Title
FIELD ION MICROSCOPY

Authors
Raghavan, N. Durai
Ranganathan, S.

Publication Date
1967-03-01

UCRL-17447

University of California

Ernest O. Lawrence Radiation Laboratory

FIELD ION MICROSCOPY

DISCLAIMER

Submitted to Indian Express, Madras

UCRL-17447
Preprint

UNIVERSITY OF CALIFORNIA
Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

FIELD ION MICROSCOPY

N. Durai Raghavan and S. Ranganathan

March 1967

FIELD ION MICROSCOPY

N. Durai Raghavan

Inorganic Materials Research Division, Lawrence Radiation Laboratory,
Department of Mineral Technology, College of Engineering,
University of California, Berkeley, California

S. Ranganathan

Inorganic Materials Research Division, Lawrence Radiation Laboratory,
Berkeley, California

INTRODUCTION

From the beginning it has been the aim of the microscopists to see the very small. For a hundred years the optical microscope has served to look into the microstructure of biological and metallurgical materials. In the last two decades more powerful techniques involving x-ray and electron microscopy have given us a keen understanding of the relation between structure and properties. These have improved resolution over the optical microscope, but still fall short of resolving individual atoms. This logical limit to microscopy has been achieved with the advent of field ion microscopy. It was invented by Professor E. W. Müller in 1951 in Berlin. He cameto Pennsylvania State University in 1954 and has been responsible for practically every major innovation in the technique. This article gives a brief description of this instrument and a few of its important applications.

THE MICROSCOPE

The field ion microscope is an exceedingly simple instrument (Fig. 1). It consists of a glass chamber which is evacuated to a high degree by suitable vacuum pumps. The specimen under investigation is polished to a sharp point and introduced into the chamber. The specimen is cooled to a low temperature by means of liquid nitrogen. Liquid hydrogen and liquid helium are also coming into use as coolants. A gas, usually helium, is leaked in at a low pressure. A positive voltage of a few kilovolts is applied to the specimen. High field regions are thus created over protruding metal atoms on the surface. They ionize the helium atoms. The resulting helium ions travel in a radial direction towards a fluorescent screen and form the highly magnified field ion image. The magnification is over a million times; the head of a pin to the same magnification would cover the city of Madras. The intensity of the image is low. It requires perfect dark adaptation for visual observations and large aperture lenses and high speed film for photographic recording. The conditions are similar to those that the astronomer faces in his study of the very big - the stars!

When the applied electric field is increased, the metal atoms can be removed as ions. Thus, the specimen surface can be peeled off layer by layer so that the bulk structure of the metal can be studied.

STRUCTURE OF METALS AND ALLOYS

Field ion micrographs from pure metals are characterized by great regularity. Figure 2 shows a typical field ion micrograph from a tungsten specimen. Each bright spot corresponds to a single atom on the surface and the circles correspond to planes in the crystal lattice. The symmetry in the micrograph reflects that in the crystal lattice. Alan Moore, an Australian physicist, has formulated an elegant approach to the interpretation of such images. A computer is used to find out the positions of all atoms near the surface of a sphere and plot them. Figure 3 was obtained in this manner on the assumption that the atoms are located at the sites of a simple cubic lattice.

When two different metals are mixed together, an alloy results. The field ion microscope has been used to study such alloys in the hope that it can give information about how the two metals are distributed. Figure 4 is a micrograph from a molybdenum-8% tantalum alloy. The natural question to ask is whether one can tell the molybdenum and the tantalum atoms apart. The answer at the time of writing is "no". One of the blocks to progress is the irregularity in the image. However, our understanding of these images is improving. Recent work has shown that when the two metals are arranged in a very regular way, one of them can be invisible.

LATTICE IMPERFECTIONS

Crystals are made of atoms arranged in a regular manner. However, imperfections which interrupt this regularity do occur and play a large part in determining the mechanical properties of metals and alloys. Vacancies occur wherever atoms are missing. The microscope has been used to pinpoint the location of such vacancies and to study the configurations they take up when they cluster together. A dislocation causes a more widespread disturbance. It can be recognized in micrographs by the presence of beautiful spirals in place of the set of concentric circles. The nature of the spirals gives us vital clues to the nature of the dislocation. The boundary between two crystals is a planar imperfection (Fig. 2). Brandon and Ranganathan have used the microscope for the study of crystal boundaries. A model for the atomic configuration at such boundaries was developed as a result of these studies. It may be remarked that this kind of information cannot be had through other techniques.

