# UV Protective Effect and Properties According to the Surface Status, Shape and Size of Silica

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## Abstract

**Background**: Silica is a typical constitutional pigment that improves the rough texture of cosmetics and absorbs sweat and sebum from the skin. Also, silica has different characteristics according to its shape, surface state and size. Some silica may improve the protective effect from UV ray. However, the relationship with the UV protection factor according to the characteristics of silica has not been significantly confirmed. Therefore, in this study, the change in the UV protection factor according to the particle size and surface state of silica was evaluated.

**Methods**: First, properties of silica were evaluated. The pH value of silica was detected by 10% silica aqueous dispersion. The oil absorption of silica was evaluated using castor oil. And the friction coefficient was determined using a Touch Meter from Heidon Inc. Next, to confirm the UV protection factor, silica was applied to the sunscreens for each particle size and surface condition.

**Results**: First, properties of silica were identified by the particle size and surface state of silica. To these results, there were significant differences in the properties of silica. Also, sunscreens with silica increased SPF and PA. Especially, novel porous type silica showed the best effect.

**Conclusion**: Sunscreen with silica has a brilliant enhancement of UV protecting. In conclusion, the purpose of this study is to suggest the possibility of developing advanced cosmetic materials in the future by confirming the shape and surface of the ideal silica that helps protect UV rays.

**Keywords:** UV protective enhancer, Specific surface area, Hollow silica, Porous Silica

**Introduction**.

In cosmetic formulation, pigments are widely applied not only to color cosmetics but also to skin care cosmetics. Pigments are colorants ingredients in cosmetics that define insoluble substances under the aqueous phase and oil phase are dispersed such as mica, kaolin, silica, etc. Among the various pigments, the inorganic pigments consist of a white pigment, a color pigment, and a constitutional pigment. First, the white pigments such as titanium dioxide and zinc oxide affect covering the skin's blemishes by covering the skin's ground color. Next, color pigments such as iron oxide, ultramarine, and ferriferrocyanide have a tinting effect that imparts colors such as red, yellow, black, blue, and green. Lastly, the constitutional pigments such as silica, mica and kaolin have important roles in the cosmetic formulation as constituents that adjust the color tone as a thinner and adhesion and gloss of the cosmetic products [1-6].

Among these constitutional pigments, silica is a typical constitutional pigment that improves the rough texture of cosmetics and absorbs sweat and sebum from the skin. For these reasons, silica is applied cosmetic formulations widely from base makeup, point makeup, sunscreen to skin care cosmetics that provide long-lasting makeup and smooth and oil-free skin. Silica used in cosmetics and personal care products is amorphous silica. This means that silica does not have a definite morphology. Although silica used in cosmetics is amorphous, they all have different properties depending on their shape, particle size, and surface state. For this reason, silica has different characteristics such as malleability, spreadability according to their properties. Therefore, it is important to utilize these properties well when applying silica in cosmetic formulation [7-9].

Recently, various shapes of silica such as porous and hollow types has been developed briskly. The silica with pore(s) could have a wider range of functions, with the unique characteristic of being able to enclose specific substances in those pore(s). Because of their structural features, this silica may improves the protective effect from ultra-violet rays (UV) by multiple diffraction and resonance effects of light through the surface and pores. However, the relationship with the UV protection factor according to the characteristics of silica has not been significantly confirmed [10-13].

Therefore, in this study, the change of the UV protection factor according to the particle size and surface state of silica was evaluated. Furthermore, the UV protection factor was maximized by applying the new porous type silica in the sunscreens.

**Materials and Methods**.

- Reagents and materials: The friction coefficient of silica was evaluated by Heidon TRIBOGEAR Type: 33 of Shinto Scientific Co. Ltd. The UV protection factor was measured by UV-2000s of Labsphere Inc. Various types of silica were supported by Xentech, Sunjin Beauty Science and Evernesol. Other chemical agents were purchased from Sigma Chemical Co.
- Preparation of sunscreen: The selected silica was applicated in sunscreen for evaluating UV protective effect. The recipe shows scheme 1. First, heat the oil phase and aqueous phase until 85℃ and dissolve each ingredient completly. Next, insert oil phase into the oil aquous phase slowly with homogenizer (3600rpm, 5min). During emulsifying, add pigments that dispersed with polyol into the outer phase of the emulsion. Finally, put the preservative.
- Measurement of oil absorption: Oil absorption of silica was measured conventionally. First, 1.0 g of sample was prepared on a glass plate. Then, castor oil was then slowly, until the pigment became spherical and without powder. Finally, the content of the added oil was measured. The measured oil content means oil absorption. Oil absorption was expressed as the amount of oil absorbed per gram of sample.
- Evaluation of friction coefficient: friction coefficient of the materials was evaluated by tribo touch meter (TRIBOGEAR Type: 33) from Shinto Scientific Co. Ltd. This device can measure friction force of the materials. So if the material has a tough or rough texture, it will show high friction. The measurement method was as follows. First, apply 15 mg of the experimental sample on the sample plate, and then, softly rub the powder unidirectionally (8 times).
- UV protective effect: In order to evaluate the UV protection factor, in vitro SPF test was conducted under ISO24443 method, 28.6 mg of each sample was applied on the PMMA (polymethylmethacrylate) plate (Helio plates HD 6, size: 4.7 cm X 4.7 cm) and dried for 30

