Measurement of the interstrip capacitance for strips covered by a metal plane

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Relevant and measurable interstrip capacitances for MCMD sensors: Part I

When a strip sensor is covered by a dielectric with a metal plane (GNDP) on top of it as in the MCMD wafers an additional capacitance appears at every strip. Denote the capacitance between GNDP and an individual strip as C_g. If GNDP is grounded an additional capacitance seen by a front-end preamplifier is simply C_g. Note that if GNDP is left floating but all strips are grounded via the electronics the additional capacitance is still C_g because GNDP is effectively grounded via numerous individual strip capacitors C_g.

Consider the effect of GNDP on the interstrip capacitance C_{is} measured in a standard way between a strip and its two nearest neighbours. The equivalent circuit diagram for such a measurement is shown in Fig.1.

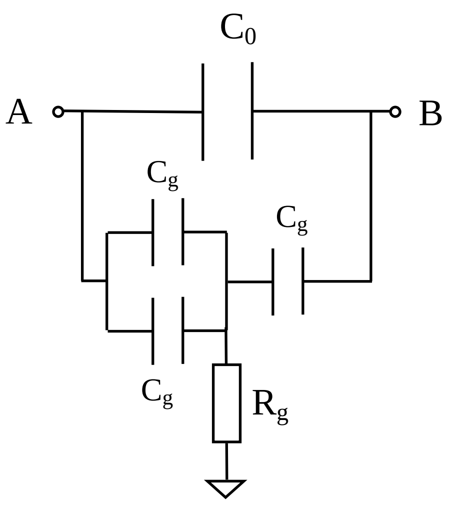

Fig. 1. Equivalent diagram for the C_{is} measurement in the presence of GNDP.

An LCR meter is connected to the points A and B. The C_0 denotes the capacitance without the GNDP, C_g is the mentioned above capacitance between a strip and GNDP, R_g is the resistance from GNDP to the ground. If GNDP is floating ($R_g \rightarrow \infty$) the additional capacitance is $2/3C_g$ i.e. underestimated by 1/3 relative to the additional capacitance which will be seen by a preamplifier. However if GNDP is grounded ($R_g \rightarrow 0$) the capacitances of $2C_g$ and C_g become parasitic capacitances to the ground connected to the LCR input points A and B. The 4-terminal measurement mode used by modern LCR meter suppresses such parasitic capacitances. Therefore the additional capacitance should practically disappear when GNDP is grounded.

To verify this conclusion a dedicated test has been made with a circuit of Fig.1 built from individual components. For MCMD sensors the values of both C_0 and C_g are of ~ 1pF. A nominal value of C_0 in the test circuit was 2 pF (the smallest capacitor available in a standard component form), C_g had nominal value of 2.2 pF and two C_g in parallel were imitated by a capacitor of 4.7 pF. The point between 2.2 and 4.7 pF could be connected to ground via a resistor. The measurements were performed at different frequencies from 1 kHz to 1 MHz.

