

Short Communication

Innovating protective gears for frontline health professionals in the COVID-19 pandemic at a low resource setting

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Abstract: We communicate briefly about the innovation of protective gear (such as Hazmat suit) and respirator mask that can be used by health care professionals as mouth and nose protection tools against the penetration of the microscopic particles containing highly contagious species into the body. As a research and development support to the local entrepreneurs willing to come up with innovative products, the structural and some surface functional properties of the polymeric materials available in local market were analyzed in comparison to the commercially available gears and masks. It has been found that the respirator masks, equivalent in structure and functional properties as the common commercially available protective gears could be developed that can be used by front-line health professionals for protection against contagious environment. The research has paved way to manufacture highly useful health care products at significantly lower costs under low resource setting.

Keywords: innovation; low resource setting; mask; morphology; microscopy; protective gear

सारांश: यो साक्षिप्त लेखमा हामी ब्याधिको समयमा अग्रपतिमा रहेर सेवा प्रदान गर्ने स्वास्थ्यकर्मीहरूको प्रयोजनार्थ संक्रामक वस्तुहरू समेत रहेको अत्यन्त शुष्म कणहरूलाई शरीर भित्र प्रवेश गर्न वाट रोक्न सुरक्षाकवच तथा रेस्परेटर मास्कको नवप्रवर्तन र विकासको बारेमा चर्चा गर्छौं। यो अनुसन्धान कार्यमा व्यावसायिक रूपमा स्थानीय बजारमा उपलब्ध सामग्रीहरूको नमुना तथा स्थानीय उद्यमीहरूले विकसित गरी बजारमा ल्याउने प्रयास गरी रहनु भएको कवच तथा मास्कका नमुनाहरूको विभिन्न भौतिक तथा रासायनिक गुणहरूको तुलनात्मक अध्ययन गरीएको थियो। मुलतः उद्यमीहरूले उक्त कार्यको लागि प्रयोगमा ल्याउने गरेको स्थानीय बजारमा उपलब्ध पोलिमरिक सामग्रीको संरचनात्मक तथा कार्यात्मक गुणहरूको अध्ययन गरिएको थियो। यो अध्ययनले स्थानीय रूपमा उपलब्ध विशेषज्ञता र सामग्रीहरू प्रयोग गरेर अब्बल दर्जाका कवच र मास्कहरू उत्पादन गर्न सकिन्छ भन्ने पाइएको छ। यो अध्ययनले संक्रामक रोगहरूको आक्रमणबाट जोगिनको लागि यस्ता अती उपयोगी उपयोगी स्वास्थ्य सेवा प्रदायक वस्तुहरू सिमित स्रोतसाधनको बावजूद कम लागतमा नै उत्पादन गरी स्थानीय उद्दमलाई सबल गराउन सकिने मार्ग प्रशस्त गरेको छ।

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1. Introduction

The current COVID-19 pandemic has created disastrous situations in the society worldwide magnifying further several socio-economic problems necessitating more rigorous analysis of the disaster impacts. The COVID-19 crisis has challenged us in multiple ways and even served as an eye opener in various aspects including the need for revisiting existing disaster mitigation strategies, redesigning education system as well as reorganizing the ways the economic sectors are being mobilized. Furthermore, the pandemic has unraveled new opportunities for value and knowledge based industrial revolution in the country. As skilled migrant workers are returning and there is aspiration of prosperous nation among citizen, the country is

now in the verge of advancing its unique development sectors based on agriculture, forestry, water, minerals and tourism.

As a response towards the COVID-19 mitigation schemes, Nepal Government has taken actions utilizing as far as possible the resources to cope with the pandemic situation. For example, in coordination with Ministry of Health, the Ministry of Education, Science and Technology formed high level committee to gather the support of all strata of the society including scientists, engineers and innovators to combat the impacts of COVID-19. In particular, several technological potentials, research and innovation gaps, and policy feedbacks have been crystallized by six thematic sub-committees (Nepal Government, Ministry of Education, Science and

Technology, Report of High Level Committee formed for combating COVID-19, June 2020). It has been, nevertheless, evidenced during the time of the lockdown that our preparedness for responding COVID-19 through materials, medicines and manufacturing of essentials has been inadequate. In this scenario, we have a challenge of developing high quality materials and techniques that can also be commercialized soon by Nepali entrepreneurs ensuring the safety of patients, healthcare professionals and security personnel.