min, SPF and PA values were measured by UV-2000s of Labsphere Inc. The UV protection factor was expressed in SPF and PA values.

**Results**.

- Physical properties of silica: In this study, various types of silica were selected. To determine the characteristics of the silica, their physical properties were evaluated. Table 1 shows their properties that their particle size, shape, pH and oil absorption. First, particle size of the selected silica was almost different. Only PS-5k and SS-5k had the same particle size. , their other properties were all different. Next, selected silica had spherical, porous and meso-porous types. Their pH was measured around pH 7.0, which is neutral pH. The oil absorption of all silica was different. It is considered that oil absorption affects the surface status of silica.
- Evaluation of friction coefficient: Friction coefficient means the toughness of materials. Most silica has a low friction coefficient that causes silky and smooth texture with in cosmetics. However, numerical data on these are difficult to find.

In this study, tribo touch meter was used for evaluating the texture of the materials, which can detect the friction of materials. The silky and smooth could be measured by friction coefficient. So this value reflects the roughness or spreadability of the materials. For this reason, the texture of silica could be inferred from the friction coefficient.

Friction coefficient of each silica is shown in Figure 1.

As a result, SS-5K had the lowest friction coefficient that means that their texture is silky and smooth. However, HS-050 showed the highest friction coefficient. However, the results could be analyzed more closely by comparing their physical properties. First, in the case of macrosize silica, the larger the particle size of silica, the lower the friction coefficient. Second, there was a large difference in the coefficient of friction depending on the shape of the particle.

- UV protective effect: In this study, the SPF in vitro test was performed by applying 3% of silica to the sunscreen. SPF in vitro test shows that UV protective effect of each silica. As a result, all of the selected silica showed the effect of SPF and PA enhancement (Figure 2). Therefore selected silica has UV protection enhancing effect significantly.

**Discussion.**

In this study, various characteristics of silica were identified for cosmetic use. First, physical properties of silica were determined. Because of physical properties, most silicas have similar pH values regardless of their particle size and shape. However, their oil absorption were different that may depend on surface status.

In measurement of friction coefficient, SS-5k showed the best texture as a cosmetic ingredient. However, the results could be analyzed more closely by comparing their physical properties. First, in the case of macro size silca, the larger the particle size of silica, the lower the friction coefficient. This means that the larger the particle size of the silica particles, the easier they is to roll on the surface. Thus, the particle size of the ordinary pigment can be an index that can roughly predict the texture of the pigment. However, nano-size, and meso-porous type pigments showed different result. Second, there was a large difference in the coefficient of friction depending on the shape of the particle. The friction coefficient was high in the order of meso-porous type, porous type, and spherical type of their shape. Therefore, SS-5k that spherical type and large size silica showed the lowest value friction coefficient. These results are believed to be able to suggest many directions when applying silica used in cosmetics.

Finally, all silica showed a boost effect of UV protection. Especially, meso-porous type of silica had the greatest effect on them. It is not easy to find materials that increase both the SPF and PA values. For this reason, silica could be applied for SPF and PA enhancers.

**Conclusion**.

Sunscreen with silica has a brilliant enhancement of UV protecting. In conclusion, the current study suggests the possibility of developing advanced cosmetic materials in the future by confirming the shape and surface of the ideal silica that helps protect UV rays and improve the texture of sunscreens.

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**Conflict of Interest Statement**. NONE.

