High current-density aluminum-nitride tunnel barriers grown by plasma nitridation from a remote plasma source.

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High current-density tunnel-junctions are needed to achieve wide band operation of sub-millimeter mixers. Aluminum-oxide barriers have an upper limit (Kleinsasser et al[1]) of 20 kA/cm^2 , beyond which excessive sub-gap leakage emerges. Aluminum-nitride has been introduced by Shiota et al[2] as a suitable alternative, allowing higher current densities for similar thicknesses. Various encouraging results have been obtained, but the control turned out to be unsatisfactory (Bumble et al[3]). Unlike thermally grown aluminum-oxide the nitridation is conducted in a nitrogen plasma with a mixture of chemically active species of various energies. Most barriers to date have been grown in a parallel plate reactor in which the aluminum is in direct contact with the plasma. Very high current-densities (54 kA/cm^2) have been reached in barriers deposited by reactive sputter deposition by Wang et al[4]. An alternative nitridation-method has been introduced by Kaul et al[5] in which a Kaufmann ion source is used to generate a controlled ion flux.

Here we report on aluminum-nitride tunnel barrier growth using an inductively coupled plasma source (Weiler et al[6]). Such a source permits the control of the fraction of atomic nitrogen[7] in the total ion flux, while also allowing energies as low as a few eV. Therefore we are able to distinguish between pure chemical processes and ion-implantation processes in the barrier growth. Tunnel junctions with critical current-densities as high as 70 kA/cm^2 have been made successfully. We have realized ten batches of which the electrical characteristics respond systematically to variations in the process parameters. Typical devices have been implemented for potential use in ALMA Band 9 mixers[8].

Standard bilayers of niobium (100 nm) and aluminum (7 nm) have been used. The growth chamber is equipped with a COPRA source from CCR[9]. A comparison is made of growth at two different positions with respect to the source, leading to different growth rates. We find, counter-intuitively, that with increasing atomic nitrogen pressure the barrier thickness-growth decreases. We conjecture that an increase in molecular recombination reduces the density of active atomic nitrogen on the surface.

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