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Research Article

Preparation of High-temperature Silicone Rubber Mold and its Application in Food Industry

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Abstract: This study aims to aid and use a new kind of multi-functional control agent by synthesis, preparation good adhesive properties and resistance to yellowing performance. Volatile low, health indicators to meet EU hygiene standards in food contact materials food grade high temperature vulcanized silicone rubber, expand the scope of application of silicone rubber. Liquid Silicone Rubber (LSR) is a new type of silicone rubber products, which is developing rapidly in recent years. In addition to holding a number of typical silicone rubber inherent advantages, LSR also has manufacturing simple process, high production efficiency, excellent overall performance, low cost, energy-saving and other features. LSR is mainly used pacifiers, bottles and other daily necessities production. Safe non-toxic silicone rubber has excellent chemical inertness, high level of hygiene, nitrosamine and other harmful substances, making it the first choice for baby supplies. In addition, the use of its good permeability characteristics can also be made of fruits and vegetables fresh atmosphere film. Tableware products in the industry, silicone rubber tableware products was a new kitchen utensils, with soft, does not damage the non-stick coating. Silicone rubber cutlery most common is silicone rubber nylon composite type tableware.

Keywords: Food e-commerce, health indicators, high temperature silicone rubber, volatile

INTRODUCTION

Liquid Silicone Rubber (LSR) is developed in RTV silicone rubber based on a new type of rubber. Its base material is a liquid silicone, both molecular terminals with reactive functional groups, "telechelic" polymer. It has a small molecular weight, low viscosity, easy molding characteristics and may be omitted mixing, pre-forming, post-treatment processes, easily automated, saving energy and labor, short production cycle and high efficiency (Glismann and Gruhn, 2001). Products produced by the liquid silicone rubber with high purity, transparency, good characteristics of low volatile matter content and has good oil resistance, chemical resistance, aging resistance, light resistance, insulation resistance and insulation properties, color a wide range of options (Yang *et al*., 2005).

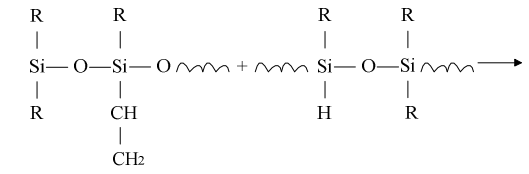
Food-grade special mold silicone mold silicone chocolate molds for food, they are RTV liquid silicone rubber, mainly used in complex mode of food, candy molds, cake molds and equipment size requirements very stable (Zhao *et al*., 2012a, 2012b). These product materials are certified by SGS environmental protection material. The product color translucent, room temperature curing, smooth color positive, non-toxic, tasteless, a certain hardness, flexibility, good tensile and tear performance, turn mode more often, it is widely used in the production of food molds. As a food-grade silicone rubber, asking them to comply with the relevant provisions of health standards US Food and Drug Administration (FDA) and good resistance to yellowing, low volatile. The usual solution is to extend the volatile issue of silicone rubber vulcanization time (Okamoto, 1988). Sec sulfide in the study is to remove the residual volatile or harmful volatile compounds, improve cross-linked, so that the physical and mechanical properties of the vulcanized rubber is stabilized. Sec curing in an oven at 200-250°C is generally carried out to extend the silicone rubber vulcanization time Sec will increase energy consumption and the silicone rubber is easy to yellowing (Boldyreva, 2003).

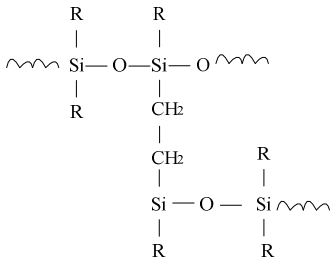
In our study, the use of a silane coupling agent through ordinary chemical treatment of metal impregnation, can further improve the adhesion properties of the metal and silicon rubber. Add molding LSR safe non-toxic, excellent performance, excellent chemical inertness, high level of hygiene, nitrosamine and other harmful substances, making it the first choice for baby supplies. In addition, the use of its good permeability characteristics can also be made of fruits and vegetables fresh atmosphere film. Due to the typical characteristics of liquid silicone rubber has medical polymer materials, after 50 years of development, it plays a not inconsiderable role in

healthcare and many other areas related to human health. With the maturing process of preparation and follow-up product processing molding technology will play a greater role in various fields and human health are closely related.

