Methodology of Development and Estimation of Quality of Heat-Resistant Antiadhesive Coatings on the Basis of Fusible Fluoroplastics for Food Industry

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ABSTRACT: Development of antiadhesive coatings for working surfaces of the food equipment in high-temperature technology is extremely important for the modern food industry. By development of the coatings as a polymeric basis, a powder fluoroplastic modified by the complex of additives is used. The studies are performed on the estimation of modifying component distribution in a polymer matrix. At present, the complexity of the problem of the development of antiadhesive coatings for alimentary purposes is conditioned by restricted selection of polymer materials suitable for food-contacting covers, which possess high thermostability, and also low surface energy responsible for a level of adhesive interplay with alimentary media. Therefore, a problem of widening of the range of thermo- and chemoresistant polymer materials by usage of number of unsoluble biologically inert polymers as film-forming components is actual. © 2008 Wiley Periodicals, Inc. J Appl Polym Sci 109: 1072–1075, 2008

Key words: fusible fluoroplastics coatings; thermostability; distribution of modifying components; structure of coatings

INTRODUCTION

Widely known bakers' coatings developed on the basis of suspension fluoroplastics[1–7] and organosilicon compounds are intended mainly for exploitation in mild conditions: on aggregates of small and medium powers of a periodic type, in regimens excluding hot idle times and thermal shocks and not intended for exploitation conditions on native-country high-performance aggregates of continuous operating, including periods of inexact and spasmodic load. Besides that, the coatings known until now technologically do not allow to create solid uniform-thickness antiburnfasting coverings neither for the grain molds nor for perforated sheets, corrugated confectionery molds, and profiles of complex configuration. Disadvantages of known domestic and foreign coatings on the basis of suspension compositions are as follows: laborious input and long duration of the process of manufacturing, and also usage in this process of ecologically hazard materials (toluene, xylene, etc.). The coating on the basis of solution systems does not provide an equal bed depth on the all surface of the equipment, which in turn generates temperature stresses and thermal deformations of covering, appearance of unequal conditions of heating on separate segments of the equipment with its subsequent buckling or burn-out, and other undesirable consequences. To the greatest degree, the elimination of the indicated negative factors is possible only using powder antiburnfasting coatings.

Thermal and chemical resistance of the fluoroplastics, their nonwettability with water, inertness to fats, oils, organic solvents, and also positive sanitary-hygienic characteristics allowed to recommend them for use in baking industry.[8,9] From powder fluoroorganic polymers suitable for a contact to food, Fluoroplast-4MB has the most valuable protective attributes. However, because of the large melt viscosity at high temperatures,[9] absence of a viscous-flow condition, and predilection of the powder to balling up, manufacturing of coatings from Fluoroplast-4MB is connected with large technical difficulties.

In this connection, the actual problem is the development of competitive compositions for antiadhesive coating on the basis of powder fluoroplastics satisfying to such requirements as: ecological and biological safety; maintenance of stable high separating effect, i.e., minimum adhesion to a product and maximum adhesion to metallic surfaces of the equipment or devices; thermostability, stability to thermal shocks, preservation of functionability at alternating temperatures; nontoxicity, chemical and physiological inertness, absence of migration of coating components into food and environment; manufacturability, capability of deposition by a homogeneous layer on the surface of complex configuration, reproducibility of parameters; high level of physical-mechanical

