SYNTHESIS OF SUNSCREEN WITH ZnO/TiO_2 NANOPARTICLES FOR BROADBAND UV BLOCKING

ANALYSIS OF INFLUENCER'S ROLE IN COSMETIC MARKETING ON SOCIAL MEDIA

A Thesis Prospectus
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The cosmetics and skincare industry is growing at a rapid pace, in 2018 valued at 507.8 billion USD, with the industry forecasted to generate 758.4 billion USD in revenue by 2025 (Petruzzi, 2024). This industry growth has been brought by more consumers wanting skincare designed with them in mind. Traditional sunscreen has left a white cast on those with darker skin, which is undesirable. My group intends to design a mineral sunscreen with zinc oxide and titanium dioxide nanoparticles to provide broad-spectrum UV protection while reducing white cast and being accessible to those with sensitivities to chemical sunscreen ingredients. Marketing these innovations is becoming more competitive, so it is important to understand the stakeholder groups that have new functions in the industry. I will use the STS framework of the social construction of technology (SCOT) to investigate the rise of influencers as a stakeholder group for marketing cosmetics on social media. Understanding influencers as a key stakeholder group allows us to understand how to market our products to consumers effectively and ethically. Because the challenge of marketing sunscreen to consumers is socio-technical in nature, it requires attending to both its technical and social aspects to accomplish successfully. In what follows, I set out two related research proposals: a technical project proposal for developing a mineral sunscreen with nanoparticle active ingredients and an STS project proposal for examining the influencer's role in marketing sunscreen and other cosmetic products on social media.

Technical Proposal

In 2020, the global sunscreen market was valued at 10.7 billion USD, this market is expected to grow at 4.0% each year from 2021-2028 (Grand View Research). Sunscreen has transformed from an occasional beach day ritual to an everyday personal cosmetic. The greater popularity of sunscreen as part of people's skincare routine raises a need for sunscreen formulation to reach a wider commercial audience. Zinc oxide (ZnO) and titanium dioxide (TiO_2) are common active ingredients used to absorb, reflect, and refract UV rays. They are used in many sunscreen formulations to avoid skin irritation and allergic reactions that chemical sunscreen ingredients can cause. Some compounds in chemical sunscreen have been found to harm coral and, in response to this, oxybenzone and octinoxate have been banned in places such as Hawaii and the U.S. Virgin Islands due to the coral-bleaching effects they have (Miller et al, 2021). However, zinc oxide and titanium dioxide are considered reef-safe, largely due to their low solubility in water. This also means that they last longer on the skin, which contributes to their overall desirability (American Chemical Society).

As of 2021, zinc oxide and titanium dioxide are the only active ingredients Generally Recognized As Safe (GRAS) by the U.S. Food and Drug Administration (FDA). Other mineral and chemical ingredients have insufficient data to be considered as GRAS. However, mineral-active ingredients have the downside of leaving a white cast on the user's skin, discouraging people from regular usage. Nanoparticles are particles so small they are invisible to the human eye and show promise to minimize or eliminate the white-cast mineral sunscreens can cause. Therefore, this capstone project aims to model a synthesis process for broad-spectrum sunscreen from direct precipitation of zinc oxide and titanium dioxide nanoparticles.

Mineral Nanoparticle Synthesis

Zinc Oxide can reflect both UVA (320-400 nm) and UVB (280-320 nm) rays of ultraviolet light away from one's skin. This is important because UV radiation can damage the DNA in skin cells and pose a significant cancer risk. Although ZnO nanoparticles do not scatter visible light, the particles still can reflect and scatter UV light.

