High-frequency impedance measurements of coated waveguides (AP)

Andrea Passarelli presents the results of measurements of coating resistivity in the sub-THz regime performed with VGV in collaboration with CERN. The study is motivated by the high frequency spectrum of the bunches circulating in the CLIC damping rings. The work is a continuation of EK work done in the past.

Two coatings have been studied: aC and NEG. Deposition of aC on copper is not optimized for the large thickness required for the measurements ($\approx 5 \mu m$). As a consequence, stress and peel-off was observed on samples. NEG was easier to coat and results concerning this material are presented.

Two types of waveguides are used, respectively with square and circular cross-section. Very smooth (low angle) pyramidal transitions are present before the waveguide to improve the signal collection. The square waveguide collects well the signal and it is easy to mill. The circular waveguide is obtained by perforation and it gives intrinsically the best symmetry.

Measurements are done with reference to a copper plate. With respect to EK work, the procedure of applying the coating is much easier and the waveguides can be re-used just exchanging the foil with coated material. This is one of the main advantages of the method.

In her measurements, EK went to upto 750 GHz: this frequency range is reachable also with this method.

MT wonders about the message given about the coating quality with aC. Indeed the thickness is far above the LHC experience (PC reminds that they are used to 100 nm scales). For high thickness the constraint on peel off is too large and there is a worse performance on coatings. Going to a smaller, well manufactured, waveguide would increase the frequency range of the measurements and the thickness required to achieve a sufficient signal-to-noise (SNR).

The measurement is done in single propagating mode. In the square waveguide the TE10 and TE01 are superimposed. The next propagating modes are the TE21 and TE12: the TE11, TM11, TE20, TE02 are either not coupled with the polarized source, or not sustainable. Similar arguments hold for the circular waveguide. The measurement frequency range is therefore 135 GHz to 300 GHz. Including multi-modal propagation in the theoretical model would extend the frequency range (ACTION).

The theoretical model computes the attenuation constant given by tangential magnetic field. The surface impedance enters into play and it can be studied with transmission line models. Comparisons of CST and analytical formulas are very good. A discrepancy at low frequency is more evident for the square waveguide than the circular one. NB asks why this is the case as CST normally finds more difficulties with round shapes. AP will investigate this aspect and attempt mesh refinements (ACTION).
AP presents results for the circular waveguide on NEG deposition of 3.9 \( \mu m \). Unfortunately, the square waveguide was not within mechanical tolerances and the pulse was not symmetrically propagated rotating the waveguide. The measurement on coating of 3.4 \( \mu m \) gives similar attenuations and resistivity. AP discards the results below 165 GHz as SNR is lower and accuracy is worse. The estimated resistivity are \( 7.9 \cdot 10^5 S/m \) and \( 8.2 \cdot 10^5 S/m \) between 170-280 GHz.

VGV stresses that precise results are behind good manufacturing. It is also needed a more performing signal generator (ACTION).

The difference with respect to EK results \( 3.5 \cdot 10^5 S/m \) can be explained in the more homogeneous coating profile obtained with this new measurement method. EK recommends to perform DC measurements to further confirm the obtained resistivity values (ACTION). EK measured between \( 4.5 \cdot 10^5 S/m \) and \( 1 \cdot 10^6 S/m \) in DC for different coating samples and different coating setups (i.e. alloy composition). In EK work, the effect of non-homogeneous profile could have been mitigating by a rotating source.

MT comments that it is difficult to make aC so thick. He asks if the SNR is linear with thickness. VGV answers that for higher frequency range the waveguide can be made smaller and smaller thickness is required.

MT comments that the flat geometry is a great advantage as it clears out one difficulty encountered in EK work where waveguide with edges had to be coated (shaded areas).

PC comments that, to improve the adherence of aC, the ultimate step is to remove the oxide on the copper to have stronger bond between Ti and substrate.

*Minutes written by: N. Biancacci*