# FAST FORWARD FROM MACRO TO MICRO

## NANOMATERIALS IN HERITAGE BUILDINGS

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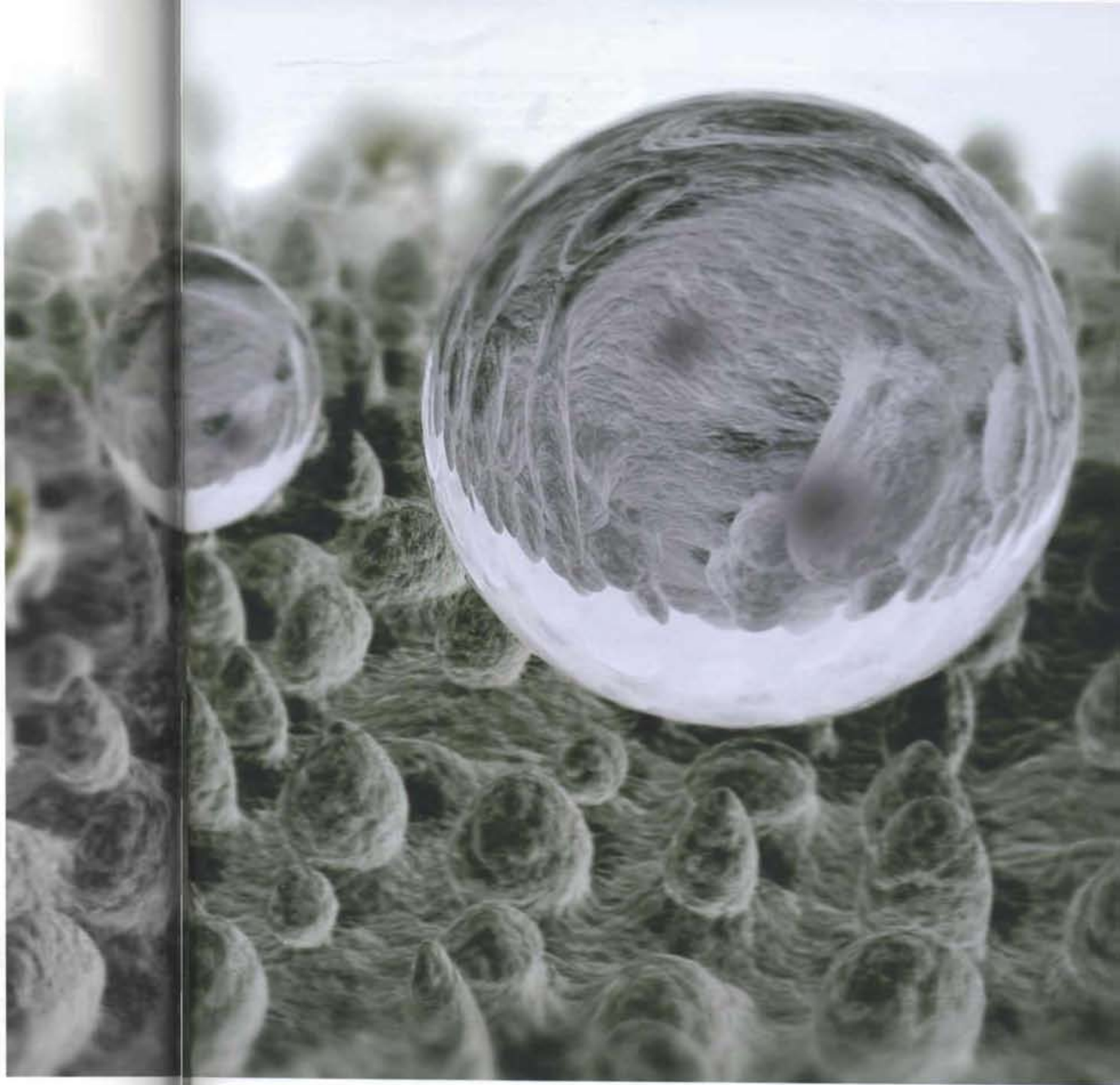
Historic monuments, old building structures and innovative nanomaterials harmonize well with one another. At first glance this may seem an unlikely combination, but on closer inspection it becomes clear that it offers promising potential:

