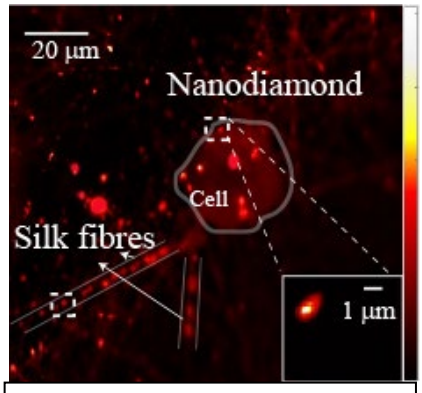
Smart silk membrane: Hybrid optical platform for wound sensing applications

Asma Khalid[1*], Laura Hung[1], Ethan Ellul[1], Jean-Philippe Tetienne[1], Dongbi Bai[1], Amanda Abraham[1], Lu Peng[2], Achini Vidanapathirana[3], Azim Arman[3], Denver Linklater[1], Hanif Haidari[4], Zlatko Kopecki[4], Georgy Kalenkov[3], Jiawen Li[2], Mark Fear[5], Suzanne Rea[5], Allison Cowin[4], Fiona Wood[5], Elena Ivanova[1], Shadi Houshyar[1], Robert A. McLaughlin[3], Christina Bursill[3,6], Brant Gibson[1]

[1] School of Science, RMIT University, Melbourne, VIC 3000, Australia
[2] Faculty of Sciences, Engineering and Technology, University of Adelaide, Adelaide, SA 5005, Australia
[3] Faculty of Health and Medical Sciences, University of Adelaide, Adelaide, SA 5005, Australia
[4] Future Industries Institute, University of South Australia, Mawson Lakes, SA 5095, Australia Centre for
[5] Cell Therapy, Regenerative Medicine, University of Western Australia, Perth, WA 6009
[6] South Australian Health and Medical Research Institute (SAHMRI), Adelaide, SA 5001, Australia

Our work aims to develop a biocompatible, transparent silk dressing, integrated with temperature and pH sensors, capable of monitoring early signs of infections, healing disruptions and scar formation via light-based measurements.

Introduction: Assessing wound repair and monitoring of infections requires the removal of dressings, which is painful and disruptive to healing and is based on subjective visual wound observation. Improving this process is crucial as earlier interventions will help reduce the complications that arise from wound infection. Measuring the temperature and pH of the wound surface can provide objective indicators of wound healing and any underlying infections[1,2]. A clinically diagnosed wound infection elevates the temperature by 3-5° C compared to healthy skin[1]. The pH of wound fluid rises[2] prior to the onset of more vital signs of local infection. Measuring temperature and pH through silk dressings, via light-based measurements, will be useful to provide real-time insights into the healing responses during early stages of wound progression. In addition, optical coherence tomography will observe the vascularization and scar formation during wound healing.



Nanodiamond embedded silk membrane (dressing) cultured with HaCaT cells, used for thermal sensing in biological environment[3].

Results: We have shown that silk membranes and films embedded with nano and microdiamond sensors can monitor temperature changes in the wound relevant range of 32-40 °C[3]. In vitro tests revealed that the hybrid membranes enable eukaryotic cell attachment and promote healthy cell growth. In an *in vivo* wound healing model, the hybrid membranes enabled wound healing and did not cause adverse effects on wound closure. The membranes were found to be biocidal towards major skin wounds infecting bacteria[3]. Moreover, the pH-sensitive fluorophores can be encapsulated within silk to provide measurements of acidity or basicity *in situ* in mice[4]. In conclusion, multiple fluorescent sensors embedded in silk dressings can be used as a platform for biosensing.

1. A Chanmugam, et al. Advances in Skin & Wound Care, 30 (9), 2017.
2. S Ono, et al. Burns, 41 (4), 2015.
3. A Khalid, et al, ACS Applied Materials & Interfaces, 12(43), 2020.
4. A Khalid, et al, Sensor and actuators B. Chemicals, 311, 2020.