The ZnO needed for our sunscreen will be synthesized through direct precipitation. The advantages of the direct precipitation method are the small range of particle sizes it produces, cheap raw materials, and the ability to be done in a continuous operation. Common precipitation precursors are zinc sulfate and zinc nitrate (Ghorbani et al. 2015). Zinc nitrate will be used in our process because it is significantly cheaper to purchase. Using zinc nitrate as the precursor, it is combined with hydroxides such as NaOH, KOH, or LiOH. A precipitation reaction occurs when these precursors are mixed, yielding $Zn(OH)_2$. This is then filtered, washed with distilled water and alcohol, and then calcined in an oven at high temperatures over several hours. The $Zn(OH)_2$ is dehydrated in the oven and is then recrystallized to produce ZnO on the nanoparticle scale (Wang et al, 2010).

$$Zn(NO_3)_2 + 2XOH \rightarrow Zn(OH)_2 + 2XNO_3$$

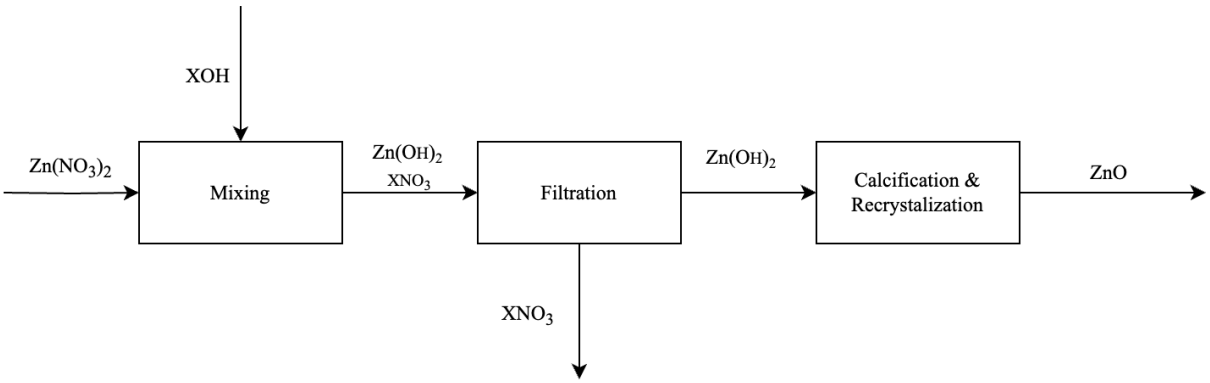

Figure 1: Process flow diagram of direct precipitation of ZnO from $Zn(NO_3)_2$.

Titanium dioxide (TiO_2) will be synthesized similarly to ZnO using titanium (IV) isopropoxide and isopropyl alcohol and distilled water as a precursor. This produces a white precipitate of TiO_2 and $(CH_3)_2CHOH$, aka rubbing alcohol, which can be separated and sold for profit. The properties of our TiO_2 product can be controlled by the amount of water, reaction conditions, and the presence of additives to obtain our desired particle size and composition. Magnesium oxide is a common substance used to neutralize this reaction and yield TiO_2 in the desired crystal structures (Li et al. 2008). The white precipitate is filtered out and dried into a powder.