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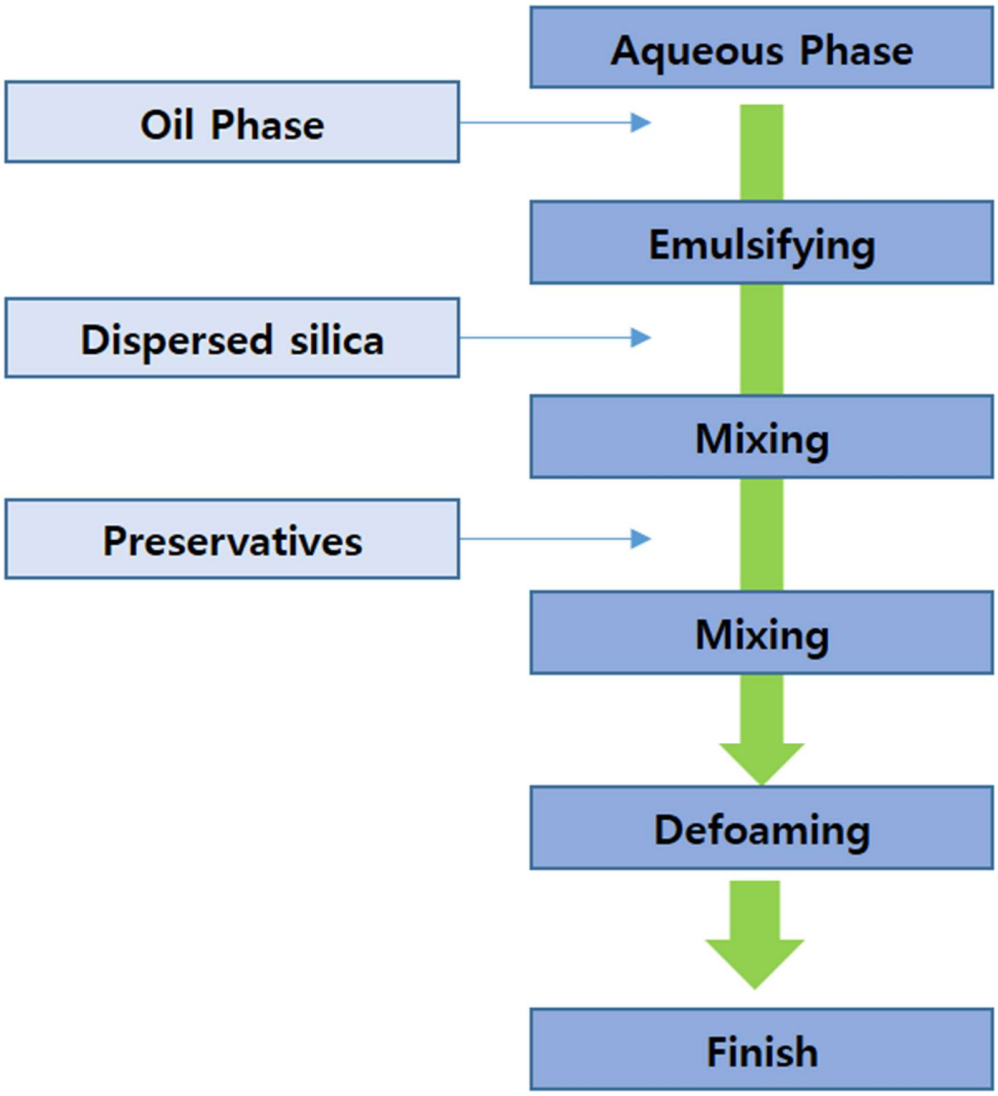


**Scheme 1. Preparation of O/W Sunscreen**

**Table 1. Physical Properties of Silica**

| | Particle Size | Shape | pH | Oil Absorpstion |
|---|---|---|---|---|
| **PS-7.5K** | 7.5 µm | Porous | 7.41 | 0.95 |
| **PS-5K** | 5 µm | Porous | 7.01 | 1.31 |
| **SS-5K** | 5 µm | Spherical | 7.26 | 0.92 |
| **MS-1K** | 1 µm | Meso-porous | 6.89 | 0.33 |
| **MS-300** | 0.3 µm (300 nm) | Meso-porous | 7.17 | 0.48 |
| **MS-050** | 0.05 µm (50nm) | Meso-porous | 6.94 | 3.09 |

