Auger spectroscopy and x-ray structure analysis have been used to study the chemical and phase inhomogeneity in single crystals of the austenitic nitrided stainless steel Cr22Ni17Mo3 with various morphologies of the dendritic structure. In single crystals grown in the $<100>$ direction with a classical dendritic structure the interaxial regions are highly enriched with S, N, and C and weakly enriched with Mo, V, and Mn. At the same time these regions have a high density of particles of the type $\text{Me}_2\text{C}_6$, $\text{Me}_2\text{C}_3$, and vanadium carbonitrides, oriented in the growth direction. The axial regions have a subcellular structure, with oxygen-rich subcell boundaries. In single crystals with growth direction close to $<110>$, in which only secondary dendrite axes are formed, the alloying elements, impurities, and second-phase particles are distributed relatively uniformly throughout the ingot.

Single crystals of complex alloy austenitic steels crystallize with a dendritic structure, whose morphology is determined by the relative orientation of the dendrite growth direction and the crystallization direction [1]. Dendritic crystallization is accompanied by the formation of chemical and phase inhomogeneity, but almost no data have been published on the effect of the morphology of the dendritic structure on the type of inhomogeneity. Ma et al. [2] noted the effect of the orientation of the seed crystal on the distribution of elements in the specimen, which they tentatively attributed to dendrite branching. Since the distribution of components in the structure of the alloy has a substantial effect on its technological and service properties, it is of interest to make a detailed investigation of the distribution of elements and secondary phase in single crystals with various morphologies of the dendritic structure.

We have solved this problem on single crystals of nitrided stainless steel containing 22.4 Cr-17.2 Ni-2.6 Mo-2.8 Mn-0.5 V-0.22 Si-0.01 S-0.015 C-0.27 N, the remainder Fe (wt. %). The single crystals were Bridgeman-grown in a helium atmosphere on a seed crystal with a given crystallographic orientation at a rate of $(1.5-4) \times 10^{-2}$ mm/sec at a temperature 150-200°C above the liquidus. We studied the structure of the single crystals by means of optical microscopy, x-ray structure analysis of the precipitates obtained by anode dissolution of the samples at a current density of 1 A/cm² in an electrolyte consisting of ethyl alcohol with 5% hydrochloric acid and 3% ammonia, x-ray microanalysis, and Auger spectroscopy. Electron microscopy could not be used to determine the composition of the precipitates, since particles were precipitated during the preparation of the foils and replicas.

We studied single crystals with $<100>$ and $<110>$ growth axes. The structure of $<100>$ single crystals differed substantially from that of the $<110>$ crystals by the presence of primary stems of dendrites. In cross section these dendrites have a classical cruciform structure (Fig. 1a). When the growth direction is close to $<110>$, only secondary branches of dendrites are observed in the longitudinal section of the single crystal (Fig. 1b).

The tendency of the components of the steel to form segregations can be characterized in the first approximation from the distribution coefficients $k$ determined for the binary systems. The values of $k$ for the constituent elements of the steel S, C, Mn, N, Si, Mo, Ni, V, and Cr are 0.08, 0.15, 0.2, 0.34, 0.62, 0.72, 0.76, 0.82, and 0.91, respectively [3]. The elements S, C, Mn, and N segregate strongly in iron while Si, Mo, Ni, V, and Cr segregate weakly. Naturally, it is necessary to take account of the mutual effect of the components on their tendency toward liquidation. In austenitic stainless steels carbon forms compounds with a number of alloying elements and, raising its content in the local region, increases the non-uniformity of the alloying elements, except nickel [4].
Fig. 1. Structure of initial single crystals of austenitic stainless steel with \(<100\) (a) and \(<110\) (b) growth direction; cross section (a) and longitudinal section (b). 100×.

Fig. 2. Dendrite microstructure in various magnifications (a, b) and in characteristic oxygen emission (c): a) 300×; b, c) 1500×.

Fig. 3. Distribution of elements in the axial and interaxial regions of the dendritic structure of a single crystal with \(<110\) growth direction (a, b) and in the former axial region of the dendritic structure of a single crystal with \(<100\) growth direction (c). 1500×.