$$Ti(OCH(CH_3)_2)_4 + 2H_2O \rightarrow TiO_2 + 4(CH_3)_2CHOH$$

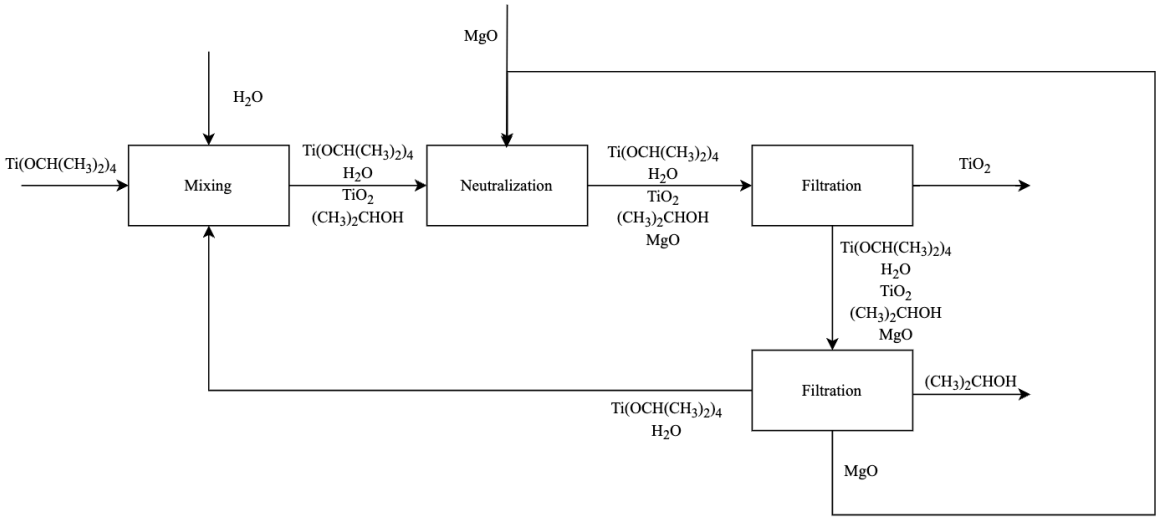

Figure 2: Process flow diagram of direct precipitation of TiO_2 from $Ti(OCH(CH_3)_2)$.

Triglyceride Synthesis

Sunscreens contain various inactive ingredients that act as emollients, dispersing agents, and antioxidants. One compound that serves these functions is caprylic/capric triglyceride. Caprylic triglyceride is a mixed triester formed from palm or coconut oils and glycerin (Mungali et al., 2021). For this process, palm oil is the best choice for making the product as affordable as possible. Palm oil is significantly cheaper, coming in at roughly $688 per MT versus $1,159 per MT of coconut oil (Bamber et al., 2016). The synthesis of caprylic triglyceride begins with saponification, followed by esterification. Saponification uses steam hydrolysis to separate the caprylic and capric fatty acids from glycerol in palm oil. This process is run at high temperatures and pressures, roughly 250 °C and 50 bar respectively (Nitbani et al., 2020). Once this separation has been completed, the caprylic acid and glycerol are reacted via esterification to produce the caprylic/capric triglycerides. The conditions for this process are conducted at a high temperature and pressure, with a catalyst (Liu et al., 2021). After, final purification is done to deodorize the product. One of the components of caprylic triglyceride that enhances its attractiveness as an

additive is caprylic acid. Caprylic acid adds benefits such as increased shelf life, homogeneous dispersion of active ingredients, moisture, and free radical protection. The increased shelf life is a result of the stability of the component, which is incredibly resistant to oxidation (Mungali et al., 2021). This classifies caprylic acid as an antioxidant, which could protect the skin from damaging free radicals from the sun and free radicals from the breakdown of the zinc oxide. Also, as an emollient, caprylic acid protects the moisture barrier of the skin and is recommended for sensitive skin (Mungali et al., 2021). Finally, capric acid allows other ingredients in the product to remain suspended and prevent any separation.

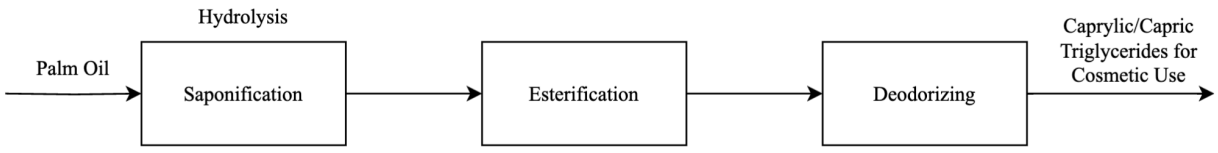

Figure 3: Process flow diagram of caprylic/capric triglyceride production.

Importance

ZnO and TiO_2 are both white and are effective at reflecting light. As a result, mineral sunscreens can often leave a white cast, the white residue on the skin after sunscreen application. As a result, people feel less inclined to use sunscreen to avoid a pale or ashy appearance, especially for those with darker skin tones. However, this can be avoided through the use of metal oxide nanoparticles (Addae & Weiss, 2024). ZnO and TiO_2 particles should be smaller than 50 nm for them not to be visible to the human eye. However, TiO_2 also has a skin permeation threshold of 45 nanometers, meaning it is important to precisely control its size (Filon et al., 2015). Because of this, nanoparticles can reduce the white cast from mineral sunscreens currently on the market.

