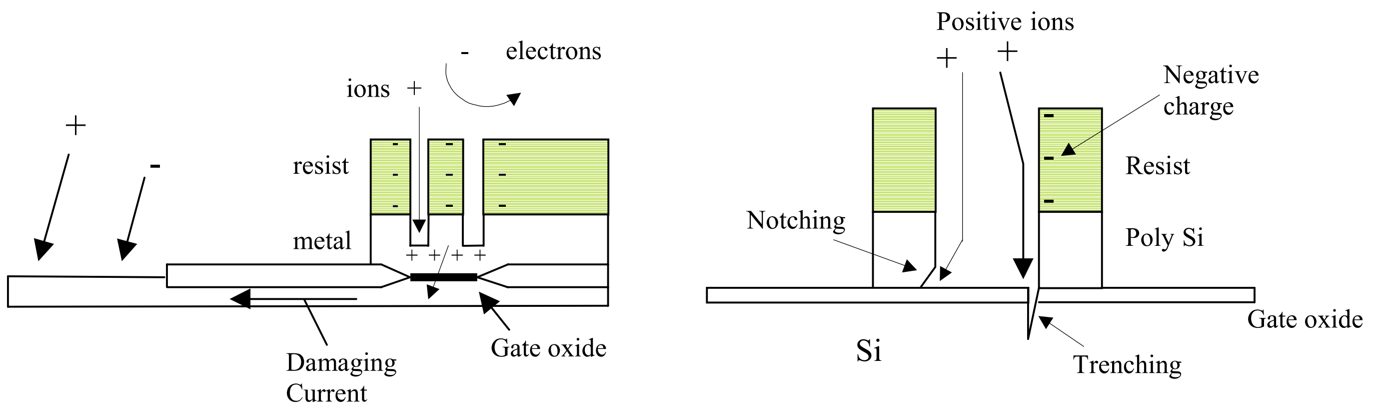
SmartProbe Application Note No. 1
Plasma Process Induced Damage

Plasma charging damage occurs through plasma-wafer interactions. In plasma process reactors, several amps of positive ion and electron current are driven from the plasma through the wafer. These fluxes of charged particles are neutralised and re-distributed on the wafer. The SmartProbe measures the bulk plasma parameters, including the bulk and fast electron temperatures kT_e and kT_f, the electron energy distribution (EEDF), the bulk and fast electron densities N_e, N_f, the ion density N_i, the plasma potential V_P and the floating potential V_f. This note outlines the importance of these parameters to plasma induced device damage.

Recent work[1,2] suggests that the main cause of plasma damage is electron shadowing. This is illustrated below for two scenarios which lead to device damage. In both cases photoresist islands charge to the plasma floating potential. In the first case electrons are deflected and prevented from reaching the underlying substrate. A positive charge builds up which eventually can drive a current through the gate oxide and back to the plasma via open areas. Catastrophic damage can result, particularly for thin gate oxides. The second case demonstrates how plasma charging can impact the gate structure – focussing of ions by residual charge can lead to poly notching or gate oxide trenching. Thus it can be seen how plasma damage impacts device yield.



Reports (see P2ID proceedings, ’97, ’98 and ’99) suggest that decreasing electron temperature or plasma density may decrease plasma-induced damage. Either of the two may be more important for damage, depending on conditions. For example, it appears that at low electron temperatures plasma damage is not a strong function of electron density, but increases rapidly with increased electron temperature. At higher electron temperatures, plasma damage increases rapidly with plasma density. Thus to minimise plasma damage it is important to measure both electron temperature and electron density over the process window. Furthermore, recent work on plasma source design has demonstrated that it is, in particular, the fast electron group or high energy electrons which are responsible for plasma induced damage.

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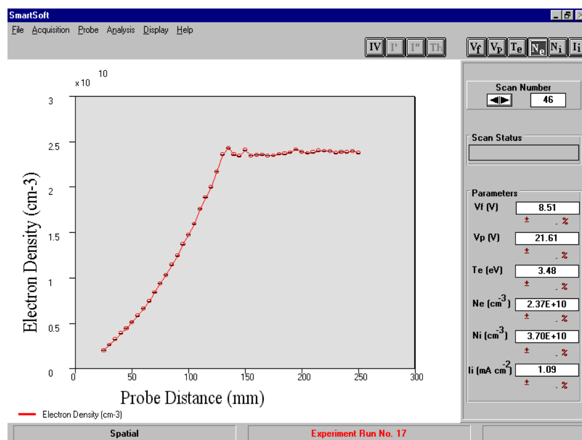
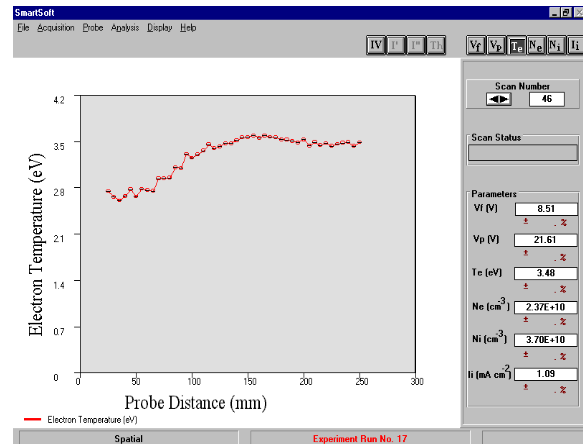
Sources (such as pulsed rf coil or low frequency rf bias) have been developed in an attempt to alleviate damage.

Plasma charge damage is typically measured using CHARM wafers or using the QUANTOX system. Both techniques are expensive and only measure the charge build up after the event. Scientific Systems SmartProbe offers the ability to measure the cause of charge build-up without running device wafers. The process can be tuned to avoid potentially damaging recipes by monitoring kT_e and N_e in a DOE type experiment. Running many expensive charge monitoring wafers can be avoided. The SmartProbe system also measures both the bulk and fast electron temperatures, the EEDF and plasma densities, allowing the user to identify potentially damaging process recipes more readily[3].

The SmartProbe system is the only commercially available Langmuir probe system to address and solve all the problems associated with plasma measurements in RF sources. The SmartProbe compensates for both the rf plasma potential oscillation and any low frequency or dc shift in V_p. Furthermore, accurate measurements can be made in sources with no reference ground and in sources with beat frequencies derived from the difference between coil and bias power frequencies.





Spatial scans across a commercial ICP chamber taken with the SmartProbe are shown. Each scan is taken across a 200mm wafer; the wafer centre is at 250mm and the wafer edge is at 150mm. Both scans can be taken in seconds, so that the entire process field can be mapped very quickly.

References

1. K Hashimoto, Jpn J Appl Phys, 33, 6013, 1994
2. V Vahedi, N Benjamin, A Perry, P2ID-2, 41, 1997
3. MV Malyshev, VM Donnelly, JI Colonell and S Samukawa, P2ID-4, 149, 1999

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