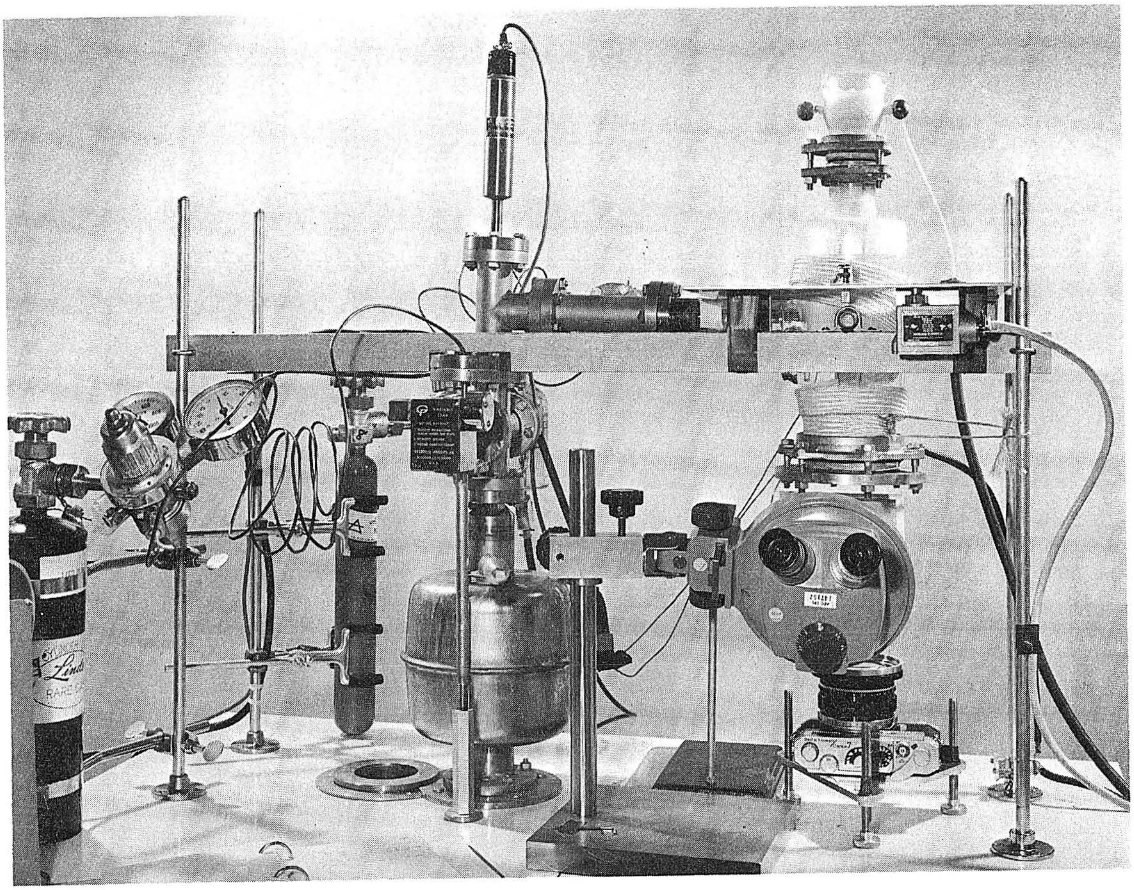
OTHER STUDIES

Some of the more spectacular results have been obtained by turning the field ion microscope into a miniature laboratory. A source that emits alpha-particles was placed near the specimen. The damage introduced by the passage of a single alpha-particle has been recorded. This affords us fresh insights into the dynamics of radiation damage. Another line of investigation is the study of adsorption and diffusion. In the careful hands of Dr. Gert Ehrlich of General Electric Laboratory, USA, the microscope has been persuaded to yield many beautiful results. He has deposited a few nitrogen atoms on a tungsten surface and has followed their migration on heating the specimen. Finally a field that is of much promise is the study of organic macromolecules, which is of obvious importance to biologists. Last year Rendulic and Müller succeeded in occluding large molecules in a platinum cage and subsequently imaging the molecules. As yet the pictures show very little fine detail but with an improvement in technique, we may expect with confidence that the field ion microscope will play a useful role in biology and metallurgy even as its cousin - the transmission electron microscope - does.