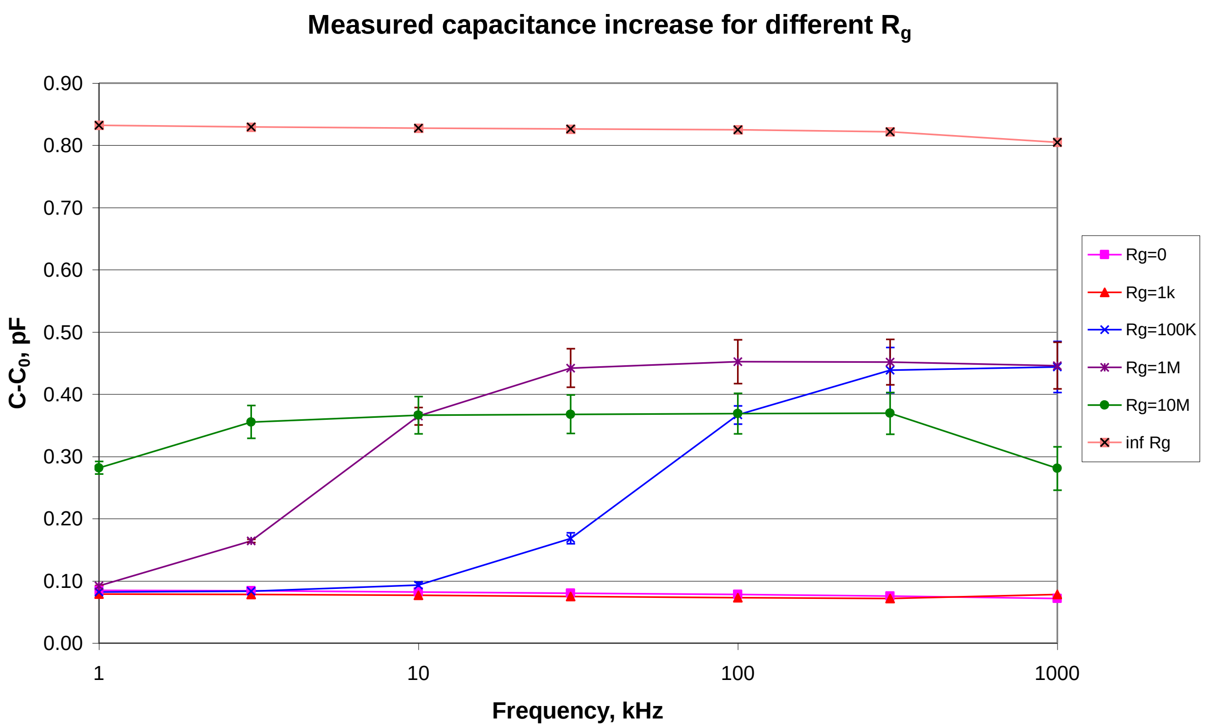

Fig.2 Additional to C_0 capacitance vs. frequency for different R_g.

First the measurements were made with C_0 capacitor only. Its value was found to be ~1.6 pF. Then the second chain of capacitors was added and capacitance was measured for the resistor R_g with one of the following values: 0 Ω, 1kΩ, 100kΩ, 1MΩ, 10MΩ, infinity (no resistor). The capacitance additional to C_0 is presented in Fig.2.

The maximum additional capacitance of ~0.8 pF was observed for infinite R_g . Nominal capacitor values give a bit higher number: 1/(1/2.2+1/4.7)=1.5 pF. However a stray capacitance to the ground of ~ pF may exist in the connector used for R_g connection and reduce the measured capacitance of the additional chain. As expected for small R_g the additional capacitance practically disappeared. The remaining <0.1 pF is probably due to a stray capacitance between the wires soldered to the points A and B when the additional capacitor chain was added. Note that even a large value resistor R_g reduced the additional capacitance by ~ factor 2. This is probably due to a stray capacitance of the resistor itself which might be comparable to the small capacitances used in the test circuit.

In conclusion, the additional interstrip capacitance in the MCMD wafers should be evaluated with GNDP floating rather than grounded. The measurement of the capacitance between a strip and GNDP would also be of interest.

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Relevant and measurable interstrip capacitances for MCMD sensors
Part II

As discussed in Part I for the MCMD sensors the standard measurement of the interstrip capacitance C_{is} as the one between a strip and its two immediate neighbours has problems in incorporating properly the capacitance C_g between the strip and the metal plane (GNDP). If the GNDP is grounded the four-terminal measurement by the LCR meter excludes C_g as stray capacitors to the ground connected at the points between which the capacitance is measured. To see the effect of C_g the GNDP should be left floating but in practice it is difficult to achieve because GNDP is capacitively coupled to the strip plane which in turn is connected to the grounded Bias Rail. As the result the C_{is} for a solid GNDP increases only by ~0.15 pF for a floating GNDP compared to the grounded one instead of expected ~1 pF. As was mentioned in Part I a possible way out of this problem is to measure the C_g directly. This is a topic of the present Note. The discussed methods are illustrated by the measurements with two sensors from wafer 14 (6 μm BCB): X3Y3 with solid GNDP and X3Y2 with GNDP having 25% coverage.

Relatively simple and straightforward method is to measure the capacitance between the strip plane and GNDP from the impedance between the Bias Rail and GNDP measured in C_s-R_s mode. The C_s divided by the number of strips covered by GNDP gives the C_g. Fig.1 shows the C_s measured at 1 kHz frequency for both sensors. Bias Rail was connected to ground via 1MΩ and GNDP via 100 kΩ. Using 128 and 126 as the number of covered strips for solid and 25% GNDP sensors respectively one gets the plateau C_g values of 1.89 and 0.76 pF. The drawback of this method is that the parasitic capacitance of the bias resistor circuit limits its applicability to relatively low frequencies while for the front-end electronics the high frequencies are more relevant.