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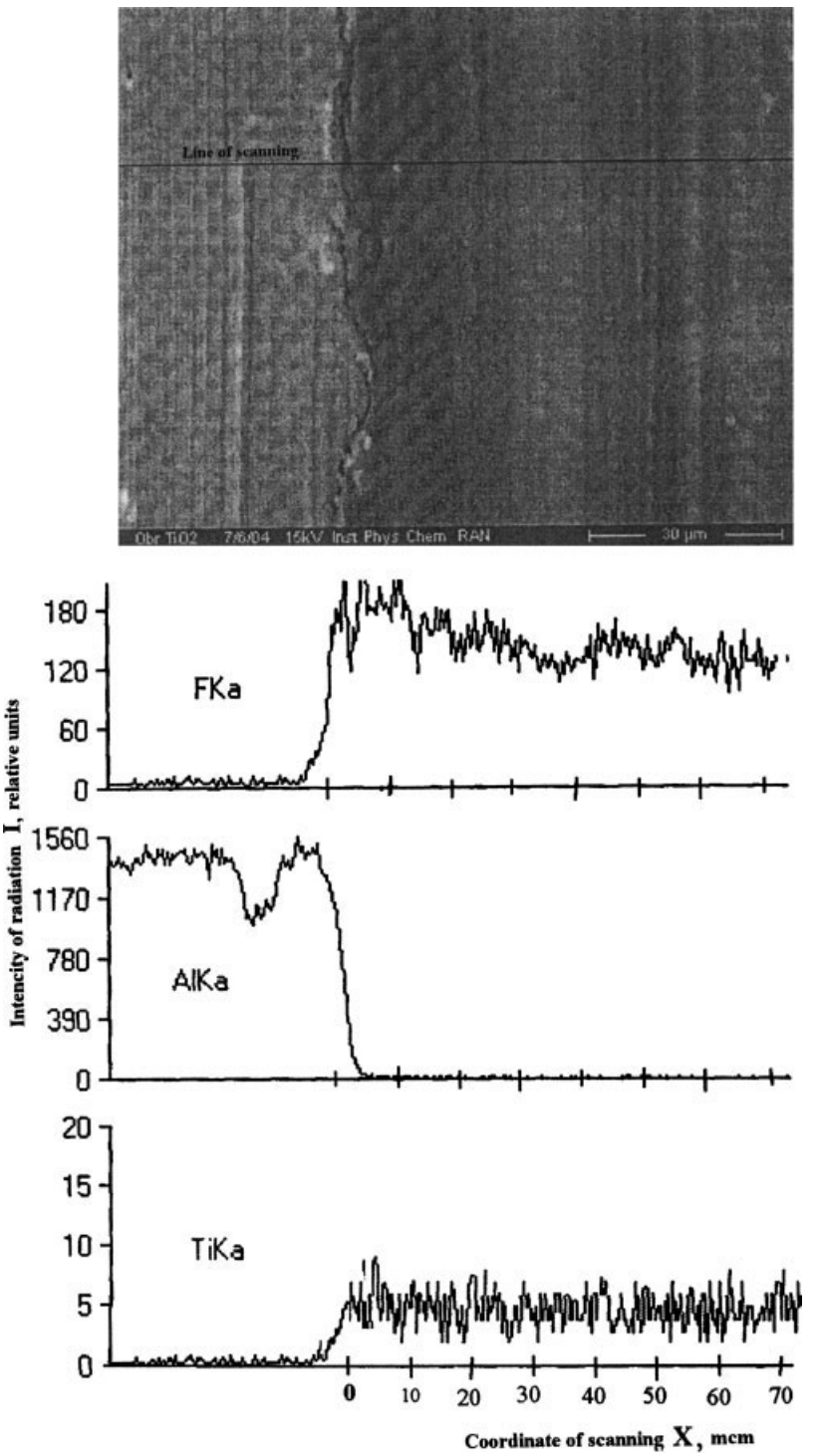

Figure 1 Electron micrograph and irradiation spectra of elements.

properties providing long-lived exploitation of coatings in a given temperature range: strength, elasticity, abrading resistance, durability, etc.; technical, social, and economic efficiency of use.

In MSUAB during a number of years, complex researches were carried out concerning with the technology of powder polymer compositions and multifunctional protective coatings on this basis. Recently, coating heat stabilizers and two generations of antiburnfasting coatings predominantly used for deposition on the bakers' mold internal surfaces and other technological equipment of baking industry were designed, approved, and introduced in the food-processing industry. A distinctive feature of exploitation of the baking industry is the very rigid requirements to thermal, mechanical, and adhesive stability

of antiburnfasting coatings. Within the framework of further development of studies on the creation of a new generation of separating coatings with improved functional properties, we have carried out the researches, as a result of which new modifying complexes for powder fluoroplastic compositions were developed.

As contrasted to precursor compositions on the basis of powder fluoroplastics, modifying agents are excluded from their content, because their presence results in cover cracking and loss of antiburnfasting properties at hardening of operation conditions. Toxic components (for example, triphenylphoshine) are also excluded. The compositions are modified with the components providing increase in adhesion strength of a powder coating to a surface of metal shapes. High adhesion strength stay unchanged after numerous cyclic heating to high temperatures.

In collaboration with the Institute of Physical Chemistry of Russian Academy of Sciences, the structure of new coatings was studied by the method of electron microscopy. The study was executed with the scanning microscope ''Philips'' equipped with an electron probe analyzer ''Kevex.'' Use of the microanalyzer allowed to evaluate the distribution of modifying components in the fluoroplastic compositions. Samples of films formed on a neutral (glass) support and also samples of coatings on a metal support (silumin) were studied. The surface of coatings, and the structure of cross-sectional shears of films and metal-supported coatings were also investigated. Cross-sectional shears were prepared with the use of a ultramicrotome. The microscope permission at this study was 60 Å.