MATERIALS AND METHODS

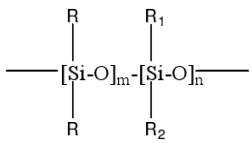
Classification and vulcanization mechanism: Development and molding of LSR began in the late 2000 (Bellare and Neven, 2007), at present, most of the liquid silicone rubber is prepared from by addition method in which liquid silicone rubber. It is based on vinyl-containing polydimethylsiloxane as the base polymer, low molecular weight silicone oil as a crosslinking agent, in the presence of a platinum catalyst under conditions of heat cross-linked into a network structure, its curing reaction mechanism as follows:





Compared with condensation type LSR, the curing process does not produce byproducts; minimal shrinkage; to deep sulfide (Gentry and Ramzan, 2006).

Silicone rubber is the main chain Si-O units, the organic groups are pendant groups of a linear polymer. It is typical of semi-inorganic semi-organic polymers, inorganic polymer having both heat resistance, but also has an organic polymer flexibility. Its structural formula is generally:



wherein, R, R_1 and R_2 are an organic group, such as methyl, vinyl, phenyl, trifluoropropyl, m, n is a polymerization degree, can be varied over a wide range. Table 1 compares the bond partially with silicon atoms and atoms are bonded to carbon atoms when. As can be seen, Si-O bond than CC bond energy is much higher, so that compared to silicone rubber and ordinary rubber having higher stability, such as heat resistance, weather resistance, electrical insulation and chemical stability.

Table 1: Bond energy

Si bond	Bond energy (kJ/mol)	C bond	Bond energy (kJ/mol)
Si-Si	222	C-Si	318
Si-C	318	C-C	345
Si-H	318	C-H	413
Si-O	451	C-O	357
Si-N	-	C-N	304
Si-F	564	C-F	485
Si-Cl	380	C-Cl	339
Si-Br	309	C-Br	284
Si-I	234	C-I	213

Properties of silicone rubber: Typical component silicone rubber is polydimethylsiloxane having minimal intermolecular forces and molecular structure of spiral curls. Therefore, the silicone rubber composition is by its having high resilience, high compression resistance and excellent resistance to cold. In addition, the molecular structure of pointing out-CH_3 groups may rotate freely, so that the silicon rubber also has a unique hydrophobic surface properties and release properties and the like (Zhao *et al*., 2013, 2014).

Silicone rubber has excellent weather resistance, oxygen, ozone and ultraviolet light is very stable. Prolonged exposure to the weather, little change in their physical and mechanical properties, after decades of outdoor exposure test, no cracking or degradation tacky and other aging phenomena. DC company had silicone rubber for 20 years outdoors natural aging test and found that its performance aging is very small.

Silicone rubber resistance to tracking the performance is excellent. Through specific formulation and process prepared with silicone rubber insulators, in harsh environmental conditions of resistance to tracking and resistance to electrical erosion resistance, evaluation results generally reached 4.5, which is applied to the transmission and distribution of silicone rubber insulators material provided a guarantee.

Rubber compounding and remill:

- Silicone rubber raw rubber into a kneader control agent is added and kneaded for several minutes at room temperature, so control agent uniformly dispersed in silicone rubber.
- Adding various compounding agents kneading, the addition order was: silica (added in portions), silicone oil, zinc stearate, vacuum kneading under heating for some time, after cooling the material.
- **Remill:** Rubber after a period of time, into a two-roll mill machine remill, adding a vulcanizing agent, after kneading and rolling showings evenly. Specific process was shown in Fig. 1.