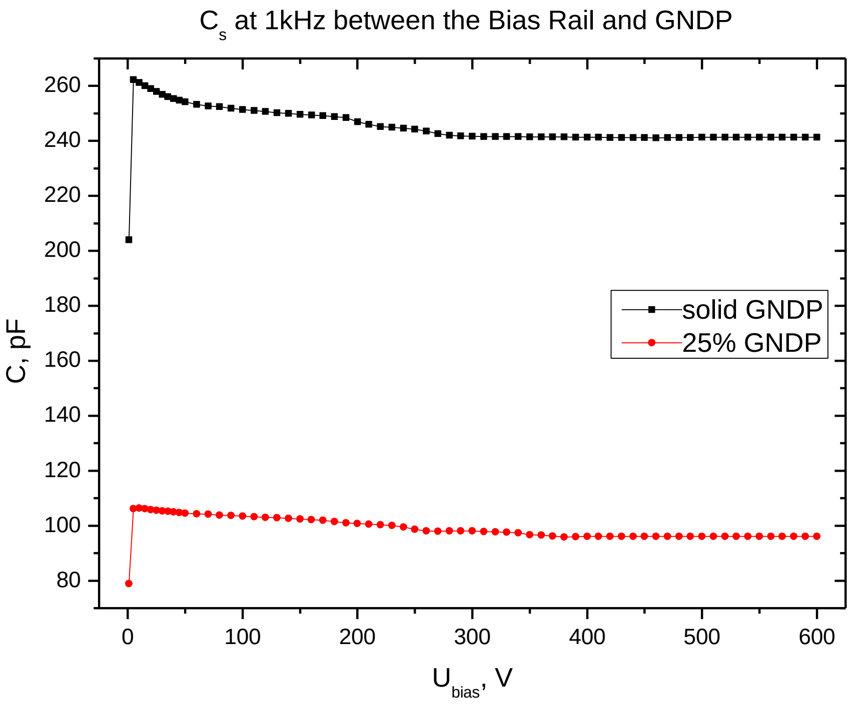

Fig.1 Capacitance between the Bias Rail and GNDP.

Another method, which should work well at high frequencies, is to measure the capacitance between GNDP and one or several consecutive strips connected together. The problem here is that C_g is comparable with C_{is} and the results should be properly corrected for this. Clearly the larger is the number of strips the smaller are the corrections, but using a large number of probe needles is difficult.

Let us consider a simple model of equivalent circuit for such a measurement. Assume that C_{is} consists simply of two capacitance C_{ss} between two adjacent strips. Assume also that for any number of consecutive connected strips the measured capacitance has an additional contribution of two parallel chains consisting of C_{ss} and C_g connected in series: $2C_{ss}C_g/(C_{ss}+C_g) = 2C_{is}C_g/(C_{is}+2C_g)$. For *n* consecutive strips the measured capacitance C_m can the be written as

$$C_m = nC_g + \frac{2C_{is}C_g}{C_{is} + 2C_g} \quad (1)$$

Solving equation (1) and leaving only a positive solution one gets for C_g

$$C_g = \frac{2C_m - (n+2)C_{is} + \sqrt{(2C_m - (n+2)C_{is})^2 + 8nC_mC_{is}}}{4n} \quad (2)$$

which allows finding C_g from the measured value C_m if C_{is} is known.

The measurements of this type were performed with one and with two adjacent strips for the sensors X3Y3 (solid GNDP) and X3Y2 (25% GNDP). The C_{is} was taken from the measurements for similar sensors X5Y3 and X5Y4 but with grounded GNDP. The results for 1 MHz frequency are presented in Fig.2.

