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Abstract
I would like to thank Larry Himmel for an excellent introduction into what people call exo-electron emission. We are not going to present too much in the way of results right now either, but we do have a few, and it is more or less going to be an update on what has been going on here in the Science Center as far as the phenomenon of fatigue enhanced photo-emission is concerned,

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ENERGY DISTRIBUTION OF PHOTO-STIMULATED ELECTRON EMISSION FROM FATIGUE SPECIMENS

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I would like to thank Larry Himmel for an excellent introduction into what people call exo-electron emission. We are not going to present too much in the way of results right now either, but we do have a few, and it is more or less going to be an update on what has been going on here in the Science Center as far as the phenomenon of fatigue enhanced photo-emission is concerned.

Some work had previously been performed here by Tennyson Smith, George Alers, Don Thompson, and Robin Young on 1100 series aluminum. In these experiments they measured the total electron emission from an aluminum sample as a function of fatigue at different strain amplitudes. They observed the emission current to increase as the state of fatigue progressed at a given strain amplitude, as shown in Fig. 1. The total emission was also observed to increase with increasing strain amplitude. They also investigated the dependence of the emission on an overlying oxide layer and found that as the thickness of the oxide increased, the amount of emission decreased. This seems merely to be an overlayer effect as the aluminum oxide was transparent to the radiation employed.

The next logical step, of course, is to do an energy analysis of the emitted electrons. Under the auspices of the AFOSR, we have been constructing a system to do just this, and a schematic of this system is shown in Fig. 2. Fatigue and electron energy analysis will take place in an ultrahigh vacuum environment which hopefully will achieve a pressure of $1 \times 10^{-9}$ torr. A McPherson 0.3 meter monochromator, model 218, will be used to provide monochromatic light in the 3-12 eV range using a Hinteregger arc lamp as the light source with hydrogen as the working gas. The divergent light beam from the monochromator will be converged.
Fig. 1 Fatigue-enhanced photocurrent as a function of fatigue state (time) for three different strain amplitudes. Data taken from Ref. 1.
Fig. 2 Schematic diagram of ultra-high vacuum apparatus designed to measure the energy distribution of the fatigue-enhanced photocurrent.
back to a 2x2 mm spot size at the sample. Fatigue of the sample will be carried out in a cantilever beam type fashion. The energy analysis of the emitted electrons will be performed using a modulation technique which is standard for the retarding grid system employed here. The analyzer, see Fig. 3, is just a converted 4 grid LEED optics with the sample, first grid, and fourth grid grounded (described by Huchital and Rigden at the 1971 Asilomar conference on electron spectroscopy). The energy resolution of the system is enhanced by the additional inclusion of a post monochromator. The energy distribution curve may be obtained by imposing a negative ramp voltage modulated by a small AC voltage upon the second-third grid combination, and by using standard phase sensitive detection techniques, the output from the electron multiplier (which is at the same frequency as the grid modulation) can be detected.

The system will also contain an Argon ion bombardment gun to be used for sample cleaning and a grazing incidence electron gun which will be used to excite Auger transitions so that we may monitor the surface chemistry of our sample. Provision has also been made to enable an ellipsometric analysis of the sample. Since the specimen may be electrically isolated from ground, work function measurements will also be possible using the monochromator. A gas-flow type of heating-cooling mechanism will enable us to work in a temperature range of approximately 100-600°K. Also, we are going to supplement the data obtained with this instrument with scanning electron microscope pictures to determine the amount and frequency distribution of surface roughness and/or cracks.

The purpose of obtaining the energy distribution of the fatigue-enhanced photoelectrons is, of course, to attempt to gain an insight into the mechanism by which they are produced. There are two different theories which we presently find intriguing, and which we would like to experimentally support or disprove concerning the production of these electrons. One comes from the work of Endriz and Spicer. They found that, as one increases the roughness of a sample surface, incident radiation is able to be coupled more readily into exciting surface plasmons and the amount of
Fig. 3. Photograph of the energy analyzer.
photoemission is enhanced as the plasmons subsequently decay and release the absorbed energy. Another theory as to the mechanism of the production of these electrons is due to Hoenig\textsuperscript{4} and to Claytor and Brotzen\textsuperscript{5} who have suggested that the migration of vacancies to the surface and their subsequent annihilation provides the energy necessary to increase the emitted electron current. We should be able to differentiate easily between those two theories by performing the experiment as a function of temperature and noting if there is a drastic change in the emission peak as the temperature necessary for vacancy migration is traversed.

Some preliminary results have been obtained in an effort to demonstrate the feasibility of the detection scheme. We took a 1100 series aluminum sample which had been fatigued in air, placed it in the UHV system and energy-analyzed it using a mercury-argon lamp as the radiation source; 92\% of the photons emitted from this lamp have an energy of 4.89 eV. Figure 4 shows an energy scan of the electrons emitted from the sample in the energy range of -2 eV to +6 eV kinetic energy. An emission is clearly visible; the structure below 0 eV is an instrumental effect due to the emission of secondary electrons from the grid system. A SEM micrograph of the analyzed surface is also shown in the figure. A heavy oxide layer is obviously present and cracks in it resulting from the fatiguing are clearly visible.

References:
Fig. 4  Energy distribution and SEM micrograph from a fatigued oxide-covered Al surface.
DISCUSSION

PROF. PAUL FLINN (Carnegie-Mellon University): Instead of using fatigue cracks, is it possible to see this effect with scratches in order to distinguish the effect of just surface geometry from the presence of strained material?

DR. SZALKOWSKI: I think that it is possible, but I would rather pass on the question at the moment. Maybe someone else would like to answer that.

PROF. FLINN: I was thinking of the sort of thing that was done for surface diffusion measurements where you produce the periodic surface roughness with scratches. This could be annealed without destroying the roughness, but it would get rid of vacancies and other things you were suggesting.

DR. DON THOMPSON (Science Center, Rockwell International): One thing that we thought about and I don't know whether it will all fit into this experiment, is the generation of periodic spatial undulations using acoustic surface waves.

DR. OTTO BUCK (Science Center, Rockwell International): Perhaps you want to go away from scratches on annealed material. You may see that effect in tribo-physics. One scratches over a specimen surface and sees the exo-electrons coming off right after the scratch has been made.