Internally Shunted Josephson Junctions: a Unified Analysis

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Abstract — Following the ever-rising demand for new functionalities and novel materials in superconducting circuitry, we provide a complete view on the self-shunting problem in Josephson junctions relating it to specific features of a multichannel weak link between electrodes where averaging over the channels yields a bimodal distribution of transparencies with maxima near unity and zero. We provide two examples of such internally-shunted devices, four-layered Nb/Al-Al oxide-Nb junctions with strongly disordered nm-thick insulating layers where stochastic distribution of transparencies takes place on a local rather than a global scale and MoRe/W-doped Si-Si–MoRe devices with strongly inhomogeneous silicon interlayers partly doped by metallic nanoclusters where the main charge transport occurs across resonance-percolating trajectories. We show how the predicted universal distribution function of transmission coefficients can be verified experimentally without any fitting parameters and analyze some old and new experimental data from this perspective. We believe that our results can form a base for novel four-layered Josephson junctions with enhanced superconducting properties and, at the same time, well-separated metallic electrodes.

Keywords (Index Terms) — Josephson junctions, current-voltage characteristics, tunneling, charge carrier processes, distribution functions.