Superconductive Electronics with High-T_c Superconductors

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***Abstract* - With the discovery of superconductivity in Hg by Onnes in 1911, the search for materials showing superconductivity with ever higher transition temperatures started. In 1941, NbN with a T_c of 15K and in 1954 the A15 Nb-compounds Nb_3Sn with a T_c of 18.1K and in 1973 Nb_3Ge with a T_c of 23.2 K, respectively. When small cryocoolers become available, work on the development of superconductive electronics devices for non-stationary applications started: Nb_3Sn rf-SQUIDs were operated up to 14.5 K and Nb_3Ge dc-SQUIDs up to 20.5 K making liquid hydrogen operation available.**

The discovery of oxide superconductors by Bednorz and Mueller in 1986 and the subsequent discovery of YBCO by Chu et al. changed the picture dramatically – using YBCO with a T_c of 92K, superconductivity in liquid nitrogen was suddenly possible. Over the years, the deposition techniques for oxide materials improved: evaporation, oxide MBE and layer-by-layer laser ablation are now available for the fabrication of oxide films.

Josephson junctions are key-ingredients in superconductive electronics. They occur naturally in the oxide superconductors at grain boundaries, but can also artificially be fabricated at steps etched into a substrate. Also damaging a high-T_c film with an ion beam or growing multilayers epitaxially can be used to prepare high-T_c Josephson junctions. Till now, controlled and reproducible fabrication of High-Tc Josephson junctions was not successful. A change may be coming with the ion-beam writing of junctions developed by Cybart and Dynes of the UCSD and the step-edge junctions of the CSIRO: both groups have demonstrated the ability to fabricate large numbers of HTS junctions on-chip for applications such as SQIFs.

Many applications of high-T_c Superconductive Electronics have been demonstrated; only very few characteristic ones will be mentioned here: a σ-δ-modulator, a high-speed signal sampler, a SQUID-system for non-destructive evaluation (NDE) and a superconducting microwave filter. All these applications have shown excellent performance and were at the forefront of technology in their time. Nevertheless, in none of these areas high-T_c Superconductive Electronics could conquer the commercial markets. The need for cooling and the limitation in complexity took away the advantage in performance - apart from areas where the ultimate performance was needed, e.g., in science and in military applications.

If larger numbers of high-T_c Josephson junctions could be fabricated in a controlled and reproducible way, many application opportunities would open up: for a complexity of 100s of junctions for instance a number of digital applications: e.g., high-speed low-power drivers,

connecting digital circuits in Nb-technology at 4.2 K to cooled semiconductor circuits at 120 K; or for 1000s of junctions, metrology applications: precision dc- or ac-voltage standards.

Keywords **- High critical temperature, high-*T*c, superconductive electronics, Josephson junction, step-edge junction, ion-beam written junction, high-T_c electronic applications**

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