc. of the Int. Conf. on Millimeter and Submillimeter Waves and Applications II, Vol. SPIE 2558, 136-147, San Diego Convention Center, July 9-14, 1995.

### 3D-MLSI: based on [4]

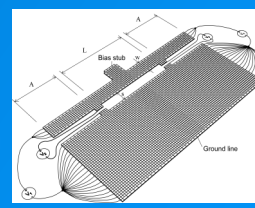
- [4] M. M. Khapaev, M. Y. Kupriyanov, E. Goldobin and M. Siegel, Current distribution simulation for superconducting multi-layered structures, Supercond. Sci. Technol., vol. 16, pp. 24-27, 2003.

### InductEx

InductEx uses FastHenry with superconductivity support as field solver, and post-processes results to calculate multi-port network inductance.

We used 2.5  $\mu\text{m}$  segment size and modelled A to be equal to the ground line width (50  $\mu\text{m}$ ).

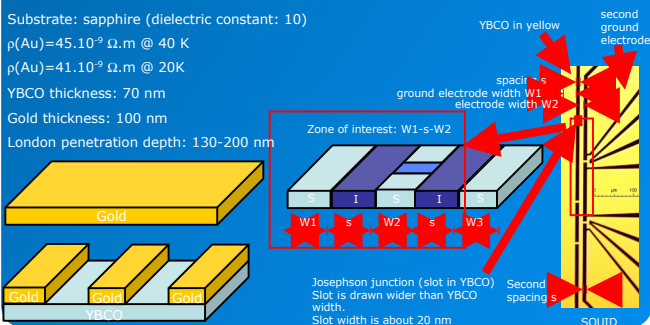
Solution time is shorter than 10 seconds.



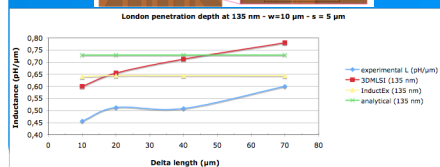
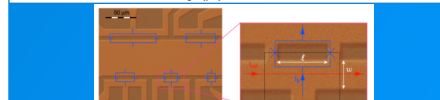
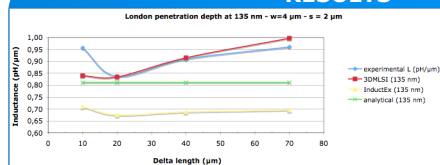
SQUID inductance modelled with InductEx

## SQUID DESIGN WITH NANO-JUNCTIONS

Substrate: sapphire (dielectric constant: 10)  
 $\rho(\text{Au}) = 45 \cdot 10^{-9} \Omega \cdot \text{m}$  @ 40 K  
 $\rho(\text{Au}) = 41 \cdot 10^{-9} \Omega \cdot \text{m}$  @ 20 K  
 YBCO thickness: 70 nm  
 Gold thickness: 100 nm  
 London penetration depth: 130-200 nm



## RESULTS



The agreement is relatively good for the smallest coplanar lines.

Surprisingly, the agreement is not as good for the wider lines. A shadow coefficient of 0.785 allows a good fit but it is still to be explained.

More experiments and simulations are in progress.