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Photocathode research at SLAC*

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Abstract. GaAs based photocathode research at SLAC will be described. Recent efforts have focused on both immediate applications and fundamental photocathode properties. This includes revisiting some old measurements with state-of-the-art instrumentation.

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Abstract. GaAs based photocathode research at SLAC will be described. Recent efforts have focused on both immediate applications and fundamental photocathode properties. This includes revisiting some old measurements with state-of-the-art instrumentation.

Metal coating the surface of GaAs has the potential for reducing the influence of charge trapped in the near surface region. Trapped charge has an adverse effect on the short pulse output properties of the NEA surface by rapidly producing a surface photovoltage which counteracts the NEA condition. A potential pitfall for use of a metal on a polarized electron emitter is depolarization upon transmission though the overlayer [1]. The effects of Pd metal overlayers on the photoemissive properties of GaAs have been probed with XPS, SEM and spin-polarized photoemission. The XPS and SEM measurements were carried out in the deposition system while the polarization measurements were conducted on the sample after transfer through a nitrogen atmosphere. Pd reacts strongly with the GaAs surface making it is necessary to heat the surface to over 500°C after Pd deposition for NEA activation to be possible. Heating to higher temperatures can diminish the XPS Pd signal, but it never disappears which is a signature of the

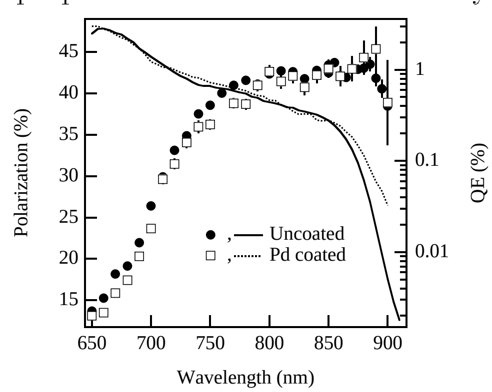

FIGURE 1. Polarization and quantum efficiency from Pd coated and uncoated 100 nm GaAs/AlGaAs as a function of wavelength. The uncoated GaAs was permitted to age for one month making the yield comparable to that of the Pd coated material.

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strong reactivity of the Pd/GaAs interface. While the overall effect of the Pd layer is to reduce the quantum efficiency by a factor of ~10 compared to a freshly cesiated surface, the addition of Pd does not affect the polarization beyond the effects attributable to the lowering of the yield as may be seen in Figure 1. The effect on nanosecond pulse emission is expected to be quantified soon.

The polarization of electrons emitted from strained GaAs has been tracked as a function of the quantum yield over two decades. Beyond the initial rise in polarization due to attenuation of the low energy tail which contains depolarized electrons [2], there is no discernible change in polarization up to a yield drop by more than a factor of 100. Therefore, unpolarized electrons from the $5x10^{18}/cm^3$ acceptor states contribute less than a factor of 10^{-3} to the near band gap photoemission current and the long wavelength rollover of the polarization seen in strained GaAs (see Figure 4) cannot be attributed to the acceptor state electrons.

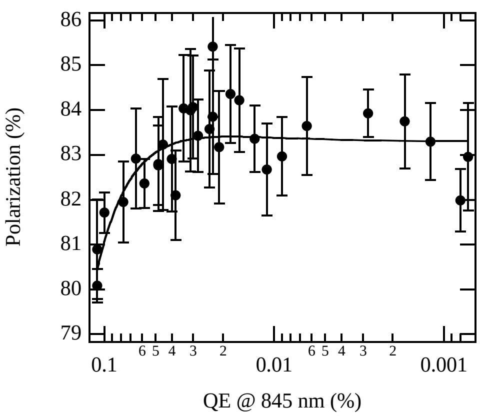

FIGURE 2. Polarization as a function of quantum efficiency. The NEA state was permitted to decay over a period of several weeks.