The authors are associated with the Field Ion Microscope section of the Inorganic Materials Research Division. One of them (S. Ranganathan) will be joining the Department of Metallurgy at Banaras Hindu University in August, 1967.

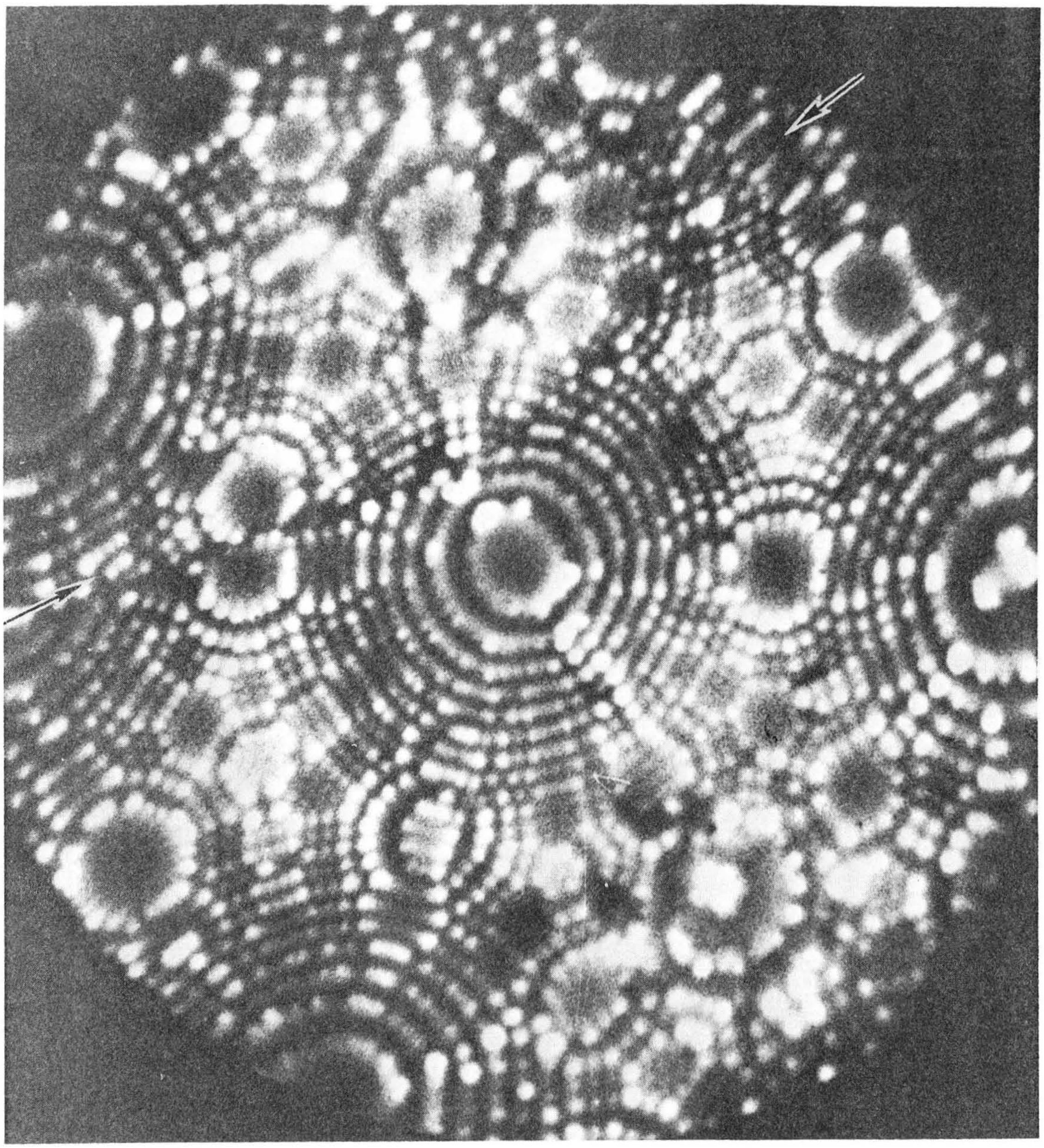
FIGURE CAPTIONS

Fig. 1	The field ion microscope.
Fig. 2	Field ion micrograph of tungsten. The boundary between two crystals is well resolved.
Fig. 3	Computer simulated field ion pattern for the simple cubic lattice.
Fig. 4	Field ion micrograph of molybdenum-tantalum alloy.



