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Compositional Imaging at the Atomic Scale with Atom Probe Tomography

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Atom probe tomography (APT) is the highest spatial resolution analytical characterization technique. The spatial resolution is very high in all three dimensions simultaneously as shown in Table 1. APT provides quantitative compositional images with high analytical sensitivity. The analytical detection efficiency is better than 50% and is uniform for all atomic and molecular species from hydrogen to the heaviest. By collecting images with greater than 10 million atoms and with low background signal, a feat which is now routine, high analytical sensitivity is achieved. Recent developments in atom probe technology have pushed the technique to larger fields of view, greater mass resolution, and greater analytical sensitivity. Furthermore, the technique can now be applied to materials independent of electrical conductivity which has not been true of commercial instruments in the past. Typical performance metrics for modern atom probes are listed in Table 1.

A major component of these advances is the commercial introduction of laser pulsing [1,2] first introduced by Kellogg and Tsong [3] and others [4] in the late 1970s. A schematic illustration of a laser pulsed local electrode atom probe (LEAP®) [5,6] is shown in Fig. 1. Laser pulsing makes it possible to analyze materials with low electrical conductivity. An example analysis of a semiconductor is shown in Fig. 2 [7]. The strained silicon-germanium layers are clearly defined and the boron distribution in the doped silicon layer is readily determined. These specimens were prepared by a coupon lift-out technique similar to that commonly used for TEM specimen preparation [8].

Table 1 Typical performance properties of current atom probes.

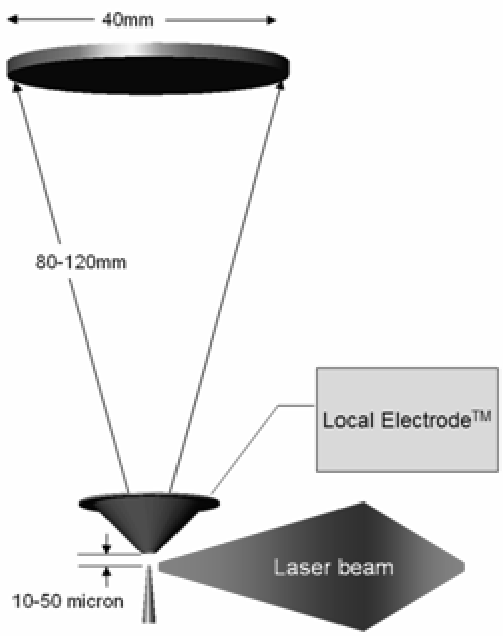
Property	**Value**
Mass resolution	>1000 FWHM > 300 FWTM
Field of View	> 100 nm diam. > 10^7 nm^3
Sensitivity	< 1 appm
Spatial Resolution	< 0.3 nm
Data collection rate	> 10^6 atoms/min.

APT is a complementary technique to TEM and SIMS and there are strong synergies between the techniques. Increasingly, methods correlation among APT, TEM and SIMS will be employed. Fig. 3 illustrates the clear correlation observed between APT and TEM for a Ferritic iron-base superalloy [9]. Good correlation is also observed between APT and secondary ion mass spectrometry.

The limits of field of view and analytical sensitivity are set by the size of the image data set in APT. Fig. 4 shows a state-of-the-art image that contains over 575 million atoms of Ag. Though this is high purity silver, oxygen and aluminum impurities are observed in the spectrum at very low concentrations [10].

[1] J. H. Bunton et al., Patent application WO2005104307.
[2] A. Menand et al., Micro Micoanal. 11(S2) (2005) 96.
[3] G. L. Kellogg and T. T. Tsong, J. Appl. Phys. 51 (2) (1980)1184.
[4] T. T. Tsong et al., J. Chem. Phys. 65(6) (1976) 2469.
[5] T. F. Kelly and D. J. Larson, Mat. Char. 44 (2000) 59.
[6] T. F. Kelly et al., Micro. Microanal. 10(3) (2004) 373.
[7] K. Thompson et al., Solid State Technology, In press.
[8] T. F. Kelly et al., US patents #6700121 and 6576900.
[9] C. Stallybrass and G. Sauthoff, Mat. Sci. Eng. A 387-389 (2004) 985.
[10] The assistance of many Imago employees who enabled this work is gratefully acknowledged.