The properties of the NEA surface created by the use of differing activation gasses, notably NF_3, O_2 and N_2O, have been quantified for 1μm thick GaAs. While there is little difference in the total yield, activations with O_2 are considerably more troublesome with regards to control. There are stages in the activation process where the partial pressure of O_2 must be actively varied even while using the codeposition technique. Lifetime measurements in a test vacuum chamber demonstrated that by a factor of two the shortest lived photocathodes were obtained with the N_2O activations; this effect is attributable to differences in the sticking coefficients of the gasses and in the pumping efficiency of the system.

First results from carbon doped NEA GaAs have been obtained. It was once thought the carbon dopant might diffuse to or segregate onto the surface, lowering the yield. However, there does not seem to be a segregation temperature below the 600°C cleaning value. By all measures, carbon doped GaAs behaves identically to NEA surfaces using Zn or Be for the *p*-type doping. Carbon is particularly attractive as it has a much lower bulk diffusion constant than either Zn or Be and can readily be used for graded doping profiles.

A precision systematic study is underway to determine the ultimate limit of polarization available from unstrained NEA GaAs. This is being done by measuring the polarization as a function of thickness while varying this parameter on a single sample of unstrained GaAs. The limit seen by extrapolation to zero thickness sets an upper bound for the depolarizing effects in $5\times10^{18}/cm^3$ carbon doped GaAs. The results for this technique applied to MBE grown GaAs are shown in Figure 3. The polarization did not reach the value measured for 100 nm, unstrained GaAs (about 44%). This is partially explained by surface roughening during the sample thinning process. AFM measurements of the surface show structures 100 nm high. The spread in thickness has smeared out the polarization response of the thinnest GaAs. Part of the lower polarization may be attributed to material-specific short spin lifetime.

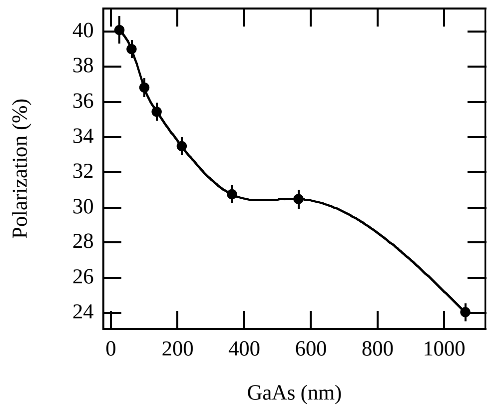

FIGURE 3. Polarization as a function of thickness as measured from carbon doped GaAs. The thickness was reduced via chemical etching.

Studies of alternate techniques for growing single strained layer GaAs are underway. Among these is the substitution of a GaAsP pseudo-substrate for the single unit growth of strain inducing and strained layers. We have obtained LPE-grown Te-doped n-type GaAsP pseudo-substrates with a GaAsP thickness of 25 μm. Strained GaAs was grown with standard MBE techniques. Polarization and quantum efficiency values from such material can be seen in Figure 4. This method may ultimately eliminate the need for the costly and occasionally nonconforming growth of the single strained GaAs layer structure as a unit. In addition, the quality of the pseudo-substrate is quite high and its use may reduce the defect density in the final layer. High defect densities are one limiting factor in achieving the highest polarizations. While the best strain obtained in the pseudo-substrate samples is not yet equal to that of the single unit growth material, a number of growth parameters are still under optimization.

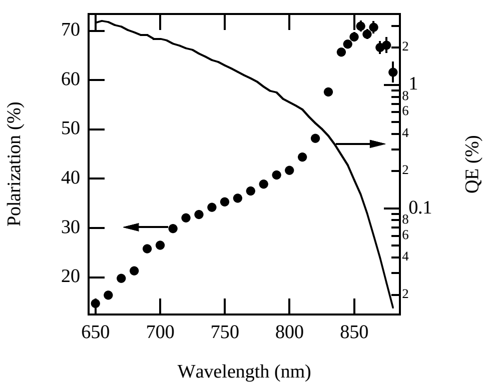

FIGURE 4. Polarization and quantum efficiency as a function of wavelength for GaAs epitaxially grown on a GaAsP pseudo-substrate at 520°C.

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