The Positron Microscope and Microprobe

The first transmission positron microscope (TPM) was realized by van House and Rich (1988). They achieved a magnification of 55 in transmitting positrons through a polymer foil. TPM may have a variety of new applications compared with transmission electron microscopy (TEM). The comparison of the contrast formation in TEM and TPM may provide valuable information on particular terms in the scattering cross-sections. The reduced small-angle scattering of positrons is governed by the much more effective screening of the nuclei. A strongly *Z*-dependent (*Z* atomic number) difference in the amplitude contrast exists between electron and positron microscopy. Thus, the comparison of the contrast mechanisms of both techniques could provide sensitive chemical information.

The positron re-emission microscope (PRM) utilizes the effect of negative positron work functions at certain surfaces (for the data see Schultz and Lynn 1988). The surface of a sample is exposed to a positron beam with an energy of several keV. The penetrating positrons thermalize and diffuse, as a result of which a large fraction reaches the surface. The lateral distribution of re-emitted positrons is used to form an image by a position-sensitive detector, such as a channel plate. A dark contrast is obtained in this image, when near-surface defects prevent positrons from emission. The PRM represents thus an extremely surface- and near-surface-sensitive tool for the detection of positron-active defects. Such a microscope was realized in a reflection geometry by van House and Rich (1988). They achieved a spatial resolution of 2.3 µm.

Positron microscopy is still in an early stage of development (for a review see Waeber 1990). The main drawback is the lack of a positron beam with sufficient brightness. The spatial resolution is limited because positron point sources are not available.

The reflection geometry of the positron re-emission microscope allows in principle operation in a microprobe mode (Hulett 1995). This is due to the fact that the chemical composition of the surface considerably influences the work function of the positrons used for the imaging (Wissman et al. 1992). The realization of a positron microprobe requires sufficiently intense positron microbeams.

In addition to the re-emission, other annihilation parameters, e.g. the Doppler-broadening *S* parameter or the positron lifetime, can be detected in a positron microscope. A promising development at Bonn University represents the combination of a scanning electron microscope with a positron microprobe. The SEM image is used to select areas of interest on the sample for subsequent positron measurements with high lateral resolution. For this purpose, a monoenergetic positron source was integrated in the optical system of a commercially available scanning electron microscope (Greif et al. 1997). The electron gun is replaced by a magnetic prism for energy filtering of the positrons. The electron and the positron beams are guided through the prism with the same magnetic field in the optical axis of the microscope (Fig. 1).

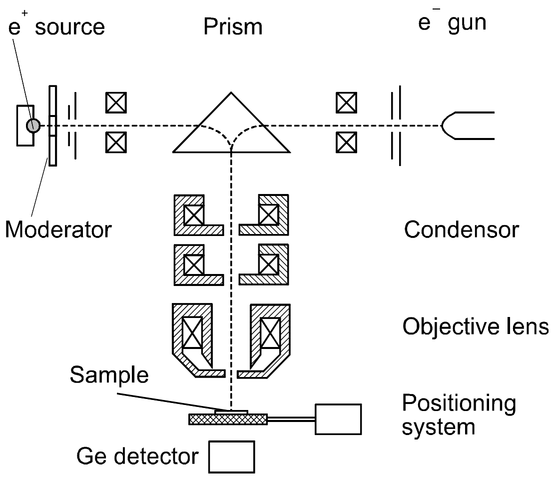

Fig. Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**.1.** Combination of a scanning electron microscope (Zeiss/Leo) and a positron microprobe as realized at Bonn University (Greif et al. 1997). The positron beam is guided through the optical axis of the microscope. The electron beam is used to select the area of interest for Doppler-broadening measurements.

As a first application, the fatigue damage profile along the cross-section of a bent copper plate was investigated (Greif et al. 1997). The observed *S* parameter profile agreed well with the fatigue damage distribution. A lateral resolution of 30 μm was achieved. A counting rate of 35 s^{-1} in the germanium detector was obtained. The annihilation events were accumulated over several hours per beam position. Such low counting rates hardly allow the formation of images and thus mainly lines scans are possible.

A very ambitious project for a scanning positron microscope for defect analysis is pursued in Munich (David et al. 1997; Triftshäuser et al. 1997). The scheme of the microscope is shown in Fig.. It represents the combination of a scanning electron microscope with a pulsed variable-energy positron beam allowing positron lifetime measurements. The positron beam, which is formed during a double-stage moderation, has a spot diameter of 1 μm or below. The positron beam, with an energy of 0.5 to 30 keV, can be used for defect imaging over sample areas of $0.6\times0.6\ mm^2$. An overall counting rate of $2\times10^4\ s^{-1}$ has been achieved at the current stage of development.

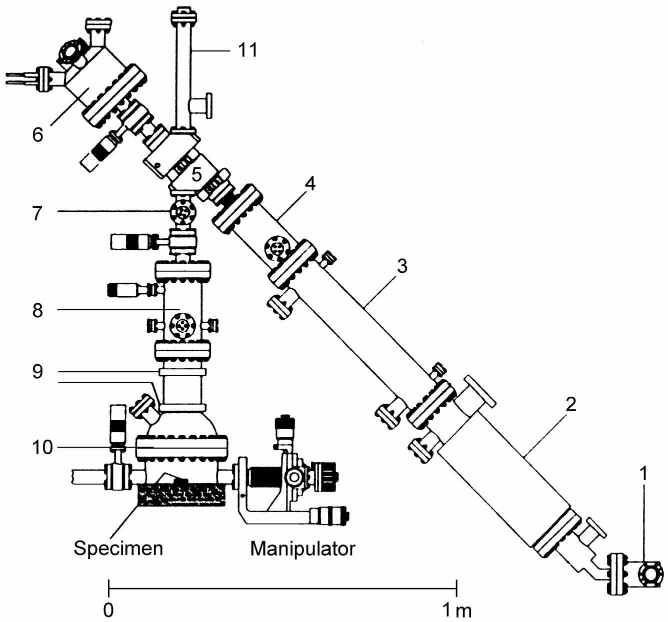

Fig. 1. Scheme of the Munich scanning positron microscope (David et al. 1997). (1) Positron source and moderator, (2) drift tube for pulse forming, (3) first buncher, (4) accelerator, (5) beam switch, (6) re-moderator, (7) second buncher, (8) main accelerator, (9) scanning coils, (10) sample chamber, (11) electron gun. Some components are rotated into the plane of drawing.