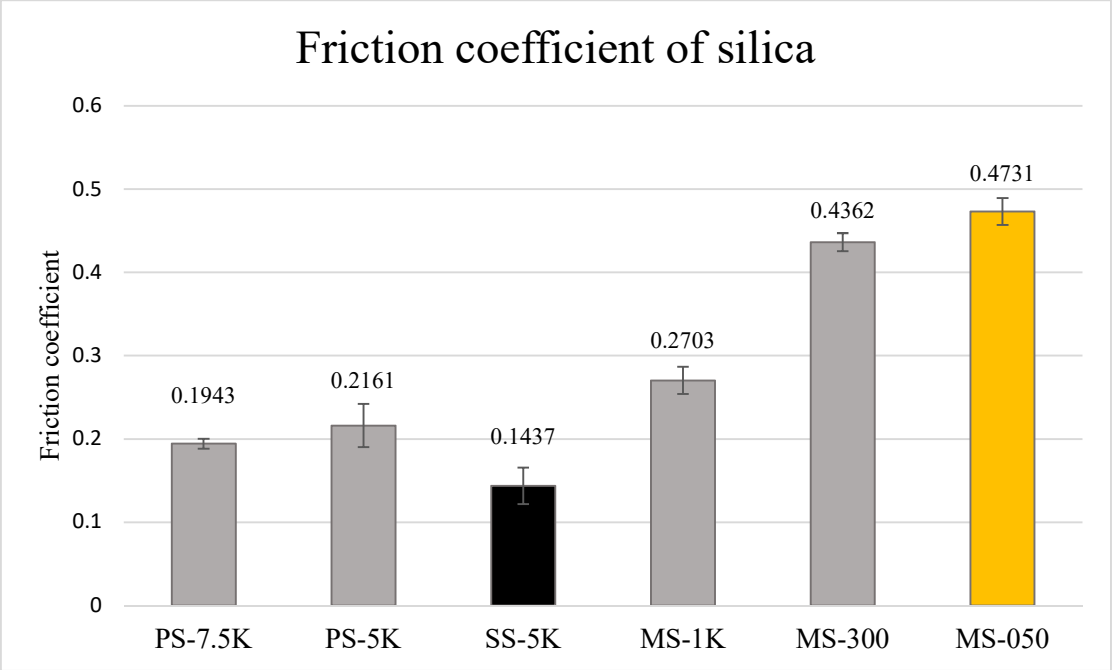


**Figure 1. Friction Coefficient of Silica**

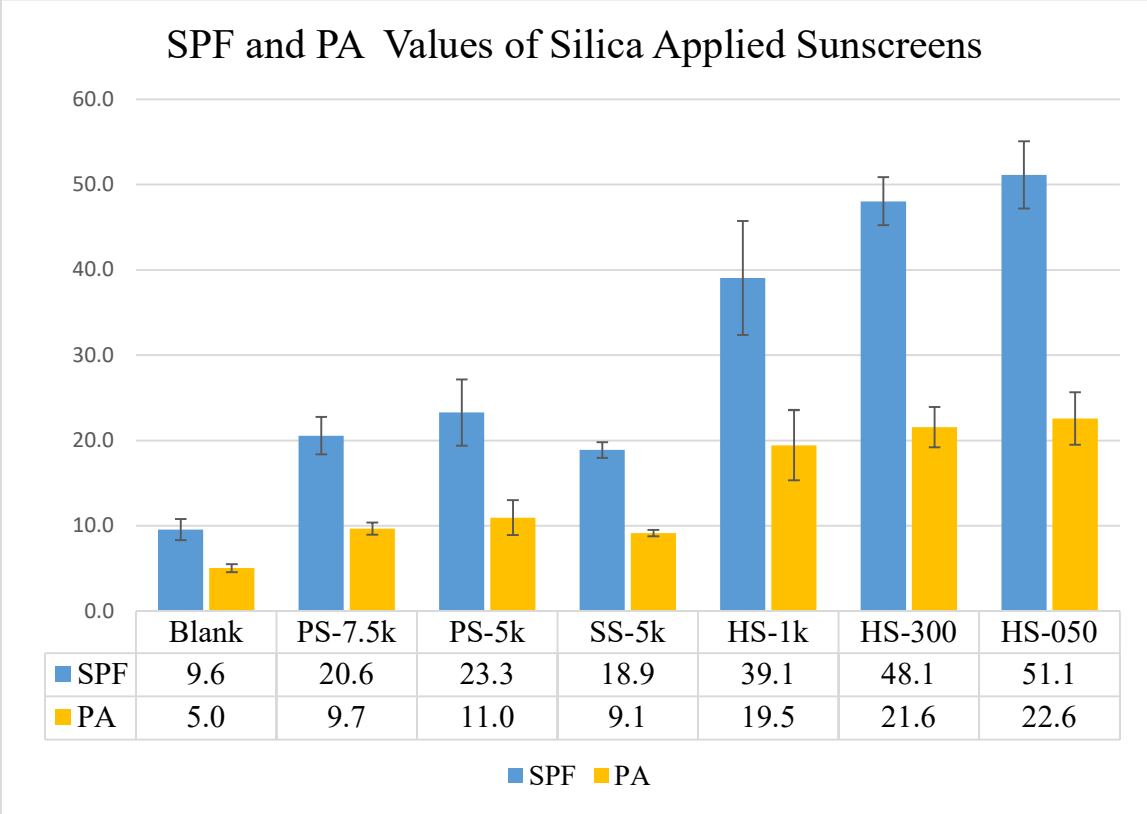


**Figure 2. SPF and PA Values of Silica Applied Sunscreens**