Referring to some of some of recent modelling studies (Marahatta et al, 2020; Bhandary et al., 2020), studies, it seems that we are in front of a quite risky situation. It is now high time to join hand-to-hand between academia and industries focusing on Research and Development (R&D) activities, for academia, entrepreneurs and business sectors, hand to hand, to develop the essential health care tools, materials as well as and diagnostics for testing infection even under in low resource settings.

There are a numbers of guidelines and published documents for the development of health care materials in settings with limited resources (Lalli et al., 2020; World Health Organization, 2012 & 2015), but our society was not prepared to manage the unprecedented situation created by the COVID-19.

Under such condition, the adventurous initiatives taken by the National Innovation Centre (NIC) at RECAST, Tribhuvan University, the Research, Development and Innovation (RDI), Kathmandu University, and the Idea Studio Nepal (ISN) to equip the frontline healthcare professionals of the country with basic Nepal made personal protective equipments, ventilators and accessories to sterilize the possibly infected items, provided a great relief.

It has been realized that such an endeavor demands a highly interdisciplinary R&D works among material scientists, biomedical researchers, and public health and policy experts with a linkage to entrepreneurs in order to translate the ideas and innovations into sustainable products (or service).

Thus, amidst the pandemic, motivated by need of the hour, we built a collaborative network and began to work on some personal protective equipments (PPEs) for use by healthcare and security professionals. Some preliminary results are communicated herein while details will be reported in future (Adhikari et. al, 2020, unpublished results).

2. Materials and Methods

We collected dozens of textile samples from the market that have been used for manufacturing some healthcare products utilizing local expertize and skills and compared their physicochemical properties with the similar imported readymade protective

gears (such as N95 and KN95 labelled masks, Hazmat suits etc.). The materials were analyzed for structural elucidation by Fourier transform infrared (FTIR, IRAffinity-1S, Shimadzu, Japan) spectroscopy, optical (OM) and scanning electron microscopy (SEM, JSM IT100, Jeol, Japan), and for surface adhesive properties by contact angle measurements.

3. Results and Discussion

In this paper, we present the summary of major results obtained on protective gears (suit and respirator masks) that have been developed.

3.1 Protective gown

The protective suit forms a part of the personal protective equipments (PPEs) used by frontline health professionals as protection against contagious diseases such as COVID-19. Such a gear requires the functionalities in the morphology of fabrics that are repulsive and non-penetrative to any kind of micro-organisms substrates while being comfortable, biocompatible, chemically inert and completely safe for biomedical applications.

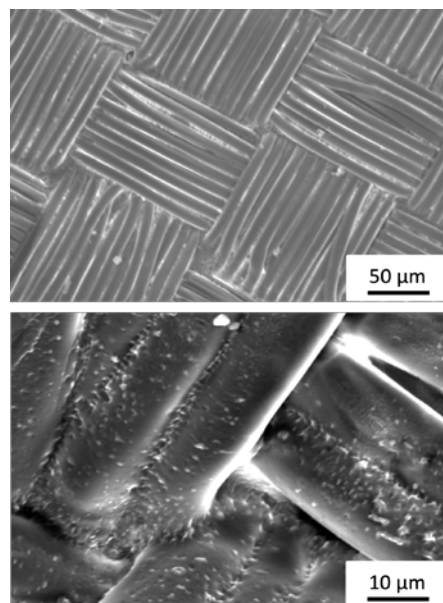


Figure 1. SEM micrographs of different magnifications of outer nylon (top), inner PU (bottom) layers of Hazmat suit

The suits, both imported and fabricated in Nepal (such as Hazmat suit) were found mostly to comprise two layers (outer nylon or polyamide (PA) and inner polyurethane (PU)), both materials being permitted as safe for biomedical applications (Maitz, 2015).

The SEM surface micrographs of such a protective gear are presented in **Figure 1**. It can be seen that the continuous and uniform nylon threads, 6-10 μm thick, are quite intact positioned in the fabric allowing practically no porous framework at the interface while the inner PU layer is quite continuous and served as plastering layer. These

architectures can restrict the penetration of the micron-sized fluid droplets through the gear. The outer nylon polymeric (and thus hydrophobic) surface further repels the aqueous-phase droplets.