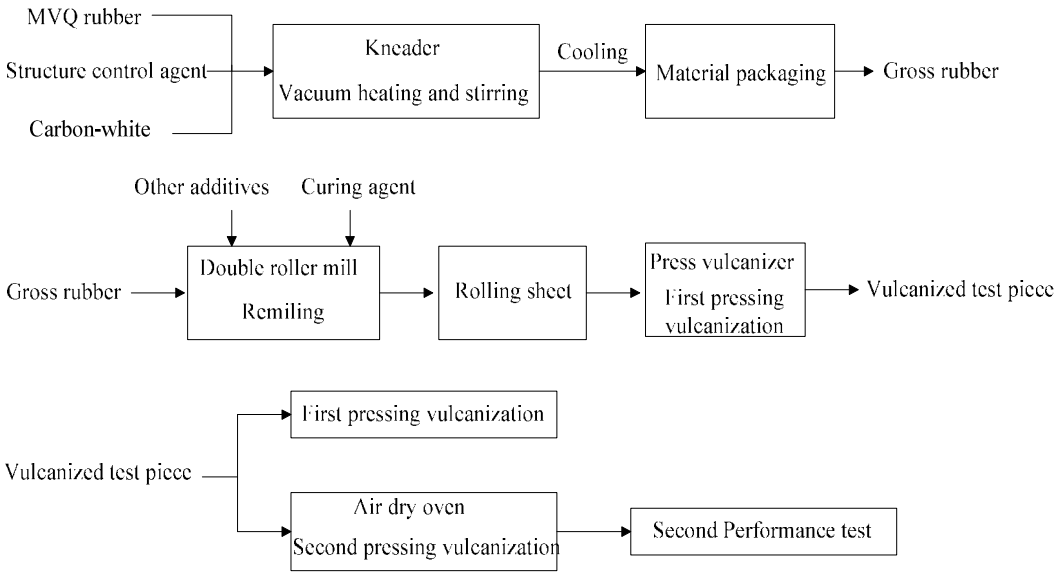


Fig. 1: Preparation of silicone rubber vulcanization process diagram

Determination of crosslink density: A known mass (about 0.2 g) of compression molded and cured sample suspended in toluene solvent containing a sufficient amount of jar stoppered bottle; swelling after 25°C 12 h, quickly removed and gently wiped with a filter study test kind of surface, weighed back jar; then repeat the process until the poor quality of the two weighing no more than 0.01 g, considered to reach equilibrium swelling. Finally, the sample was dried in an oven at 80°C 12 h, after taken out was cooled down to room temperature and placed in a desiccator and weighed. Crosslinking density according to Flory-Rehner equation, namely:

$$N_c = \frac{1}{2V_0}\left[\frac{\ln(1-V_\gamma)+V_\gamma+xV_\gamma^2}{V_\gamma/2-V_\gamma^{1/3}}\right] \quad (1)$$

where, χ interaction parameter between polymer and solvent, this test is the role of toluene and silicone rubber parameter, the value of 0.45; V0 is the molar volume of the solvent, toluene 107 cm^3/mol; Vr is swelling equilibrium test sample volume fraction of vulcanized rubber, the value press (2):

$$V_\gamma = \frac{m_d/\rho_\gamma}{\frac{m_s-m_d}{\rho_\gamma}+\frac{m_d}{\rho_\gamma}} \quad (2)$$

where,

md : The mass of dry sample after swelling

ms : The mass of the sample before drying after swelling

ρ_s : The density of the solvent, toluene was 0.86 g/cm^3

ρr : Silicone rubber raw rubber density, the value of 0.98 g/cm^3

Fig. 2: Food-grade silicone mold

RESULTS AND DISCUSSION

The liquid silicone rubber and food-related applications: Food-grade special mold silicone mold silicone chocolate molds for food, they are RTV liquid silicone rubber, mainly used in complex mode of food, candy molds, cake molds and equipment size requirements very stable. These product raw materials are certified by SGS environmental protection material. The product color translucent, room temperature curing, smooth color positive, non-toxic, tasteless, a certain hardness, good elasticity, tensile tear properties, turn mode more often, it is widely used in the production of foods such as mold (Fig. 2).

Analysis of the mechanical properties of silicone rubber: Since silicone rubber molecular chain is very soft, weak interaction between chains, thus without reinforced silicone rubber intensity is very low (less than 0.4 MPa), does not have practical value, it must be reinforced in order to be applied after the rubber products processing. Experiments show that even a small amount of fumed silica reinforced silicone rubber strength had significantly improved.

Fumed silica particles is small, the average diameter of 5-20 nm, specific surface area of 200-400

