Endowing Face Masks with Virucidal Activity via UV-Grafted Quaternized Cationic Amphiphiles

R. Helen Zha,[1,2] Mirco Sorci,[1,2] Tanner D. Fink,[1,2] Brigitte Arduini,[2] Katherine Dovidenko,[3] Vaishali Sharma,[4,5] Sneha Singh,[5,6] Caryn L. Heldt,[5,6] Edmund F. Palermo[7]

[1]Department of Chemical & Biological Engineering, Rensselaer Polytechnic Institute; [2]Center for Biotechnology and Interdisciplinary Studies, Rensselaer Polytechnic Institute; [3]Center for Materials, Devices, and Integrated Systems, Rensselaer Polytechnic Institute; [4] Department of Biological Sciences, Michigan Technological University; [5] Health Research Institute, Michigan Technological University; [6] Department of Chemical Engineering, Michigan Technological University; [7]Department of Materials Science and Engineering, Rensselaer Polytechnic Institute

Statement of Purpose: While face masks are effective in blocking the transmission of airborne viruses, a critical problem is that mask materials have no inherent virucidal activity. Consequently, the risk of cross infection increases with wear time. Thus, face masks and respirators used as medical personal protective equipment are only intended for single-use with regular disposal after patient exposure, leading to a risk of shortage during pandemics as well as significant environmental waste. The ability of face masks to protect against infection can be unequivocally improved by incorporating components that deactivate viruses on contact. Various additives and coatings with antiviral activity have been investigated, including inorganic materials such as copper, zinc, and silver. However, a potential concern for the use these inorganic materials, which are often applied as nanoparticles embedded in or non-covalently attached to the fibers of filtration media, is their adherence tenacity and inhaled toxicity in long-term use. As an alternative approach, we have developed a facile method for covalently attaching quaternized cationic amphiphiles to the surfaces of melt-blown and spunbond polypropylene fibers commonly used in face masks and N95 respirators, with the expectation that viruses will be deactivated upon contact via lipid envelope disruption.

Methods: Our strategy utilizes a UV-active benzophenone moiety to simultaneously polymerize and graft quaternized dimethylaminododecane onto polypropylene. Specifically, a C12-quaternized benzophenone was prepared in high yield with a one-step reaction. The purified compound was then coated onto polypropylene filters by drop-casting the compound onto filters, exposing to 254 nm UV light for 10 minutes to initiate the grafting reaction (Fig. 1), then sonicating in acetone to remove unbound material. Scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (SEM), and streaming current analysis were used to characterize the physicochemical properties of the coated filters. Deactivation of various enveloped viruses were tested by assaying the infectivity of mouse coronavirus, human coronavirus 229E, Suid herpesvirus 1, and a model green fluorescent lentivirus. Antibacterial activity was also tested using *Escherichia coli*. Filtration efficiency and pressure drop across coated and uncoated filters was also characterized using protocols and equipment that match the requirements for certification under NIOSH 42CFR84 standards for N95 respirators. Physisorption of a quaternary ammonium polymer was used as a comparison for the covalently grafted coating.

Results: Our grafting method was successful in generating conformal polymer coatings on melt-blown and spunbond polypropylene fibers. This coating imparted a cationic charge to fiber surfaces but did not grossly change fiber morphology or increase pressure drop across filters. For melt-blown polypropylene (used in N95 respirators), filtration efficiency was negatively impacted (from 72.% for uncoated single-ply to 51.3% for coated single-ply). However, an alternative to coating the active filtration layer was to coat spunbond polypropylene for use as an outer layer of an N95 mask, which yielded a 99.7% filtration efficiency. Coated filters demonstrated up to 4-log reduction of virus, though results varied depending on virus strain and protocol for assaying infectivity. Coated filters also showed good antibacterial activity, suggesting the broad-spectrum antimicrobial utility of our coating. In all studies, UV-grafted coatings outperformed physisorbed polymer.

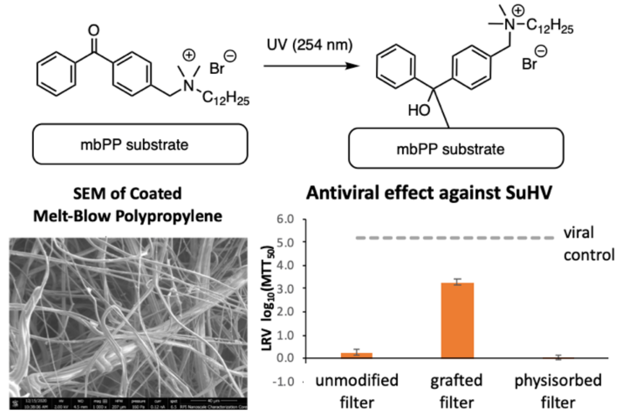

Figure 1. (Top) UV-induced grafting of quaternized cationic amphiphiles to polypropylene substrates. (Bottom right) Scanning electron microscopy of melt-blown polypropylene with grafted coating. (Bottom left) Log reduction values (LRV) of SuHV after contact with coated and uncoated polypropylene filters.

Conclusions: Grafting quaternized ammonium polymers to polypropylene filtration media by UV-induced benzophenone chemistry is a viable strategy for endowing face masks with antiviral and antibacterial activity without impacting breathability. Though filtration efficiency of melt-blown polypropylene is negatively impacted by this approach, masks with N95-level performance can be fabricated using coated spunbond polypropylene as an outer layer.

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