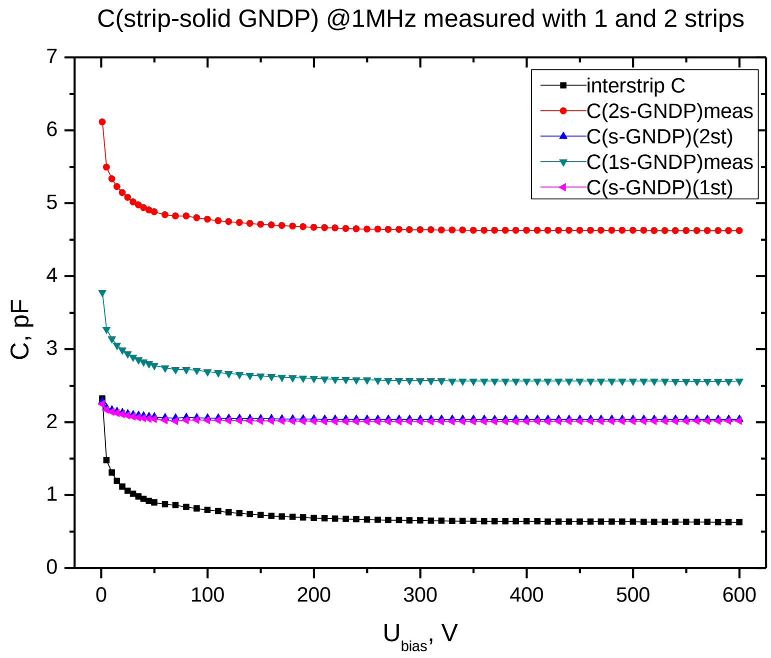

Fig.2a

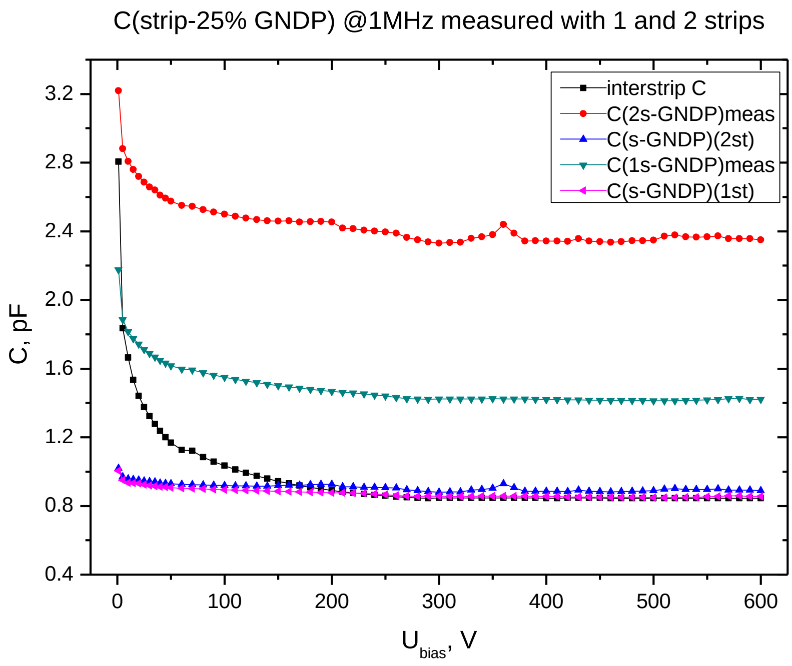

Fig. 2b

Both the GNDP and the strip(s) under the tests were connected to ground via 1 MΩ while the Bias Rail was grounded. Figure 2a is for solid and 2b for 25% GNDP. The black curves show the C_{is} (measured separately), the red (green) curve is the capacitance measured between two strips (one strip) and GNDP. All three curves have significant bias dependence. The blue and magenta curves show the C_g calculated from eq.(2) for measurements with two and one strips respectively. These curves are essentially flat and coincide for the two and one strip measurements, which shows that the above simple model for the C_g calculation works well.

The plateau values of C_g as a function of frequency are shown in Fig.3 for both sensors and both methods (the two strips results are used in high frequency data).

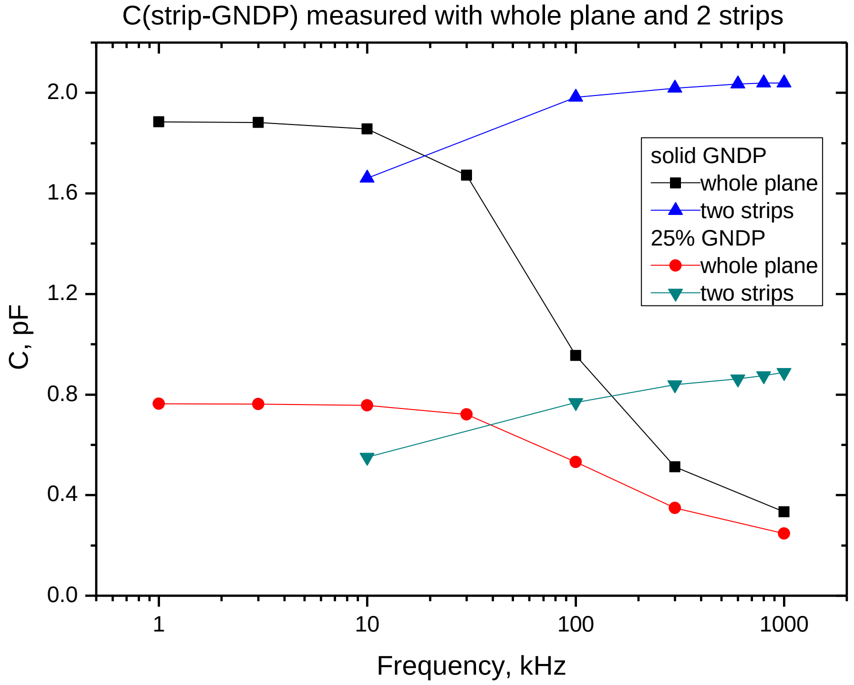

Fig.3. Frequency dependence of the C_g values for two sensors and two methods.

As expected the C_s-R_s measurements require quite low frequency, while the direct C_g measurements work better at high frequency. Both methods give C_g of ~2 pF for the solid GNDP and ~0.8 pF for the GNDP with 25% coverage. The C_g estimate for the solid GNDP calculated as a value for a flat capacitor with an area of 32 μm x 8.5 mm and a thickness of 6 μm filled with a material with ε = 2.65 (BCB) results in a value of 1.1 pF. The reasons for the discrepancy between this estimate and the experimental value still have to be understood.