Maskless nanolithography on the basis of microfocus X-ray tubes: conversion of electron energy into the BeKα line

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Projection photolithography (PPL) is the key technology of micro (nano) electronics, which determines the critical topological size of microcircuits. The most advanced topologies are achieved with the use of immersion at a wavelength of 193 nm and the extreme ultraviolet (EUV), at a wavelength of 13.5 nm, photolithography [1, 2]. The most complex and expensive elements of the infrastructure of the PPL are masks. A set of masks only in the production of a single chip can cost up to several million dollars. Therefore, because of the high cost of equipment, the high cost of masks, complex and expensive infrastructure, the PPL becomes competitive only for mass (global) production, while the market for small- and medium-scale production (up to hundreds of thousands of chips per year) is not inferior in value expression global. Therefore, it is extremely urgent to find new tools for nanolithography.

The hypothetical nanolithograph should provide the same topological norms, which gives the PPL in the region of 100-10 nm and less. The performance of such a nanolithograph can be one to three orders of magnitude lower, there should be no masks, and the cost of the lithographic process should not depend heavily on the scale of production. It is also important that the cost of a lithograph is comparable to the cost of an industrial single-beam electron lithograph. In this case, we can say that the production of nanoelectronics will become available not only to single global companies, but also to smaller companies, which is critically important for our country.

At present, multi-beam electron lithography (MBEL) is considered the most promising for such kind of the lithography. However, despite the successes, in particular in productivity [3], the prospects of MBEL are not obvious due to the strong heating of the wafer with resist in the litho process and the inter-beam interaction. As an alternative, also maskless EUV lithography is considered [4]. However, the unresolved problem of creating an effective spatial light modulator for the EUV radiation suppresses its development.

In [5], we proposed a new approach to nanolithography - a maskless X-ray lithography based on a microfocus X-ray tube chip with a thin-film target. This report discusses the basic principles of this method of nanolithography, gives the results of measurements of the conversion efficiency of electron energy to the energy of the BeKα characteristic line (λ = 11.4 nm), considers alternative wavelengths, gives data on the expected productivity of the lithograph at the most promising wavelengths.

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