Positron Annihilation Spectroscopy with *in situ* ion implantation to investigate defects in semiconductors over a wide temperature range

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PAS (Positron Annihilation Spectroscopy) is a technique that can be used to study neutral or negatively charged defects in semiconductors. Positrons are accelerated by an applied voltage and implanted into a solid sample, where they thermalize. Each positron annihilates with an electron to form two 511 keV γ-ray photons, which are Doppler-broadened due to the momentum components of the positron-electron pair. Since the momentum distribution of electrons near vacancies or voids is different than in the bulk, measuring the line shape of the 511 keV annihilation peak leads to the detection of vacancy defects [1]. The mean implantation depth of the positron beam is adjusted by changing the accelerating voltage. Combined with standardized fitting routines, PAS reveals high resolution depth profiles of the vacancy concentrations in films only tens to hundreds of nanometers thick.

For the first time, we have commissioned a dual-detector PAS measurement chamber which combines *in situ* ion implantation up to 50 kV from a gas DC-coupled plasma source, as well as a temperature controlled sample stage that can achieve temperatures from 10-1000 K. This allows the evolution of defect profiles before and after ion implantation to be observed as the sample warms and is annealed. This system will eventually be located in the McMaster Intense Positron Beam Facility (MIPBF) as an addition to the McMaster Nuclear Reactor (MNR) [2].

In this work, preliminary PAS results from the system using a Na-22 positron source will be presented. These measurements include (i) a study of Ta_2O_5 films formed by implantation of Ta metal with high doses of O for resistive memory applications [3], (ii) observing the results of process parameters on As-implanted Si wafers doped via PLAD [4], and (iii) the effect of temperature on defect evolution in Ar-implanted Si.

[1] P. G. Coleman, *Positron Beams and Their Application,* (World Scientific, Singapore, 2000).
[2] https://mnr.mcmaster.ca
[3] Materials supplied by Varian Semiconductor Equipment, SSG, Applied Materials Inc.
[4] Samples supplied by J. England, Varian Semiconductor Equipment, SSG, Applied Materials Inc.