Old buildings are not necessarily "old" in a negative sense, as in old and dilapidated. They are not blots on the landscape and they do not blight our cities. Likewise, their inhabitants do not see them as a troublesome burden. As a legacy of the past and a part of our cultural heritage they are highly prized and worth protecting. In most cases they have a distinctive charm, whether they are burgher's houses with ornamental stuccowork from the turn of the last century, colossal factory complexes from the industrial age, humble half-timbered buildings from medieval times or castles of the nobility. As historic monuments of their time, they are part of living history and as such are irreplaceable and valuable. While we have an obligation to conserve history, this does not have to be backwards-looking, a dogmatic preservation of tradition isolated from the here and now. Instead we need to integrate these buildings into the future. For a building to remain useful in the future, it must adapt – to the transformations of time and to the changes that new habits and ways of living bring with them. Adaptability



is the key to ensuring that a building continues to be filled with life and not merely that it survives over time as a museum. This means not just adapting to changing uses but also that we should be open to employing the useful properties of innovative building materials 'where they are appropriate'. What is particularly interesting in this context is the resulting symbiosis of tradition and innovation, of a historical legacy and forward-looking perspective.

The question is, of course, what does 'where appropriate' mean and where exactly does this apply? For this we need to get to the heart of the matter, both figuratively and literally, by looking at the actual building substance. In order to adequately work with and respect the essential qualities of a historical building, we first need to examine and reliably secure the original building substance. Very often, where buildings are converted, renovated, restored or revitalized, building works are first undertaken to remove building substance, for example from previous alterations. The remaining structures and building elements have endured the passage of time and retained their stability, and at the time of their construction must have represented the state of the art of construction and building technology. Measured surveys, damage appraisals and sometimes also archaeological investigations document the history and genesis of the entire building ensemble, of its parts and of the individual components that together make up the building. These investigations uncover hidden structures: rhythmic patterns of roof trusses made of steel or wood, foundations made of rough-hewn stone on which brickwork walls or irregular timber-frame structures stand as well as delicate surface finishes and stucco elements or wall and ceiling murals, all of which must be documented and surveyed. The building's proportions are also a key characteristic as they are defined by the available building technology and the materials chosen for their construction. In the past, as today, the loadbearing capacity of a structure and the accompanying room spans were dictated by the technical possibilities of the day. All of these analyses are concerned with the coarse structure of the building, with its macrostructures. And this is the point – when the original substance of the building has been exposed and tells its story and when new building elements are about to be inserted – 'where it is appropriate' to consider new concepts and approaches to construction that combine traditional building methods and historic building materials with new constructions and innovative materials created as a product of high-tech processes: where we have the potential to achieve an inspired and entirely contemporary combination of macrostructures and microstructures. Today, as in the past, the use of forward-looking building technology not only has its purposes but can also contribute through a play of contrasts to the building's design. A space-age addition to a medieval ensemble, to use an exaggerated example, may at first seem a striking and perhaps discordant contrast but on closer inspection could be an ideal pair in which the innovations of each time are made legible. Today, as in the past and in the future, this is also our chance to use innovative materials and new developments to help buildings continue to exist sustainably in the future. Sustainability is not just about finding new uses for buildings to ensure their survival or about improving their energy performance; it is also about respecting the aesthetics of its function and associated characteristics such as the form and proportion of the building and the impression and proportions of the spaces it contains. This is where, through nanotechnology, microstructures offer possibilities for fulfilling all the above criteria and requirements and thus can be of use in historic buildings – for example in the form of vacuum insulation panels, aerogel-filled glazing panels, phase change materials and photo-catalytic self-cleansing surfaces. It is, of course, a balancing act: we don't want to eliminate the much-loved patina of the traces of the building's past and we still want to be able to see the age of a building at first glance. But surely we can still achieve more, and if so, of what? Of history or the space age? It would seem that there is as much a need to achieve a harmonious interaction between new and old and to adapt buildings to changing uses as there is a need to make intelligent use of energy without impacting on the specific character of the building. This will be essential for all buildings in future and that means that energy-efficient historic monuments that retain their unique character should no longer be an exception but the rule.



Urban visions between old and new, Paris, France

Continuing this chain of thought, the question arises as to how the preserved patina of the past and the new patina of today's innovative materials could look in future, and how they will look together. It would seem that the only true way would be to use the best technologies and products available in the respective time in order to most effectively ensure that existing buildings and historic monuments last into the future.

