ISSN 1063-7850, Technical Physics Letters, 2008, Vol. 34, No. 9, pp. 763–764. © Pleiades Publishing, Ltd., 2008.
Original Russian Text © N.A. Gostishchev, A.S. Kubankin, N.N. Nasonov, V.V. Polyanskiĭ, V.I. Sergienko, V.A. Khablo, 2008, published in Pis'ma v Zhurnal Tekhnicheskoĭ Fiziki, 2008, Vol. 34, No. 17, pp. 78–82.

Angular Dependence of the Coherent Peak Position in the Polarization Bremsstrahlung Spectrum of Relativistic Electrons in Polycrystalline Targets

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Received February 4, 2008

Abstract—The spectra of the polarization bremsstrahlung (PB) in the X-ray range induced by 7-MeV electrons in polycrystalline Al, Cu, and Ni polycrystalline films have been measured and the angular dependences of the PB characteristics have been studied. The experimental data agree well with the results of theoretical calculations and show good prospects for the development of a new method of diagnostics of polycrystalline materials based on the measurement of characteristics of the coherent PB component.

PACS numbers: 78.70.-g, 78.70.Ck

DOI: 10.1134/S1063785008090137

As is known, polarization bremsstrahlung (PB) radiation appears when a high-energy particle moves in a target and its Coulomb field is scattered from atomic electrons of the substance [1, 2]. A specific feature of this mechanism is a large (comparable with atomic dimensions) value of the effective impact parameter for the collisions of the high-energy particle with atoms of the target, which leads to a significant dependence of the PB characteristics on interatomic correlations in the target. This circumstance stimulates theoretical and experimental investigations aimed at the possibility of developing a new method of diagnostics of the atomic structure based on the measurement of PB characteristics in the X-ray spectral range—in particular, in the PB spectra excited by relativistic electrons moving in polycrystalline solids [3–5], where the positions of peaks in the PB spectrum have proved to be uniquely related to the lattice parameters of microcrystalline grains in a polycrystalline substance. Moreover, the results of measurements are in good agreement with a model proposed for the PB in polycrystalline targets. It should be noted that our previous measurements [4, 5] have been performed at a fixed angle of PB emission (i.e., the angle between the electron beam axis and the direction to an X-ray detector measuring the photons emitted from the target) equal to 90°. Note that this angle determines the position of a coherent peak in the PB spectrum. This circumstance is very important for the identification of PB peaks, since the experimental spectra usually contain numerous peaks of different origin. For example, the spectra frequently contain peaks of the characteristic X-ray emission from both target atoms and those of the experimental setup, the positions of which are independent of the angle. The PB spectra of a polycrystalline target were recently measured by Takavayashi et al. [6], but the results were not compared to the theory. Quantitative measurements of the positions and shapes of coherent peaks in the PB spectra as dependent on the emission angle and a comparison of the experimental data with the results of theoretical calculations are necessary steps in the development of a method for the diagnostics of polycrystalline targets based on the PB measurements.

In this study, the PB measurements were performed on a setup employing the microtron of the Lebedev Physical Institute. An electron beam with an energy of 7 MeV was generated in the magnetooptical channel of the microtron and extracted into a vacuum chamber, where the target was mounted. The targets were polycrystalline foils of aluminum and copper with a thickness of 8.5 and 15 μm respectively, oriented with their planes at 45° relative to the incident electron beam. The X-ray radiation, emitted from the target into the frontal hemisphere, was detected with a solid angle of 1.5×10^{-6} sr by an uncooled silicon–lithium P–I–N detector with an energy resolution on the order of 200 eV in the spectral range under consideration. The electron beam intensity was measured using a Faraday cup arranged at the end of the working chamber. The vacuum level in the setup, which was separated from microtron, was maintained on a level of 10^{-5} Torr. During the data acquisition, we have simultaneously measured the number of X-ray photons in each channel of the spec-

