Mathematical Model of Extruding Biopolymer Material

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Now the extrusion method is widely applied in receiving new materials and goods from them. In extrusion, a material is exposed to influence of high temperature and pressure at the same time. Such process at its high intensity and values of parameters leads to high qualitative both structural and biochemical transformations of raw material and allows one to receive materials with absolutely different properties. Extruding plant materials, which can be considered as polymers of a biological origin, are especially interesting. However, the processes, leading to biopolymer material during extruding are not available to direct observation. Therefore, the mathematical model of extrusion process is necessary for calculation of extruders design data for their construction. In the present paper, the question of modeling the movement of biopolymer material in a zone of consolidation and melting in an one-screw extruder, i.e. in the screw channel, the screw is considered. In this zone, biopolymer material has properties of a pseudoplastic body. By modeling, it is efficient to consider the movement of material extruded in two main working zones: as viscoplastic mass in the zone of consolidation and melting (in the screw channel of the screw of an extruder), and the movement of material as fusion in the dispensing zone (in the ring channel of the forming matrix). The finite-element method, which has necessary invariance in relation to changes of design data, is applied to modeling of the biopolymer material movement in one-screw extruder. The advantage of this method is universality of use in the wide range of the biopolymer materials extruded properties and the designs of one-screw extruders. For calculation of stress condition of extruded materialб the zone of consolidation and melting of an extruder breaks into final elements. The following sequence of splitting is offered: (i) the planes, perpendicular screw axes, (ii) the space of zone divides into disks; (iii) disks divide into rings by means of cylindrical surfaces, which axis coincides with a screw axis; (iv) rings are cut by the radial planes, which form the sectors, representing final elements. In each ring, on the base of the next to the screw blade, the elements of three types are located: (i) the elements adjoining to the blade and experiencing tension, transmitted to it, which could be geometrically approximated by triangular prisms; (ii) the elements which are not adjoining to the blade, and geometrically approximated by rectangular parallelepipeds; (iii) the elements finishing a ring and being specular reflection of elements referring the screw blade. Dynamic balance of elements of three types is defined by cumulative action of forces operating on them. Based on the assumption that the sum of forces and the sum of the moments of forces, loading elements are equal to zero, systems of the equations of balance were received. It is established that for any nonzero geometrical sizes of elements, the equation, entering in the compiled systems are linearly independent. The obtained systems of equations were solved by using the boundary conditions, based on design of a screw extruder and the used technology of extrusion. The systems of the equations were completed with the equations of energy balance and rheology. Vectors of shear speeds are expressed through tension according to the rheological equation of extruded material. Taking into account the stationarity of the considered process, mechanical and thermodynamic characteristics do not change in time, and change of temperature of extruded material in the process is negligible. Distribution of temperatures in the direction from the extruder case to the screw shaft was given, but temperature change of extruded material in the process of movement was negligible. The mathematical model of the biopolymer material movement in the working zone of consolidation and melting of one-screw extruder, describing physical properties of extruded material and taking into account change of its state, is offered. The method of the formalized description of biopolymer extruding process, based on use of the finite-element analysis, which allowed to connect in the same algorithm of properties of extruded material, technology of extruding and design data of an one-screw extruder is developed. It allowed us to obtain dependences for calculation of the one-screw extruders design data in dependence on requirements to processing and obtainment of materials with novel properties.

Methods of Rise in Unipolarity of Strongly Doped Lithium Niobate Crystals without External Electric Field

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Strong spontaneous unipolarity appears in originally poly-domain crystals of $LiNbO_3$: Zn doped in threshold concentrations (~ $5.4 < C_{melt} \leq 6.76$ mol% ZnO in the melt) in conditions of high-temperature (~ 300 – 900 K) treatment and high-temperature annealing during short circuit (T = 1120 – 1270 K, t = 48 hours). Measured in static mode piezomodulus d_{333} = 16.2×10^{-12} C/N of originally poly-domain was higher than known from literature of brought to single-domain state of pure $LiNbO_3$ crystals. The effect is caused by the instability of the poly-domain state in a doped crystal $LiNbO_3$: Zn in the conditions of high temperature and conductivity. It might also be caused by decay of structure clusters that stabilize charged domain walls. Rise in unipolarity is accompanied by low-frequency disperse and jump-like anomalies on temperature dependencies of conductivity and dielectric constant. Jump-like anomalies in $\sigma(T)$ and $\varepsilon(T)$ dependencies and rise in unipolarity in the above mentioned conditions are also observed in $LiNbO_3$: Zn crystals forcefully brought to single-domain state. The latter reveals “non-switched” residual or else “stubborn” domains in such crystals. The domains decay during high-temperature treatment without applying of an electric field. Anomalies in $\sigma(T)$ and $\varepsilon(T)$ dependencies appear at certain temperature (~ 800 ± 10 K in searched samples). This indicates that start of domain structure evolution is caused by thermal decay of charged clusters. The clusters stabilize charge domain wall and their decay leads to sharp increase of additional charge carriers. The effect was searched in crystals grown from