Amidst their newer contexts, historic monuments exude a charm and character that contrasts with their surroundings, creating a stimulating tension. The natural deterioration of a building in the past shows us which building elements are most durable and re-usable, and which of them are most able to be used in combination with new materials for the future – in terms of their function, construction, and also aesthetics. Something uniquely new arises in which technological microstructures in the form of innovative nanotechnology products offering a range of diverse functions exist in symbiosis with traditional static macrostructures. This opens up a range of ever-new and inspiring possibilities that offer diverse, many-faceted and, above all, legible ways of combining the macro and micro in a building and that can be individually applied at different scales, whether for historic building ensembles or complex, historical urban constellations. Nevertheless, there are certainly situations in both macro and microstructures in which traditional approaches are more appropriate than innovation, and where reconstruction is the more appropriate path.

The use of nanotechnological materials on their own is just the beginning of this new technological revolution; the use of nanomaterials in existing buildings and historic monuments represents a much more diverse and multi-layered revolution in the way we design buildings. The development of new materials and functional surface coatings will in future have a considerable impact on working with existing buildings, and especially in the realm of the conversion and renovation of historic buildings. The way in which we build and what we build will be influenced significantly. In order to achieve forward-looking and pioneering work in the realm of existing buildings, interior designers

Modern housing will be the future's heritage, Hong Kong

and architects will need to expand their horizons and rethink how they approach the subject of historic building conservation. Without embracing technological advancements there will be no progress. And that has always been the case: for as long as we have been building, we have developed ever more advanced building methods, constructions and materials – from locally-available and natural-occurring materials such as stone, wood or plant fibers to high-tech and smart materials. Materials based on nanotechnology are the product of one of the key technologies of the 21st century and as such definitively part of the future. As with all new technologies, the benefits and dangers need to be weighed up because the opportunities it presents are too attractive to be ignored. The primary reason for employing nanomaterials is their contribution to energy-efficiency. Other promising reasons are the reduced consumption of resources and better sustainability, not to mention the reduced cost of the ongoing maintenance of buildings (a primary motivator). In the construction sector, innovations are slow to be adopted in practice, and when they are, then typically for new buildings. Existing buildings are not generally the focus of innovations, and historic monuments even less so. But it is in precisely this area that there will be greater demand in future: in technological terms these buildings are falling behind and becoming less and less attractive – however charming they may be – for investors, owners and building operators. The future, however, has a solution for this dilemma that is already available today: while their full potential for architecture in general has yet to be fully explored, in the context of the macrostructures of historic buildings, for example solid, structurally-sound oak beam constructions or rough-hewn stone masonry, the use of dynamic materials whose properties can alter in response to changes in temperature or (air) humidity is potentially game-changing. It represents a significant change in how we perceive and will experience the
legibility of time in historic buildings. The atmosphere of a space as a whole as well as how we experience the parts of an interior will be most special, an encounter of the third kind. A spatial and aesthetic interaction between the ages, the past and the present, as well as between the user and the 'smart material' which, as a product of developments in nanotechnology, possesses extremely fine microstructures that have a protective or insulating capacity. These are just some examples of aspects that not only warrant the coexistence and combination of micro and macrostructures but also stand to enrich the fields of architecture and interior design as a whole and, in the spirit of the historic monument, will keep them alive in more senses than one.

In this context, nanomaterials offer a broad range of functions that, when applied appropriately, have distinct advantages. The currently available spectrum of functions ranges from those that are comparatively well known, such as self-cleaning surfaces, to innovative niche products such as building elements made of carbon. Of all the nanomaterial-based functions that are now available on the market, the most well established is the aforementioned self-cleaning surface treatment, which is now employed around the world. With the help of this invisible layer, it is possible to reduce or even avoid all kinds of dirt and soiling. Hydrophobic, water-repellent surface coatings that employ the so-called Lotus Effect are becoming ever more popular. Although this term is actually a trademark, and thus only actually present in selected products, the name is so memorable that it has become emblematic for nanotechnology as a whole. Natural Lotus



