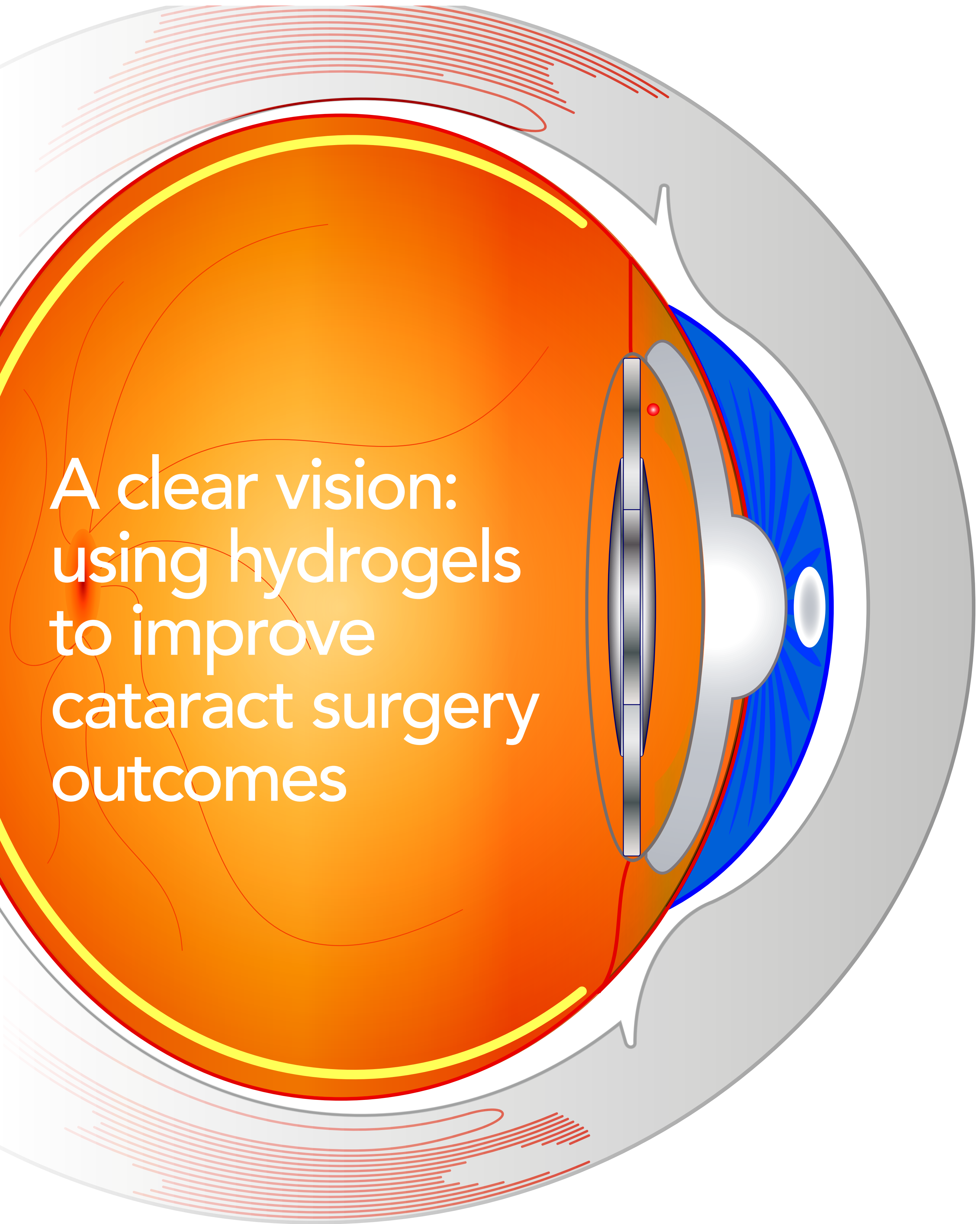
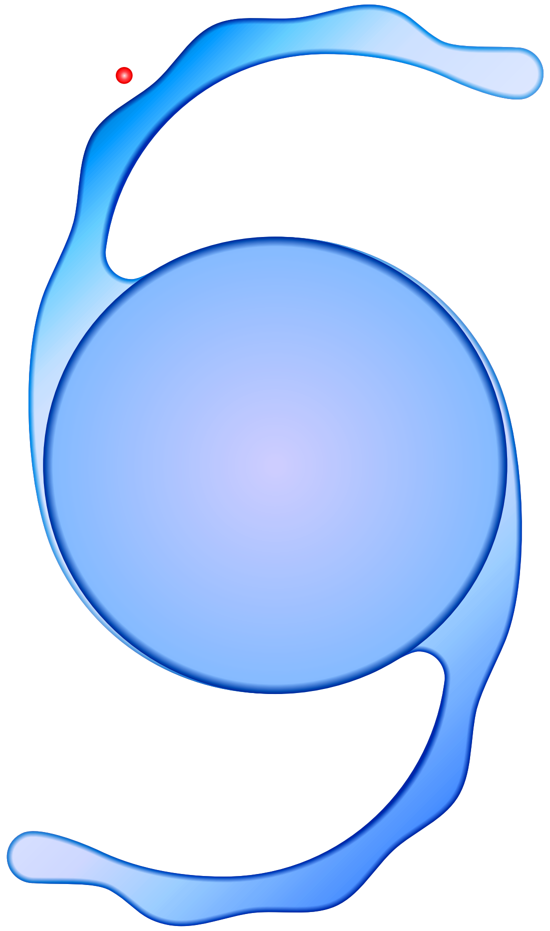


