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Wafer-scale CVD graphene-based Josephson field-effect transistors: toward superconducting quantum integrated circuits

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Josephson field-effect transistors (JoFETs) are some of the most desired building blocks of superconducting electronics. Instead of electric current or magnetic flux control of superconductivity, the superconducting proximity coupling in JoFETs can be controlled with an electrostatic gate. Owing to its unique properties, graphene has been identified as a promising candidate for the JoFET channel (weak link). The all-electrical control of JoFETs is expected to enable a plethora of applications in graphene-based quantum coherent electronics, classical digital superconducting electronics, microwave bolometers, non-reciprocal components, and quantum-limited parametric amplifiers [1-3].

In my talk, I will present our recent results on the scalable chemical vapor deposition CVD graphene JoFET platform developed at VTT [4]. A cross-sectional schematic featuring our JoFET device structure is shown in Fig. 1(a). Using the top-down fabrication process on 6” (150 mm) wafers with optimized contact resistance and wafer-scale device yield reaching 90% (see Fig. 1(b)), we demonstrate the local top gate tunability of superconducting proximity coupling in aluminum-graphene-aluminum Josephson junctions (see Fig. 1(c)) and study the JoFET geometry and temperature dependences. Building upon our unique wafer-scale JoFET platform, I will discuss our next steps toward large-scale classical and quantum coherent superconducting electronics.

[1] Wang et al. *Nat Nano.* **14**, 120–125 (2019).
[2] Kokkoniemi et al., *Nature* **586**, 47–5 (2020).
[3] Butseraen et al., *Nat. Nano.* **17**, 1153–1158 (2022).
[4] Generalov et al. *arXiv:2401.05089* (2024).

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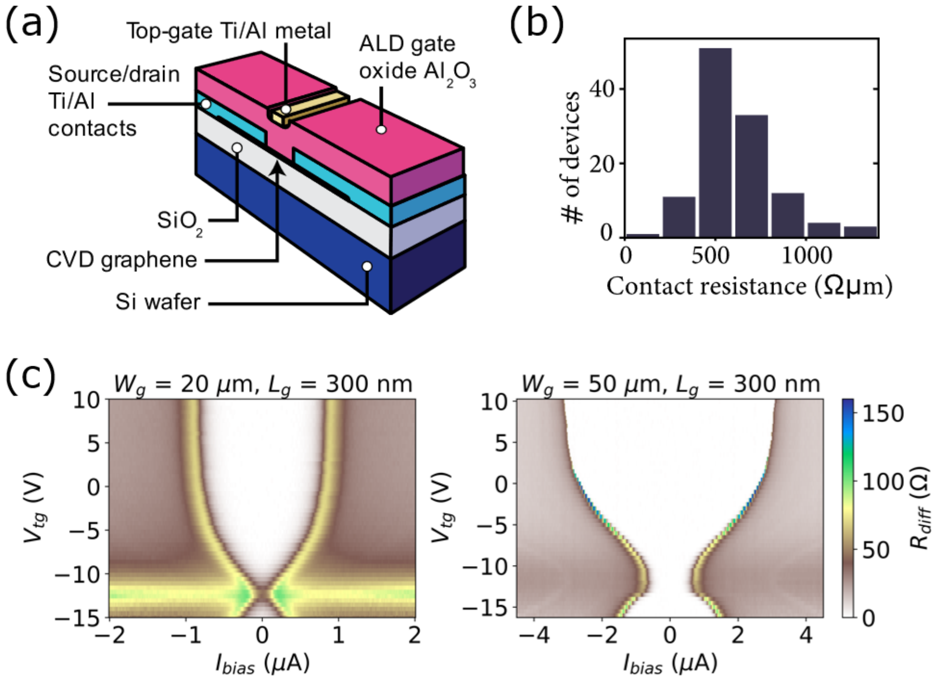

Figure 1. (a) Cross-section of a JoFET. **(b)** Room temperature contact resistance distribution for sub-micron JoFETs. **(c)** 4-probe measurements of differential resistance (R_{diff}) as a function of top-gate voltage (V_{tg}) and bias current (I_{bias}) for two JoFETs with gate length L_{g} = 300 nm and channel width W_{g} = 20 and 50 μm at 40 mK.