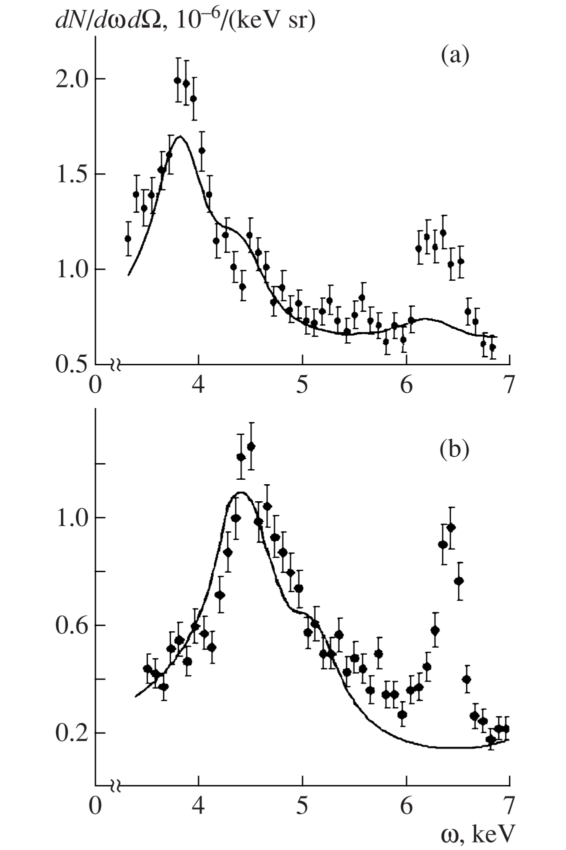

Fig. 1. Energy distributions of the yield of bremsstrahlung X-ray photons per electron (in a unit solid angle) measured at an emission angle of (a) 90° and (b) 75°.

trum and the number of electrons transmitted through the foil target.

The typical PB spectra measured (as the photon yield per electron) from an aluminum target at an angle of 90° and 75° are presented in Fig. 1 in the form of the spectral-angular PB radiation density versus photon energy, which is in fact measured in such experiments. The experimental spectra are compared to the theoretical curves, which were calculated using a general formula for the spectral-angular distribution of the intensity of PB induced by relativistic electrons in a polycrystalline target [7] with the known values of interplanar distances in aluminum crystals. The theoretical curves also take into account the absorption of X-ray photons in the target. The measured curves clearly display a coherent PB peak, the maximum of which shifts from 3.78 keV for the emission angle of 90° to 4.44 keV for 75°. As can be seen, there is a good agreement between the measured and calculated spectra with respect to both positions and absolute values of the PB yield. The spectra also contain a background, representing the characteristic peak of iron at 6.4 keV, which is due to the electrons striking the walls and other parts of the working chamber. The measurements at 90° and smaller emission angles were performed using different targets, which accounts for a difference in the iron signal.

The spectra of PB photons emitted from a copper foil target were measured at emission angles of 90°, 83°, and 75°. The corresponding sift of the coherent PB peak from 4.27 (90°) to 4.62 keV (83°) and 4.95 keV (75°) also agrees with the results of theoretical calculations.

The results presented above show the possibility of reliably identifying the coherent PB peaks with respect to their positions in the spectra depending on the emission angle and demonstrate the agreement between experiment and the theoretical model of PB developed with the participation of the authors. The proposed scheme does not require cumbersome experimentation and has good prospects for the development of a new method of diagnostics of polycrystalline materials based on the measurement of characteristics of the coherent PB component.

Acknowledgments. The authors are grateful to A.N. Eliseev and I.E. Vnukov for their help in carrying out experiments.

This study was supported in part by the Federal Targeted Program "Research and Development in Selected Directions for Scientific-Technological Complex of Russia in 2007–2012" (project no. 02.5131.11.3374) and the Russian Foundation for Basic Research (project no. 07-02-1226-ofi).

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Translated by P. Pozdeev