CC/NUMBER 3
JANUARY 21, 1985

This Week's Citation Classic™

Ritchie R H. Plasma losses by fast electrons in thin films.
Phys. Rev. **106**:874-81, 1957.
[Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN]

The response of a plane-bound electron gas to an incident, swift, charged particle was studied theoretically. It was predicted that measured electron energy loss spectra should exhibit structure due to surface collective modes. The dispersive properties of the surface plasmon (SP) due to the proximity of the two bounding surfaces were discussed, and distinguishing characteristics of losses to SPs were described. [The *SCI*® indicates that this paper has been cited in over 435 publications since 1957.]

R.H. Ritchie
Oak Ridge National Laboratory
Oak Ridge, TN 37831
and
Department of Physics
University of Tennessee
Knoxville, TN 37916

July 26, 1984

The paper was written while I was a staff member in the Health Physics Division at Oak Ridge National Laboratory (ORNL) and a part-time graduate student in the Department of Physics at the University of Tennessee. With my colleagues R.D. Birkhoff and J. Neufeld, I had been analyzing electron energy loss data[1] and learning about the dielectric theory of energy loss.[2] I became curious about the distribution of energy losses when a swift electron passes through a thin metal foil and worked out the theoretical spectrum for this case using both local dielectric theory and the hydrodynamical model of Bloch[3] to describe the response of the metal.

Subsequently, Birkhoff and I both submitted abstracts of papers to a conference at the University of Maryland, although I was unable to attend because of a conflicting business trip. Birkhoff was kind enough to present my paper in addition to his own. After delivering my paper, he was startled at the vociferous criticism of my work from a prestigious English physicist (later a Nobel laureate) in the audience. He had worked on the same problem but did not find the surface plasmon (SP).

Very concerned about this criticism, when I returned to ORNL, I contacted David Pines, who was an attendee at the conference. He very kindly discussed these results with me and encouraged me to go ahead and submit my paper for publication. I studied the paper by my English critic[4] and decided that he had not found surface modes in the bounded plasma because he had required that the electric field of the modes should vanish at the surfaces. In fact, he had discussed only the volume plasmon modes in a bounded medium.

Although I could find no definitive evidence that the losses to SPs had been observed in any of the published results on characteristic energy losses by electrons to metallic films, I could see no reason why the SP would not be generated with appreciable probability in a properly designed experiment. So I described the distinguishing characteristics of losses to these modes as completely as I could on the basis of the model at hand and sent the paper to *Physical Review*.

About three years later, in a lovely series of experiments, Cedric Powell and John Swan,[5,6] at the University of Western Australia, fully confirmed the existence of SP losses by electrons in reflection geometry.

The reason this paper has been so frequently cited lies in the rapid development of surface science over the last two decades. The SP is a prominent feature in electron energy loss experiments, low energy electron diffraction, Auger electron spectroscopy, the optical response of solids, photoemission work, and many other areas of active research. It has been shown to be intimately involved in the image force on a charge external to a metal. In addition, the SP has served as a stimulus to the development of the many-body theory of the bounded electron gas (see, for example, reference 7). Several reviews covering recent developments are available (see, for example, references 8 and 9).

I have been most fortunate to have worked in an interdisciplinary division at ORNL that has continually maintained a strong basic physics effort. This enlightened atmosphere has made it a delightful place to be. I would like especially to express my appreciation for the support of Karl Z. Morgan (then division director); of my colleagues Birkhoff, G.S. Hurst, and Neufeld; and of many others in our division for their help and guidance over the years.

1. **Blackstock A W, Ritchie R H & Birkhoff R D.** Mean free path for discrete electron energy losses in metallic foils. *Phys. Rev.* **100**:1078-83, 1955.
2. **Neufeld J & Ritchie R H.** Passage of charged particles through plasma. *Phys. Rev.* **98**:1632-42, 1955. (Cited 75 times since 1955.)
3. **Bloch F.** Bremsvermögen von atomen mit mehreven elektronen. *Z. Phys.* **81**:363-76, 1933. (Cited 205 times since 1955.)
4. **Gabor D.** Collective oscillations and characteristic electron energy losses. *Phil. Mag.* **1**:1-18, 1956. (Cited 15 times since 1956.)
5. **Powell C J & Swan J B.** Origin of the characteristic electron energy losses in aluminum. *Phys. Rev.* **115**:869-75, 1959. (Cited 115 times since 1959.)
6. ------------------------------. Effect of oxidation on the characteristic loss spectra of aluminum and magnesium. *Phys. Rev.* **118**:640-3, 1960. 135 times since 1960.)
7. **Wikborg E & Inglesfield J E.** Collective modes and ground state energy of the semi-infinite electron gas. *Phys. Scr.* **15**:37-55, 1977. (Cited 15 times.)
8. **Ritchie R H.** Surface plasmons in solids. *Surface Sci.* **34**:1-19, 1973. (Cited 145 times.)
9. **Raether H.** Surface plasma oscillations and their applications. *Phys. Thin Films* **9**:145-261, 1977. (Cited 75 times.)

