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Editorial

Materials Science in the time of Coronavirus

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Before 2020, phrases such as "social distancing" and "lock down" were not part of our normal vocabulary; however, it seems now that they are at the core of every conversation. We scientists naturally look to see where we might be best placed to help as we start to piece together what this new normal means for us.

Tackling a problem of the magnitude of a global pandemic cannot be undertaken by a single discipline. At this point, while we are still in the early stages of this crisis, where emergency medical care and reducing pressure on health services are the priority, we look to our clinicians, epidemiologists, and experts in the biomedical sciences for frontline solutions. However, we must think more broadly about the role of materials science.

Traditionally, when we think about "viral infection" our thoughts first turn to vaccines. After all, these have been arguably one the most successful public health interventions in human history, rendering what were once fatal or seriously debilitating diseases a thing of the past thanks to a simple course of inoculations. They will always remain the heavy artillery in our fight against viruses; however, in the situation we face at present, a vaccine against COVID-19 remains some way into the future.

What then of antiviral agents? Over the last 50 years, more than 90 drugs have been approved as antivirals, yet these target only nine human infectious diseases [1]. It is tempting to think that the development of new antiviral agents is beyond the scope of what we traditionally call materials science, yet the scientific literature belies this view, where the impact can be had is in the development of new delivery vectors which enhance the properties of existing antiviral agents, such as their pharmacokinetics, and reduce unwanted side effects. One of the contributions from materials and chemistry is covered in an Invited Viewpoint in this issue [2].

There is a startling array of different materials which have been employed, each with a different potential benefit. Recent work by Jones et al. [3] demonstrated nontoxic, broad-spectrum antiviral

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cyclodextrins (a type of cyclic sugar), modified with mercaptoundecane sulfonic acids, which were shown to be virucidal at micromolar concentrations in vitro against a range of viruses including herpes simplex virus (HSV), respiratory syncytial virus (RSV), dengue virus, and Zika virus. Earlier work by Cagno et al. [4] demonstrated the importance of strong multivalent binding, leading to virus deformation and loss of infectivity, which was achieved by the modification of gold nanoparticles with the same undecane sulfonic acid. "Nanosponges" based around branched polymeric cyclodextrins have found promise as potential antiviral drug delivery vectors [5], while flexible nano-gels which can mimic the heparan sulfate proteoglycans on the cell surface and have been shown to shield viruses and block their entry to the cell [6]. While not yet employed in the clinic, these findings show that there is a potential for materials researchers to collaborate effectively with colleagues in the health and life sciences and find new and elegant ways to reimagine antivirals.

A subject which has been dominant in the news around COVID-19 is that of testing. Discussion of the deployment, efficacy, and availability of tests has run to many thousands of words, with the only agreement seeming to be that wide-scale testing is critical to understand the spread of infection. Again, looking to the future, the design and fabrication of new materials may here play a role. The detection limit for HIV has been improved by the use of magnetic microparticles together with nanoparticles tagged with oligonucleotide "bar codes" which improve the real-time immuno-PCR amplification process for the detection of HIV [7]. Voltammetric detection of viral hepatitis has also been demonstrated with the use of ferrocene-capped gold nanoparticles conjugated to DNA [8]. While these examples only provide a snapshot of the current research capability, and clearly there is a more pressing need for immediately available diagnostics, it is conceivable that through collaboration, rapid development of testing for COVID-19 and related viral infections can be achieved in the near future.

The challenges for materials science do not stop at the design of new drug delivery vectors or diagnostic tools. Any new discovery which works in the laboratory must be rigorously tested, scaled up, and implemented in such a way that that it confers added benefits over the current state of the art. There are many factors to be considered, including complexity of fabrication and usage, cost-effectiveness, and stability. Translation to a clinical setting requires adherence to regulatory frameworks which are generally outside of the skills set of the bench-based materials scientist. This is why, more than ever, working across the disciplines is crucial if we are to reap the benefits of any new technology.