3.2 Respirator mask

Various kinds of masks available in the market which claim to be N95 or similar and are safe for frontline healthcare workers are generally quite expensive.

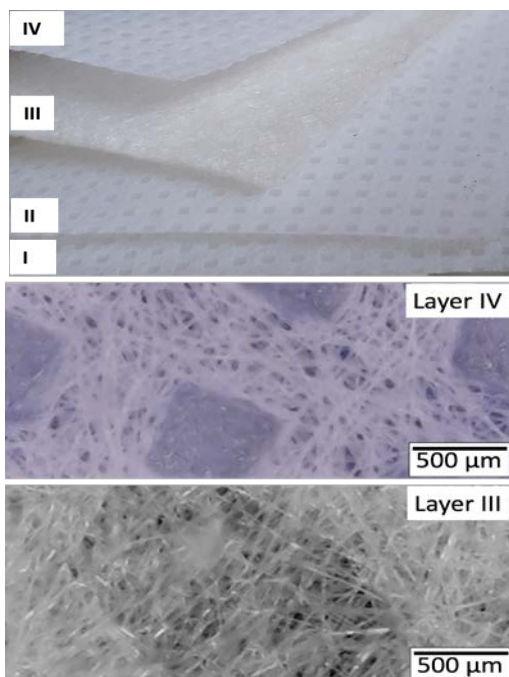


Figure 2. Photograph of 4 mask layers (top); and optical micrographs of outer iPP (IV) and inner PET filter (III) layers

The availability of the masks is, nevertheless, not very easy. We carried out performed different tests on commercial N95 respirator masks and designed ourselves inexpensive yet quite safe masks having equivalent functionalities in terms of structures and properties of commercial ones.

Figure 2 shows the photograph of the cross-section of the mask comprising different layers; the outer layer (I, II and IV) being non-woven isotactic polypropylene (iPP) and an inner layer (III) polyethylene terephthalate (PET). The detailed morphology of the layers is illustrated by optical micrographs presented in **Figure 2**. Their highly porous structures insure good breathability of the masks. The densely entangled fibrils of the filter layer (III) may contribute to make the masks safe for inhalation as well as for preventing the droplets to enter through it. The samples were further studied by scanning electron microscope which demonstrated highly fibrillar and yet highly porous structures (Adhikari et al., 2020, unpublished results).

The surface properties of different layers were studied *via* contact angle measurements; the magnitude of the angles reflects the hydrophobicity

of the samples. The results are given in **Table 1**.

Table 1: List of the surface properties of the tested materials

Materials In layers	Contact angle (°)	Surface Energy (mJ/ m ²)	Thickness (mm)	Surface Density (mg/ cm ²)
Outer Layer I	118.4± 0.6°	12.5 ± 0.6	0.286 mm	5.85
Middle Layer II	121.6 ± 1.7°	10.8± 0.8	0.328 mm	5.94
Middle Layer III	109.9 ± 3°	17.2± 1.8	0.868 mm	18.8
Inner Layer IV	117.3± 2.4°	12.9 ± 1.3	0.286 mm	6.21

As shown by fairly large contact angles and lower surface energies, the iPP surfaces of layers I, II; and IV as well as filter layer III are quite hydrophobic; one of the most important requirements of the porous materials used for respirator masks. Our masks have also been found to fulfil other requirements on gas permeability, and resistance to microparticles penetrations (Adhikari et al., 2020, unpublished results).

4. Conclusions and Recommendations

Under low resource setting, we have successfully worked on development of protective gears that are recommendable as protection against contagious environment. The research has paved way to manufacture highly useful masks at significantly lower costs under low resource setting. The structural and surface properties of the materials suitable for the named purpose were elucidated. The materials possessed primarily hydrophobic surfaces implying the nature of the substance to repel the fluid-borne microbes from penetrating through it.

Authors' Contributions: RA, TL, DPS, and SS designed experiments and drafted manuscript. Other authors performed tests and analyzed the data.

Conflicts of Interest: Not applicable.

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