Modelling proximity effects in x-ray Transition Edge Sensors (TESs) for space-based applications

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Abstract—Central to the operation of current and future space instruments such as I-XFU and SPICA are transition edge sensors (TESs) where the superconducting properties of the TES are spatially modulated due to the presence of additional normal metal structures such as the X-ray photon absorber itself. Due to the long-range, lateral superconducting proximity effect the superconducting properties of the TES are modified so that a detailed microscopic model is needed to account for its effective superconducting transition temperature T_c, its magnetic field dependencies and even perhaps its intrinsic noise properties.

The best way to account for this proximity effect in a microscopic model is to use the Usadel equations, modelling the TES as a weak link. So far, this has been done for standard TES geometries, i.e. S-S'-S weak links, and for particular values of the phase difference between the two electrodes which allow the Usadel equations to be simplified and solved using analytical methods. We have extended the existing models to model more complex TES geometries, for example a S-S'-S''-S'-S weak link, and to allow for arbitrary values of phase across the sensor.

The results of these models are used in a Resistively Shunted Josephson Junction phenomenological model to find the resistance of the sensor as a function of temperature and current, R(T,I). From this the experimentally measurable small signal electrothermal parameters α and β can be determined, which will allow the results from this work to be compared with future experimental observations. Additionally, we can use this model to obtain the variation of the supercurrent as a function of the magnetic field experienced by the TES, which will allow us to examine the effects of stray magnetic fields, such as those found in space, on TES performance.