A clear vision: using hydrogels to improve cataract surgery outcomes



Dr Tina Sabel and her team in the 'Nanopatterned Biomaterials' group at Technische Universität Berlin focus their research efforts on novel photosensitive materials. These materials have multiple possible applications but Dr Sabel's current research has the potential to assist millions of people suffering from cataract.

Cataract is the predominant cause of vision loss in people over 40 years old. Typically associated with ageing, the lens of the eye becomes cloudy leading to a loss of acuity of vision.

A normal healthy eye has a lens that consists mostly of water and proteins that are arranged to keep the lens clear and functional – all light can pass through the pupil and reach the optical nerve. However, as people age, portions of the proteins in the lens congregate and clump together, thus triggering the formation of a cloud-like condition over a small area of the lens. This opacity eventually spreads to adjacent fibre cells and results in a slow but profound deterioration of the individual's vision. Treatment usually involves surgery, especially in cases where vision has been seriously compromised; the clouded lens is removed and is replaced by an intraocular lens.

THE ROLE OF INTRAOCULAR LENSES

Intraocular lenses (IOLs) are artificial lenses that are typically used to replace a cloudy lens following cataract surgery. When the natural lens is removed, the eye's ability to focus is lost and the IOL replaces the lens, restoring vision. The first series of successful IOLs were made of polymethylmethacrylate (PMMA) – a very commonly used thermoplastic polymer – owing to its high transparency and biocompatibility with human tissue (it was not attacked and rejected by the immune system). Early versions of IOLs were not as flexible as a biological lens meaning that, while they improved vision, they did not restore it to pre-cataract acuity. The latest technological advancements, however, have allowed IOLs to become far more pliable, stable and compatible within their biological environment, and thus solve a variety of visual problems.

CHALLENGES OF IOLS

Since the beginning of the 1980s, folded IOLs made from silicone have been used because they allow minimally invasive surgery. However, these folded IOLs were subject to a gradual loss of accommodation (the process by which the eye adapts its optical power to focus on subjects at various distances) and so multifocal IOLs were introduced in the beginning of the 1990s. Yet, these novel biomaterials did not manage to limit the degree of induced photic phenomena such as 'halos' or glare around observed objects. Even the latest generation of IOLs that exhibit reduced photic phenomena and consist of ultra-flat, bifocal IOLs with diffractive–refractive optics still exhibit persistent problems such as post-operative calcification and secondary cataract. Innovative research is needed in order to overcome such problems and introduce IOLs that have enhanced functionality and give patients a greater degree of freedom.

A NOVEL APPROACH

It comes as no surprise that there is still plenty of room for improvement and one area that is particularly promising is the development of IOLs that can operate by means of 'function by structure'. This means IOLs made of novel biomaterials whose structure can be custom designed in order to fit the optical and mechanical challenges in terms of their respective surface and volume properties. In other words, if we could allow for the transfer of optical functionality (e.g., the ability to give visual ►

The functionality of the 3D patterned hydrogel implant has the capacity to come as close as possible to the desired functionality of the young natural eye lens

acuity) into the IOL volume, this would give greater freedom in the design of the geometric shape (e.g., to allow for easier insertion) and the option to separately use the surface in terms of a specific interaction with the biological environment (e.g., to ensure it is long-lasting and elicits no immune response). This is where Dr Sabel's work unfolds its novel approach.

With a background in Physics, but working in the Chemistry department, Dr Sabel's research focuses on photosensitive polymers for holographic and photolithographic applications, specifically, the implementation of three-dimensional patterned hydrogels for IOLs. Using these new materials could overcome the limitations of existing IOLs such as the long-term preservation and/or restoration of accommodation.