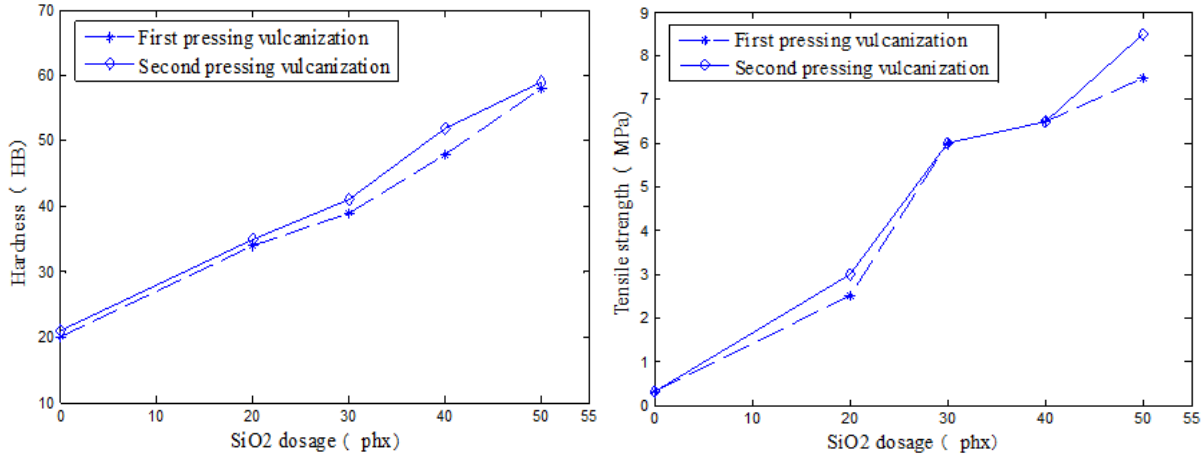


Fig. 3: Silicon rubber hardness with the increase in the amount of fumed silica

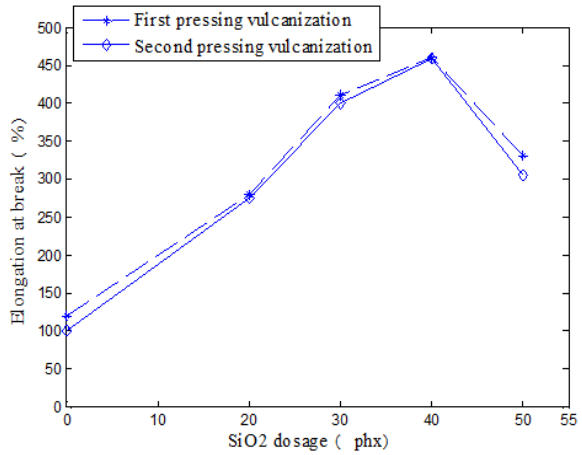


Fig. 4: The silicone rubber elongation at break with increasing amount of fumed silica

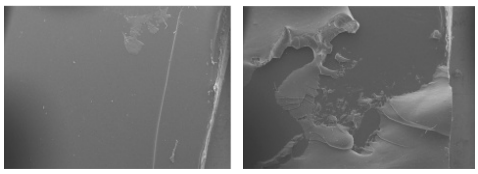


Fig. 5: TS different amount of silicone rubber and nylon plate bonding interface SEM image

m^2/g, can be uniformly dispersed in silicone rubber and silicone rubber molecules and strong interaction, so that the silicone rubber mold the amount and hardness increased. As it can be seen from Fig. 3, with the increase in the amount of fumed silica, silicon rubber hardness, tensile strength and tear strength were increased. After the fumed silica in an amount of 0 parts, i.e., not been reinforced silicone rubber tensile strength and tear strength are very small (less than 1) and 20 parts of fumed silica, to enhance the tensile strength of 8- 11 times the tear strength enhanced 10-16 fold enhancement effect is obvious.

As it can be seen from Fig. 4, the silicone rubber elongation at break with increasing amount of fumed silica to a substantial increase in the fracture when the fumed silica used in an amount of about 40 parts by elongation reaches a maximum and then decreases rapidly. The amount of fumed silica increases to a certain value, vulcanized rubber physical crosslinking increases, toughness decreased, resulting in mobile hard rubber molecular chain, resulting in lower elongation at break.

SEM is a focused electron beam scanned the sample surface to the secondary electron, X-rays and other physical signals to generate a modulation imaging, to obtain information about the surface of the material. Figure 5 is not the same amount of TS, silicone rubber and nylon sheet bonding interface SEM photograph. As can be seen from the figure, when no added TS, clear silicone rubber and nylon sheet bonding interface, almost no silicone rubber adhered to the nylon plate, poor adhesive properties of silicone rubber; TS increases the amount of silicone rubber adhered to the nylon panel, indicating the interfacial adhesion properties of silicone rubber and nylon sheet has been improved and enhanced. From silicone rubber and nylon plate bonding interface damage form, when not add TS, silicone rubber and destruction in the form of a nylon plate for interface bonding interface destruction; TS increases the amount of silicone rubber and nylon plate bonding interface failure mode from the interface into a mixing damage or even destroy the cohesive failure, adhesive properties of silicone rubber gradually.

CONCLUSION

This study aims to aid and use a new kind of multi-functional control agent by synthesis, preparation good adhesive properties and resistance to yellowing performance. The volatile low, health indicators to

meet EU hygiene standards in food contact materials food grade high temperature vulcanized silicone rubber, expand the scope of application of silicone rubber. The results showed that the use of a silane coupling agent through ordinary chemical treatment of metal impregnation, can further improve the adhesion properties of the metal and silicon rubber, silane coupling agent KH550 treatment effect is better; compared with methyl vinyl silicone rubber adhesive performance methyl vinyl phenyl silicone rubber and metal better. Use silicone rubber incorporation get adhesion. This method is incorporated into the bond component in silicone rubber, the raw rubber after curing on a metal surface to be bonded.

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