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Microfluidic cooling for detectors and electronics

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Micro-channel cooling is gaining considerable attention as an alternative technique for cooling of high energy physics detectors and front-end electronics. We are evaluating this technology for future tracking devices where material budget limitations are a major concern. Micro channel cooling is currently under investigation as an option for the cooling of the NA62 Gigatracker silicon pixel detector and its front-end electronics where a micro-fabricated cooling plate would stand directly in the beam. Other possible applications are also being studied in the context of LHC detectors upgrades.
In this paper, the current status of this R&D at CERN will be presented.

Summary 500 words

Microfluidic devices are being studied for the development of novel cooling systems for high energy physics (HEP) detectors and front-end electronics. They are very appealing for applications in this field given the possibility to achieve increased heat transfers with reduced material budget. The fabrication of these devices relies on proven manufacturing processes with great potential of integration in particle detectors and front-end electronics.

Recently, the Detector Technology Group of the Physics Department at CERN has started developing and studying the application of this technology for the next generation of HEP experiments. The goal in the first stage of this development is to place a thin micro-channel cooling plate in direct contact with sensors or electronics.
Standard micro-fabrication techniques allow for the production of silicon cooling plates thus suppressing all problems related to temperature expansion coefficient mismatch in extremely thin configurations.

This technique is currently under investigation as an option for the cooling of the NA62 Gigatracker silicon pixel detector and its front-end electronics where the micro-fabricated cooling plate stands directly in the beam. In this particular case, micro-channel cooling meets both the very aggressive material budget specification (0.5% of X0 for detector layer, 0.15% of X0 for cooling) and the anticipated 2 W/cm2 power dissipation by the active electronics with uniform temperature distributions. The configuration under study consists of 100 µm thick silicon wafers in which micro-channels are etched. They are closed by 50 µm Pyrex wafers anodically bonded to the silicon. This bonding technique does not require any intermediate layer. However, the coupling to the front-end electronics will require a thin thermal interface.

Furthermore, for future developments, preliminary studies show that if properly integrated in the fabrication process-flow the micro-channels might be directly embedded into the sensors or the read-out chips without the need to thermally interface them with additional layers.

At the moment, the micro-channel cooling plates produced are tested with C6F14 single phase liquid cooling. This fluid exhibits a good radiation resistance as well as thermal and chemical stability. Moreover it is well-known from experience in several LHC detectors. In a later stage, evaporative cooling will also be implemented, including the possible use of CO2.

The computational fluid dynamic simulations show excellent correlation with experimental data. All the tests performed so far show excellent heat extraction capabilities and very uniform flow distribution over large arrays of micro-channels guaranteeing uniform temperature distributions on surfaces of the order of 60 x 40 mm.

Other configurations are also being studied in the context of LHC detector upgrades where extreme limitations on material budget are a major concern for standard cooling techniques. For instance, possible arrangements suitable for the upgrade of the ALICE silicon pixel detector detector are being envisaged.

The same fabrication techniques can easily be adapted to a wide variety of geometries depending on the detector's configuration and experimental environment.

Primary authors: MAPELLI, Alessandro (CERN); PETAGNA, Paolo (CERN)

Co-authors: CATINACCIO, Andrea (CERN); NUESSLE, Georg (UCL); VAN LINTEL, Harald (EPFL); DAGUIN, Jerome (CERN); RENAUD, Philippe (EPFL)

Presenter: PETAGNA, Paolo (CERN)

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