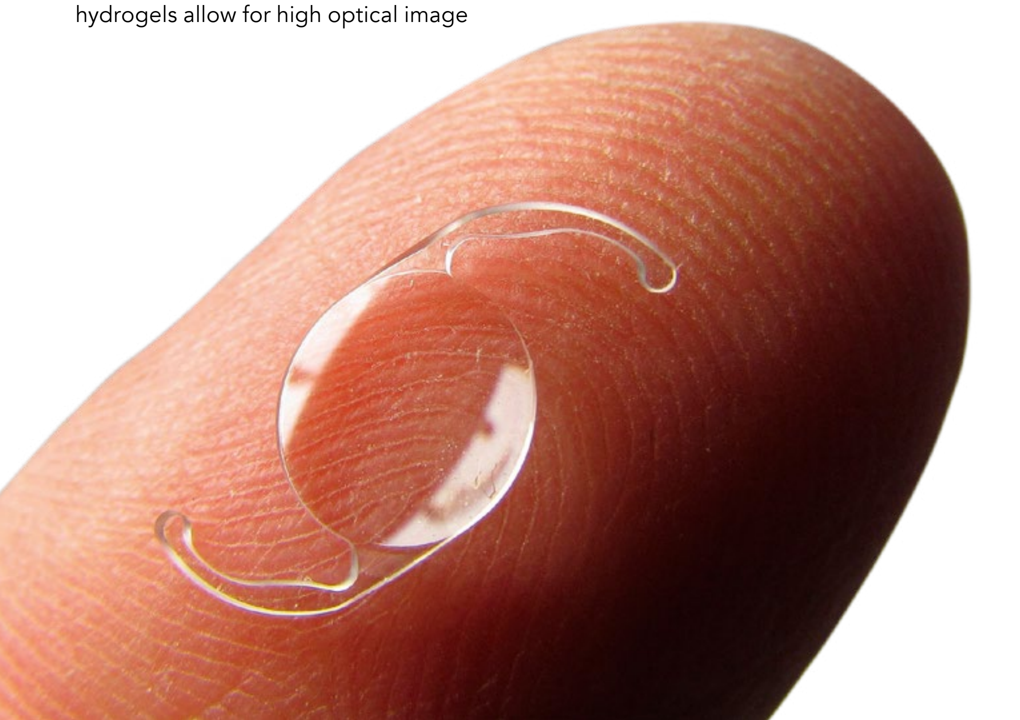
Such photosensitive biomaterials can be optically patterned by means of photo-induced crosslinking and by means of volume holographic structuration – where a pattern is recorded inside a volume of light-sensitive material and the consequent hologram is reconstructed by one of the recording waves. This process allows for optical structuration in three dimensions through the entire volume of a photosensitive material, thus allowing for three-dimensional optical structure within the bulk (by means of diffraction) and two-dimensional topographic patterns on the surface (interaction with the biological environment).