The Journal of Materials Science has long welcomed submissions in the area of materials research which impacts on the health and life sciences, with papers relevant to this field being categorized under "Materials for the Life Sciences." We broadened from just "Biomaterials" to reflect the fact papers demonstrating new materials applications in all facets of the biomedical sciences are passing across the editors" desk more often than in the past. Materials for Life Sciences covers a broad range of topics, including new materials for implants, bioimaging materials, materials for tissue scaffolds, drug delivery, and rapid diagnostics. It is in these latter two areas where our best efforts for materials solutions to the threat posed to us by viruses.

When we emerge from the other side of this crisis, the world will not look the same; however, maybe some small comfort can be taken from the thought that the way we work might be changed for the better. John Donne famously wrote "No Man is an Island"—the same is true of our scientific outlook. Though physical distance temporarily separates us, we should strive to collaborate across scientific "continents," listening to experts in other fields and offering our expertise where we can. Outbreaks will always happen. It is our job as scientists to lay the foundations of our defenses. We can then be assured that the next time we face what seems like an insurmountable challenge, we can do so stronger, together.

Compliance with ethical standards

Conflict of interest The author is an editor of the Journal of Materials Science and associate professor of physics at the University of Bristol. She is the Director of the Bristol Centre for Functional Nanomaterials and has research interests in soft materials with applications in biomedical sciences and health care.

References

[1] De Clercq E, Li G (2016) Approved antiviral drugs over the past 50 years. Clin Microbiol Rev 29(3):695–747. https://doi.org/10.1128/cmr.00102-15

[2] Jones S (2020) How materials can beat a virus. J Mater Sci. https://doi.org/10.1007/s10853-020-04678-4

[3] Jones ST, Cagno V, Janeček M, Ortiz D, Gasilova N, Piret J, Gasbarri M, Constant DA, Han Y, Vuković L, Král P, Kaiser L, Huang S, Constant S, Kirkegaard K, Boivin G, Stellacci F, Tapparel C (2020) Modified cyclodextrins as broad-spectrum antivirals. Sci Adv 6(5):eaax9318. https://doi.org/10.1126/sciadv.aax9318

[4] Cagno V, Andreozzi P, D'Alicarnasso M, Jacob Silva P, Mueller M, Galloux M, Le Goffic R, Jones ST, Vallino M, Hodek J, Weber J, Sen S, Janeček E-R, Bekdemir A, Sanavio B, Martinelli C, Donalisio M, Rameix Welti M-A, Eleouet J-F, Han Y, Kaiser L, Vukovic L, Tapparel C, Král P, Krol S, Lembo D, Stellacci F (2018) Broad-spectrum non-toxic antiviral nanoparticles with a virucidal inhibition mechanism. Nat Mater 17(2):195–203. https://doi.org/10.1038/nmat5053

[5] Lembo D, Trotta F, Cavalli R (2018) Cyclodextrin-based nanosponges as vehicles for antiviral drugs: challenges and perspectives. Nanomedicine 13(5):477–480. https://doi.org/10.2217/nnm-2017-0383

[6] Dey P, Bergmann T, Cuellar-Camacho JL, Ehrmann S, Chowdhury MS, Zhang M, Dahmani I, Haag R, Azab W (2018) Multivalent flexible nanogels exhibit broad-spectrum antiviral activity by blocking virus entry. ACS Nano 12(7):6429–6442. https://doi.org/10.1021/acsnano.8b01616

[7] Kim E-Y, Stanton J, Korber BT, Krebs K, Bogdan D, Kunstman K, Wu S, Phair JP, Mirkin CA, Wolinsky SM (2008) Detection of HIV-1 p24 Gag in plasma by a nanoparticle-based bio-barcode-amplification method. Nanomedicine 3(3):293–303. https://doi.org/10.2217/17435889.3.3.293

[8] Wang J, Li J, Baca AJ, Hu J, Zhou F, Yan W, Pang D-W (2003) Amplified voltammetric detection of DNA hybridization via oxidation of ferrocene caps on gold nanoparticle/streptavidin conjugates. Anal Chem 75(15):3941–3945. https://doi.org/10.1021/ac0344079

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