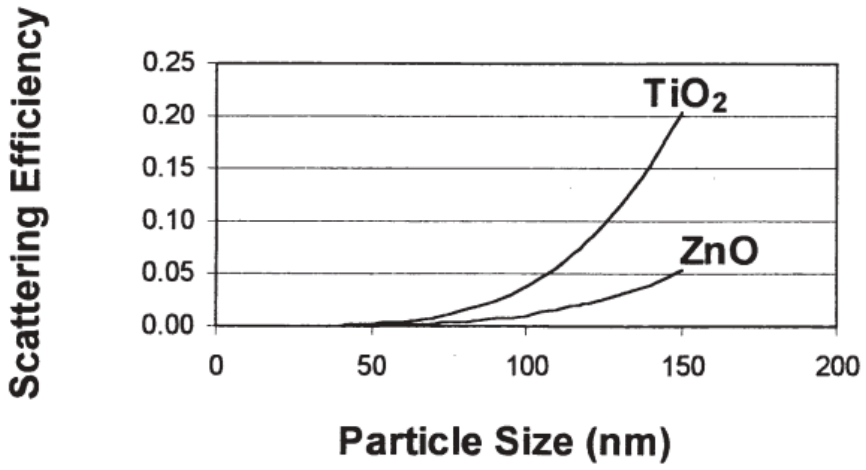

Figure 4: Scattering efficiency in comparison to nanoparticle size (Pinnell et al., 2000).

The sunscreen that will be produced is planned to be hypoallergenic and fragrance-free. Mineral sunscreens are regarded to be better for those with sensitive skin since they lack some compounds in chemical sunscreens that can be irritants. Another source of irritation can come from the use of fragrances. In a 2019 study, it was found that fragrances are the most common allergen in high SPF sunscreens found in the United States (Keyes, 2019). By making the product with ingredients that cause minimal allergic reactions, it allows anyone to use the sunscreen without discomfort. The selected ingredients are also known to be non-comedogenic, or non-pore-clogging, allowing the sunscreen to be used by those who are acne-prone.

There are a handful of sunscreens on the market that utilize mineral nanoparticles. Some of the most popular are Murad's City Skin Age Defense Broad Spectrum SPF 50 | PA++++ and La Roche Posay's Anthelios Mineral Zinc Oxide Sunscreen SPF 50. Both of these products are being sold for more than twenty dollars per fluid ounce compared to the roughly three dollars per fluid ounce of regular mineral sunscreen, which poses an issue with the affordability of this type of product (La Roche Posay, Murad Skincare). This increased cost is due to the more complex

and expensive development of these novel sunscreens, but it also significantly hinders their accessibility and marketability towards a wider market. Minimizing the cost of this product through optimization of its synthesis is necessary to increase the accessibility of this product such that the average consumer can afford a visually pleasing and non-comedogenic sun-blocking product.

Execution:

This work will be completed by modeling the synthesis process of zinc oxide, titanium dioxide, and triglyceride to optimize variables such as flow rates, temperature, and reaction rate. Modeling the processes themselves will be performed using Aspen Plus Version 14 with raw material thermodynamic data obtained from NIST Thermodata Engine (TDE) (Aspentech: Knowledge base, 2017). Additionally, both safety and cost analyses will be performed to assess the viability of this product on the market. This design work will be done over the course of two semesters, with a detailed deliverable in the spring of 2025.

STS Proposal

In May 2007, Michelle Phan uploaded the first YouTube makeup tutorial with her very first video, “Natural Looking Makeup Tutorial”. This 7-minute video inspired a trend that became an essential video format where YouTubers talked their viewers through their makeup routines. As viewership increased, cosmetic brands caught on. Brands moved from celebrity, mainstream TV campaigns to sending influencers PR packages, brand deals, and brand trips. The main form of advertising moved to people’s phones and computers. YouTubers started connecting with their audience, sharing personal stories while trying on different cosmetics (Cramer 2023).