In Figure 1, a cross-sectional shear of the silumin support (left-hand light part) with the coating and a characteristic distribution of basic elements (fluorine, aluminum, and titanium) on the scanning pathway of the cross-sectional shear are shown.

On the basis of the results of the electron microscopic analysis, it has been concluded that the defects on the border aluminum-fluoroplastic are not revealed.

The intensity (I) of a secondary X-irradiation characteristic for the given element is shown on an ordinate axis of the graphs in relative units, and a position coordinate (X) of a scanned sample site is shown on an abscissa axis, assuming a border between the support and the coating as zero point.

The appearance of irradiation from fluorine and titanium is observed in the same coordinates. The relation of a mean emission power to the scanning point coordinate allows to conclude on an uniform distribution of these elements on the sample depth and, therefore, on the component distribution in the bulk of the sample.

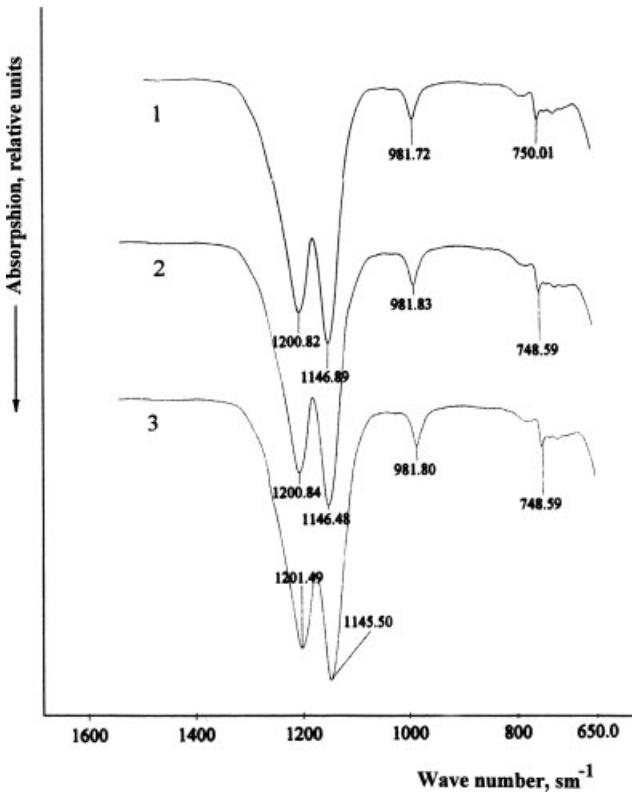

Figure 2 Absorption spectra of a coating surface in K-area (DTIR method). (1) sample of fluoroplastic 4-MB (Teflon FEP); (2) 4-MB+TiO2+Cr2O3+BN; (3) 4-MB+DFSD+BN.

The analysis of microphotographs obtained from the surface of films and coatings, and also from their cross-sectional shears (the analysis was performed on the following element: nitrogen, boron, titanium, chromium, oxygen), convinces that the fluoroplastic coating with the offered modifying components has rather homogeneous structure and is characterized by an uniform distribution of the additives. Such structure, probably, occurs as a result of not only component composition, but also of the regimen of coating formation, and provides the stability of properties during cyclic exposures to high temperatures.

Together with the Research Institute of Plastics we studied free films of the initial fluoroplastic and of two modified fluoroplastic compositions by the method of IR-spectroscopy. Spectra were recorded on the IR-Fourier spectrophotometer ''Spectrum One'' of the corp. Perkin–Elmer by a method < on a lumen >, and also with the use of an attachment ''Universal ATR'' by a method of disturbed total internal reflection. In the latter case, the spectra were identical for all three tested samples: there were absorption bands in the wave number regions of 1200, 1150, 980, and 750 cm^{-1} (Fig. 2). The observed effect could be explained to that the upper layer of the coating (depth less than 1 μm) is impoverished with modifying components, and their main part is

distributed in the bulk of the sample and on the border with the support. At such distribution of modifying components in the coating, the danger of their migration at the contact with food is considerably reduced, the physiological inertness of fluoroplastic is saved, and simultaneously the minimal level of adhesive interaction between the coating and the product is provided.

The proposed solution allows to form antiadhesive thermoresistant coatings adequate to the modern requirements of the food-processing industry, and by combination of their consumer properties conforming to the best foreign samples.

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