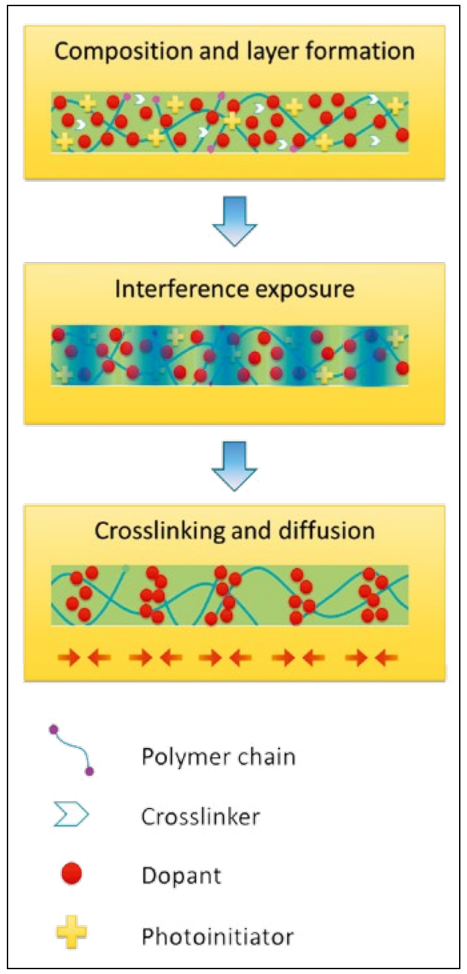
ADVANTAGES OF SUCH AN APPROACH

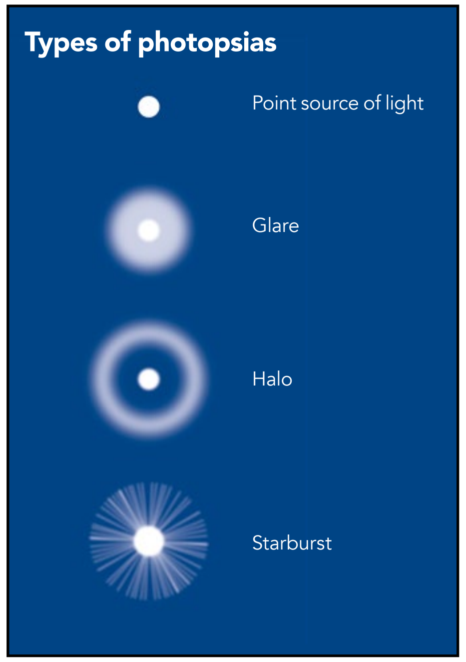
There are profound advantages when using such materials for IOLs, especially when it comes to clinical situations. 3D patterned hydrogels allow for high optical image quality, significantly decreased photic phenomena and high mechanical flexibility. However, and most importantly, the functionality of the implant has the capacity to come as close as possible to the desired functionality of the young natural eye lens. Furthermore, such a novel approach has the capacity to effectively prevent issues such as the opacification and calcification of the IOL, based on the transfer of optical functionality from the surface into the volume of the IOL implant.

Looking to the future, Dr Sabel's investigations regarding the integration of 3D patterned hydrogels for intraocular, function-enhanced lenses have the capacity to offer custom-based solutions to patients undergoing cataract surgery by exploiting the properties of photoresponsive polymers, volume holographic techniques and multifunctional biomaterials.

Cataract is the predominant cause of vision loss in people over 40 years old







Top image illustrates the principle of uv-curable polymer for 3D optical patterning.
Bottom image shows the three different types of photopsia or light distortion.
Left image is an example of an intraocular lens implant. Frank C. Müller [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

Q&A

What is your motivation behind working in such a well-examined field?

My motivation is to look at things with fresh eyes and without prejudice. It is exciting to work in such an interdisciplinary field and on a project that requires basic research while at the same time having such a concrete application for the benefit of many people. It is also quite a challenge to merge several well-examined fields for the opening up of this novel application for volume holography.

What exactly is volume holography and how does it work?

In general, volume holography allows us to store and restore complex information in a purely optical way. More specifically, a hologram is written into the volume of a photosensitive material by interference laser exposure in the sub-second range. No development or other post-exposure treatment is needed. The resulting micropattern can also be observed by optical microscopy. Finally, a volume hologram fulfils its function by diffracting light in a pre-defined way. This function can also be to focus light. Therefore, a volume hologram can operate as a lens, while at the same time it is very flat, light and flexible.

Looking to the future: Will 3D patterned hydrogels for intraocular, function-enhanced lenses ultimately substitute the existing lenses used following cataract surgery?

Yes, if the transfer of optical functionality into the IOL volume succeeds, there is a good chance that such novel 3D patterned IOLs will be a convincing substitute with advantages regarding optical functionality and biocompatibility and maybe also the ability to allow for accommodation. It could also be crucial that volume holography has the potential to allow for the fabrication of superior performance IOLs with highest precision and low cost.

Can this technique prevent the calcification of the IOL even after 10–20 years?

I believe this is possible. One of the main benefits we expect from the transfer of optical functionality into the IOL volume is the resulting free surface of the IOL implant. We know that the surface topography crucially impacts how cells behave on a certain biomaterial surface. A different surface topography on one and the same material can determine if cells do adhere and spread or if the surface appears to be anti-adhesive. Against this background, we consider the free surface of an IOL implant as a significant opportunity to improve the interaction with the biological tissue of the eye.

What are your primary targets regarding this novel technique in the next five years? E.g., designing prototypes, etc.

The first goal is to compose and optimise the hydrogel mixture for the 3D optical structuring. Therefore, it is necessary to investigate the impact of individual components on the complex process of 3D optical patterning. Secondly, we are curious to study the cellular response on the 3D and surface patterns, respectively, in order to estimate the interaction with biological tissue. Based on those basic investigations we are indeed working towards a real application, including the design of prototypes.

My motivation is to look at things with fresh eyes and without prejudice

Detail

RESEARCH OBJECTIVES

Dr Sabel's team in the department of chemistry in Technische Universität Berlin, is currently performing pioneering research in the field of novel materials that can be used to create intraocular lenses.

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BIO

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