High temperature superconductivity was discovered in single unit-cell thick FeSe films grown on a SrTiO$_3$(001) substrate by molecular beam epitaxy. In situ scanning tunneling microscopy revealed a superconducting gap as large as 20 meV in single unit-cell thick FeSe films [1]. By ex situ transport measurements on single unit-cell thick FeSe films protected with FeTe layer, we demonstrated an onset $T_C$ above 40 K and a critical current density $J_C \sim 1.7 \times 10^6$ A/cm$^2$ at 2 K, which are much higher than $T_C \sim 8$ K and $J_C \sim 10^4$ A/cm$^2$ for bulk FeSe [2,3], and that the characteristics of the transition are consistent with a two-dimensional superconductor undergoing a Berezinskii-Kosterlitz-Thouless transition. The superconductivity is further confirmed by measuring Meissner effect. The simple structure of the current system provides an ideal platform for understanding the underlying physics of high-$T_C$ superconductivity.

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