1



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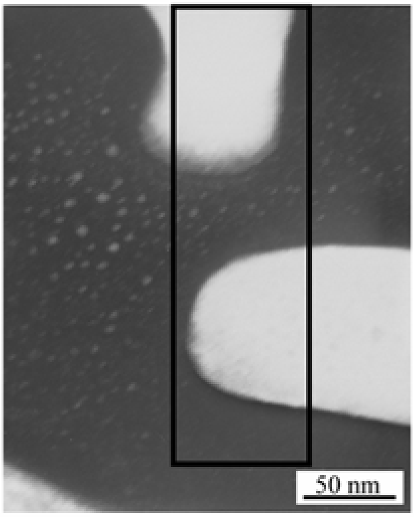

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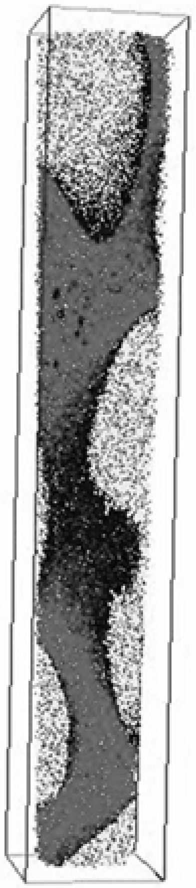

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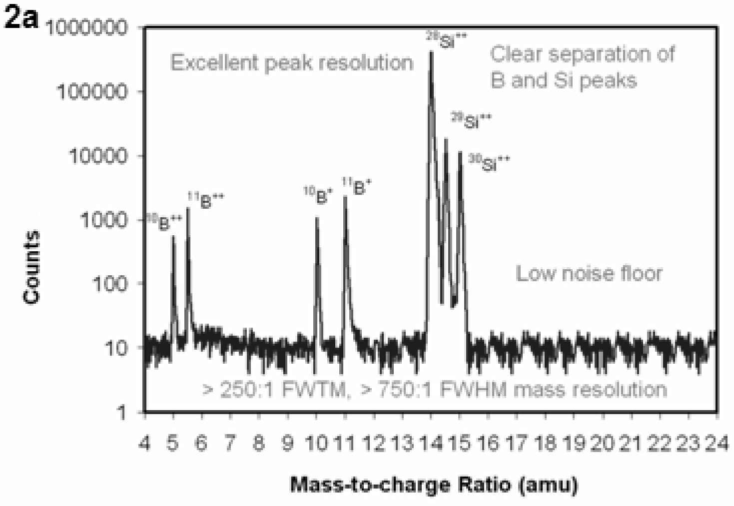

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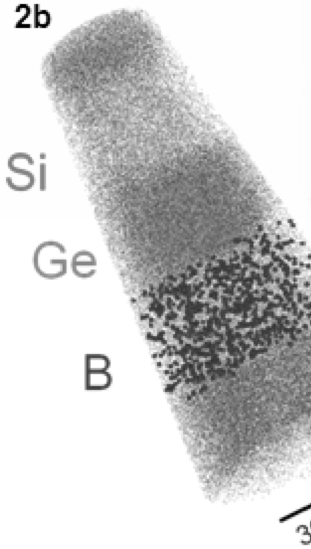

4

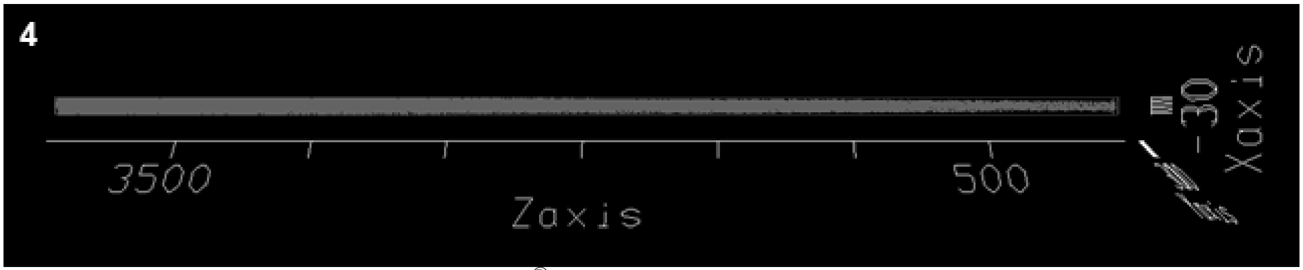

Fig. 1 Schematic of a laser pulsed LEAP®.

Fig. 2 a) Mass spectrum from 2b. b) Atom map of SiGe multilayer structure.

Fig. 3 a) TEM dark field of multi-phase Fe-base superalloy (courtesy C. Stallybrass, A. Schneider and G. Sauthoff). b) LEAP image of same alloy.

Fig. 4 LEAP® image of Ag containing 575 million atoms. Z axis labeled in nm