Appearance of Quantum Fluctuations in Submicron Intrinsic Josephson Junctions of $Bi_2Sr_2CaCu_2O_{8+\delta}$ Single Crystal Whiskers

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The tunneling of cooper pairs is more precise when the normal resistance of a submicron junction belongs in the range of quantum resistance and the characteristics of junctions are changed with quantum effect. To observe this quantum effect we have fabricated various in-plane area intrinsic Josephson junction (IJJ) stacks from 4 μm^2 down to 0.16 μm^2 in $Bi_2Sr_2CaCu_2O_{8+\delta}$ single crystal whisker through three-dimensional focused ion beam etching technique. A strong suppression in critical current density (J_c) is noticed in current-voltage characteristics for stacks of in-plane area $S < 1$ μm^2 at 30 K. This suppression in J_c is archived for the first time ever at 30 K and is attributed due to quantum fluctuations of phase. The conditions for quantum region (charging energy > Josephson energy, thermal energy, and damping rate) are obeyed by submicron junctions at 30 K. The estimated ratio of Josephson energy and charging energy is less than 1 for submicron stacks which induced these quantum fluctuations. The array of IJJs stack is following the Ambegaokar-Baratoff relation and reflects a good quality junction in submicron range as well.