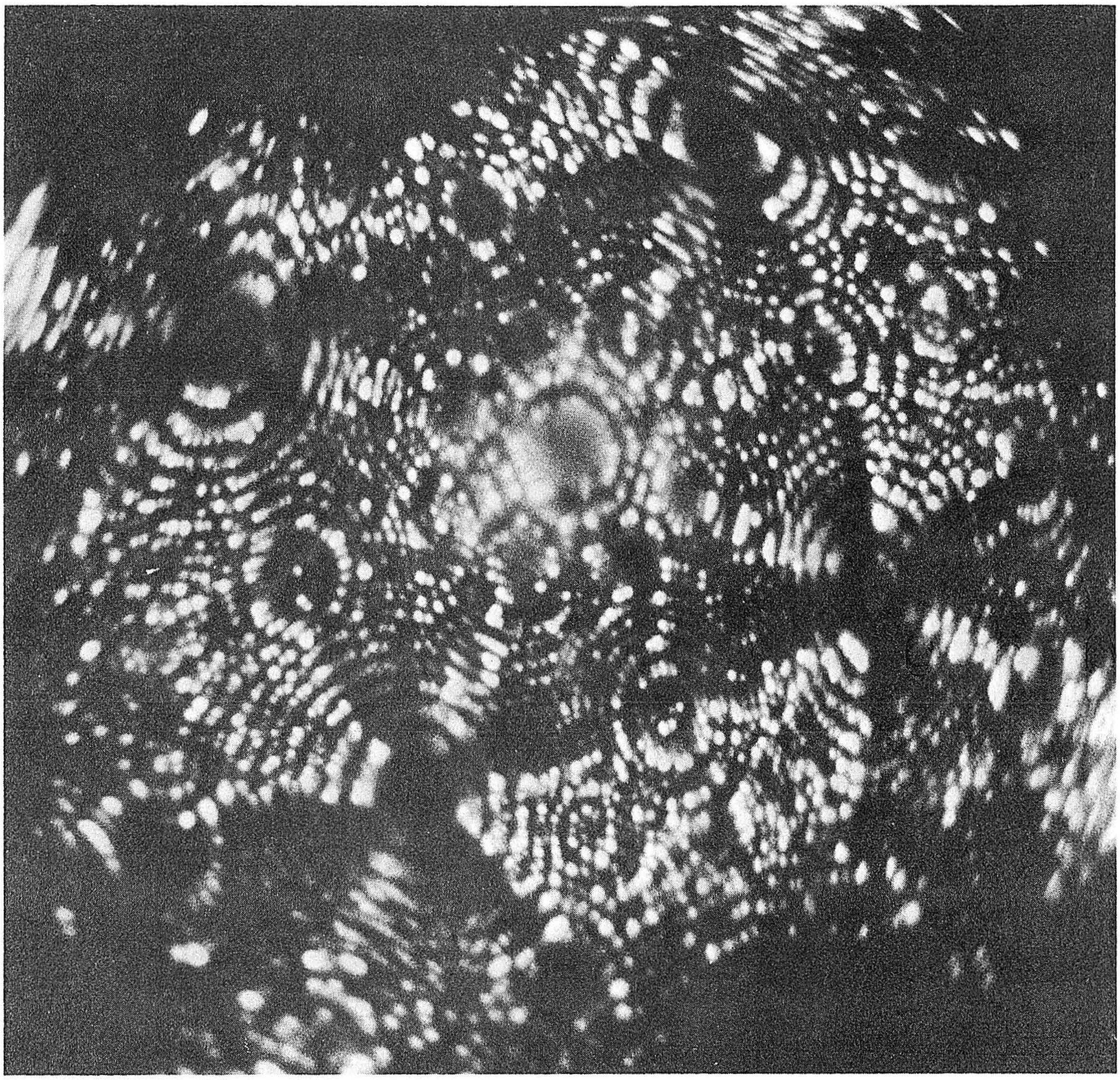
IM 1963

Fig. 1



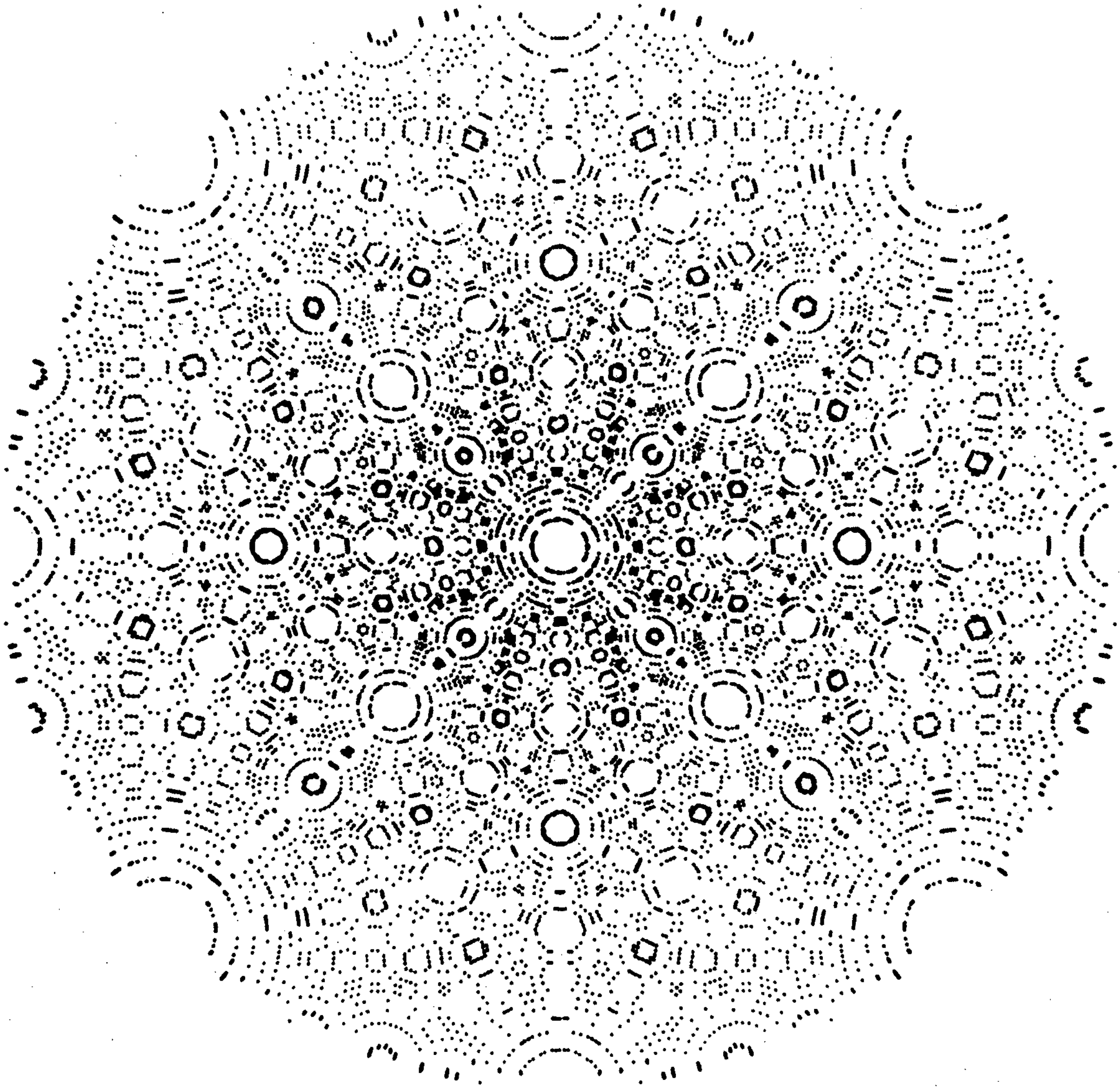
XBB 674-2162

Fig. 2



XBB 674-2163

Fig. 3



XBB 672-754

Fig. 4