**Merging tradition and future, London**

flower surfaces are micro-rough and their self-cleaning property is a product of their hydrophobicity. Artificial Lotus Effect surfaces function the same way, but are unfortunately susceptible to mechanical abrasion and unlike their cousin in the natural world are not able to heal themselves. Lotus Effect surfaces are often confused with so-called easy-to-clean surfaces that have a reduced surface attraction and, like the Lotus Effect, are hydrophobic, causing water to run off in droplets. Lotus Effect pain ts have been available on the market for more than ten years but are still regarded as innovative and are ideal for use on the façades of historic buildings were water tends to accumulate, such as on the surface of horizontal cornices. In the context of historic monument preservation the use of such paint avoids the need for a sheet metal zinc cornice covering with rainwater drip, which falsifies the original appearance of the building and is not authentic to the original structure. Photocatalytic (semi) self-cleaning surfaces employ a different technique and are able to reduce dirt accumulation by decomposing organic dirt and allowing the loose dirt particles to wash off from its hydrophilic surface on a film of water the next time the surface is wetted. Although none of these surfaces are completely

**Restored half-timbered house of 1728 and its extension, Kreuzau, Germany**

self-cleansing, the cleaning interval can be extended significantly: a coat of façade paint, for example, lasts much longer and needs to be repainted less often. Similarly, glazing remains cleaner for longer, as do roof tiles. Self-cleaning surfaces are therefore an elegant solution for maintaining the well cared-for appearance of historic buildings. Surfaces that are prone to algae formation can also be given an additional anti-bacteria treatment.

With respect to energy-efficiency, historic monuments and many normal existing buildings are generally inadequately insulated. Where buildings are of historical architectural value, one cannot simply follow the general trend of applying thermal matting as insulation to the façades. This approach is not appropriate as it obscures the face of the building and its appearance in the urban context, in short robbing it of its cultural identity. Another approach is to dispense with external insulation completely and to apply insulation on the interior that does not impact on the outer façade. High-performance insulation materials such as vacuum insulation panels (VIPs) are a new option that provides good insulation at very thin thicknesses. Almost ten times thinner than conventional thermal insulation, they take up much less space, leaving more of the interior available as usable and therefore lettable space, which is especially important in cities. Glazing that contains aerogel offers much improved insulation while allowing a soft diffuse light to illuminate the room. Phase Change Materials (PCMs) change their aggregate state from fluid to solid and back and are bound in microcapsules, allowing them to serve as a temperature buffer absorbing heat, as well as vice versa, giving off heat: as such they can be used for both heating and cooling. PCM additives can be found in



**Steel footbridge in a historic barn 1778, Düren, Germany**

plasters, building boards and foamed concrete blocks, all building materials that are already commonly used in the renovation of old buildings. Thermochromic glass reduces the effect of the sun, avoiding the need for blinds, curtains and other added elements. In the field of conservation, thermochromic glass can be used to protect room where direct sunlight can be damaging. Electrochromic glass can also be darkened on demand, and does not require electricity to retain its state. It likewise avoids the need for blinds, but it still requires an intervention in the building substance during installation. Anti-fingerprint surfaces can be applied to glass or stainless steel and significantly reduce the visibility of fingerprints. Many historic buildings are repeatedly sprayed with graffiti and are constantly being cleaned. Conventional protective coatings function as a sacrificial layer that needs to be removed. A disadvantage is that they are not vapor permeable, preventing the building from giving off moisture as it should. Nanomaterial-based anti-graffiti coatings on the other hand provide the necessary protection and are simultaneously vapor-permeable, preserving the characteristics of the building substance. Hydrophobic coatings for historic buildings frontages made of brick or wood are a further way of improving the durability of exposed building elements. Other interesting applications using conductive coatings and lighting will become available in the future. Currently, effect-pigments and dichroitic surfaces can be used to dynamically change the appearance of surfaces. Super lightweight and strong materials such as Ultra-High-Performance-Concrete (UHPC) and carbon building elements offer potential for building very slender new constructions, which have potential for use in the extensions to existing buildings. In addition to the aforementioned functions, a range of further innovations are expected to be make their way from the realm of the science community to industry and the market place, fuelled by enlightened designers, architects and clients. The undertaking of applied research and the transferal of findings into market-ready products are therefore beneficial from both a constructional and aesthetic perspective.

Buildings that have stood the test of time and are today regarded as historic monuments were typically state-of-the-art examples of the outstanding technology of their day. By the same means, the modern-day renovation and conversion of historic buildings should ideally adhere to the same principle, employing the most innovative construction methods in the interest of preserving such monuments for the future. Then as now, the building construction and its later renovation are innovative examples of the best of what is possible at the respective time. Sooner or later both will be recede into the past – it is just a matter of time until the apparent contradictions have merged into a harmonious whole.

**Laser cut steel stair in a half timbered house 1728, Kreuzau, Germany**