The 2020 COVID-19 pandemic sent people inside and to a new sharing platform, a short-form video platform called TikTok, which reinvented beauty content. TikTok’s format of a “For You Page” feeds the content directly to the viewer with a simple scroll. A TikTok video can secure at least one view by just pressing post, no subscribers are needed. The endless content feed structure allows more videos to be shared and viewed, creating a whole group of micro-influencers, influencers with 1,000 – 100,000 followers, and building a community of trust with their audience.

Another COVID-19-related trend shift was skincare becoming something people value when going about their everyday lives. The heavy makeup looks common in 2016 have given way to more “minimal” looks. A pandemic shifted minds from putting on a face for the public every day to more self-care-focused content with people stuck in their homes. A 2021 survey by

Scieszko titled “How has the pandemic lockdown changed our daily facial skincare habits?” examined the personal care habits of 412 women in Poland. They found that 15% of “respondents declared providing themselves full face care … two to three times a week,” while during the pandemic, this became 46% of respondents.

Because social media democratizes information by lowering the threshold for posting and sharing, companies have employed the structure of the trusted influencer to their advantage (Spinner, 2021). Consumers now rely on influences, with whom they’ve built parasocial relationships, rather than traditional experts like dermatologists. The global influencer market was valued at 21.1 billion USD as of 2023 (Statistica 2024). A total of 69% of consumers rely on influencer recommendations when purchasing items (Matter Communications, 2023). Influencers play an increasingly important role in all industries, with marketing, reviewing, criticizing, and raising awareness. Especially on the platform TikTok, where 68.8% of influencer marketing takes place; Instagram and YouTube are 46.7% and 33.1%, respectively. (Influencer Marketing Hub, 2024)

I will use the social construction of technology to analyze the rise of this new stakeholder group of influencers. Social Construction of Technology (SCOT), as described by Bijker, Kline, and Pinch, states that technological development is socially constructed through revisions and iterations that address the various priorities and concerns of many social groups with a stake in the design. Key concepts include relevant social groups (stakeholders like influencers, consumers, and companies), interpretive flexibility (different meanings each group has assigned

to the technology), and stabilization and closure (when a design becomes accepted and major changes cease). These influencers are a new group of stakeholders, influencing what cosmetics are made with and what products will be successful; as an engineer, this recognition is essential. Influencer marketing focuses on aesthetic packaging, viral items, complex routines, and solving issues like acne, dark spots, and wrinkles. These stakeholders come with new effects on the consumer base like promoting conformity by following what's trendy or highlighting new things consumers should be insecure about. This power over the consumer base means skincare companies need to revise their product lines to remain relevant and profitable. By looking at social media content related to sunscreen advertising and surveying consumer opinions, I will analyze how social media platforms and influencers shape technological innovation in cosmetics, democratizing beauty trends, and prioritizing consumer-driven demands rather than traditional stakeholders with medical expertise like dermatologists. By applying SCOT, this project will study the relationship between influencers and cosmetic companies, offering insights into the evolving dynamic of consumer trust, product design, and manufacturing strategies.

Conclusion

This prospectus outlines two complementary projects: the design of a nanoparticle-based mineral sunscreen and a socio-technical analysis of influencer marketing. Our technical project focuses on optimizing sunscreen synthesis for performance and accessibility. This improves on pre-existing designs where the minerals of larger particle size left a white cast on the user's skin. By addressing both functional and aesthetic concerns, this design caters to consumer demands

for effective and inclusive products. The STS proposal will employ the SCOT framework to provide further insight into a new stakeholder group in the cosmetic industry. This analysis highlights how influencers shape product development and stabilization by representing and creating consumer priorities without necessarily requiring traditional medical or chemical expertise. Together, these approaches help bridge the gap between innovative product development and consumer-oriented, responsible marketing practices, enhancing both product value and consumer trust.

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