SCIENTIFIC REPORT

Nano-technology

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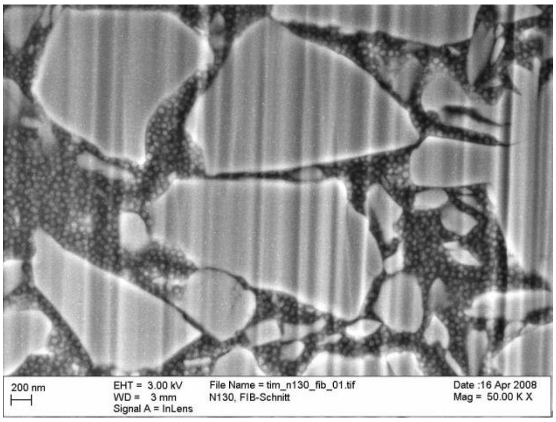


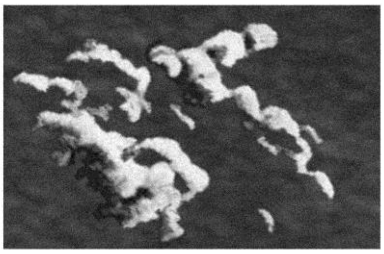
VOCO offers a multitude of products that contain nano-scaled fillers, e.g. the products in the Grandio and Futurabond families. What does integration of nano-technology mean and which properties are imparted to the materials by these special fillers?

Nano is the mathematical prefix for the order of magnitude below "micro" (1 µm = 1000 nm). It is not, however, a protected term. Anyone can call anything "nano". If it simply concerned a new designation, then nano-technology could hardly be regarded as one of the pivotal technologies of the 21st century [1].

The size comparison of a nano-particle to a soccer ball is the same as a soccer ball to the earth. The diameter of a nano-particle corresponds to ca. 500 atoms. Biologically, a nano-particle corresponds to the dimension of the smallest bacterial and/or the largest known enzyme.

A nano-particle is commonly identified as a particle with a diameter of 10-100 nm; thus, just below the wavelength of visible light. [2] A defining boundary for what "nano" is and is not is unnecessary. The unusual properties of nano-scaled materials automatically deliver this classification and speak for themselves: Nano-scaled metal becomes a semiconductor or pigment, ceramic becomes clear, glass becomes an adhesive and much more.

The main reason that this key technology has permeated a list of application ranges only in the last few years, is that the dimension is technically difficult to access. Construction in nano-dimension was previously a domain of nature. In principle, two strategies are technically possible. The first, the "top down" strategy, consists of reducing the size of larger particles by, for example, grinding and sifting. The second, the "bottom-up" strategy, describes the development of nano-particles starting from atoms or molecules, with controlled sol-gel crystallization or flame pyrolysis. Both possible strategies present a physical problem: agglomerization.



Agglomerated nano-particles from the flame pyrolysis do not exhibit the properties of isolated nano-particles.

Nano-particles have a quite large surface in comparison to their volume and therewith, higher surface energies. Untreated, they immediately agglutinate to the usual micro-particles of ca. 0.5 µm (500 nm) in diameter and lose the phenomenal properties of the original nano-particles. It is therefore necessary to chemically inactivate the surface of freshly generated nano-particles in order to enable their isolation. Their special properties can only be used in this way.

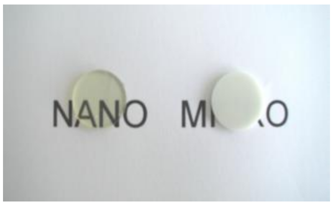
One of the special properties of nano-particles is their effect on the viscosity of ambient liquid. On the basis of the properties of micro-particles, one would expect that an extremely viscous mass develops with nano-particles that cannot be processed, due to the repeated, drastic increase in the surface. Amazingly, the isolated nano-particles do not behave like a solid when embedded in a resin matrix, but rather like a liquid.

While a mixture of micro-fillers with resin yields a sticky, thick mass, the same filler content with real nano-particles is liquid like oil. Flowable composites with over 80 % filler content can also be manufactured on this basis.

This special property of nano-fillers facilitates a never before achieved filler content of 87 % in composites. Grandio, the nano-hybrid composite, exhibits shrinkage of only 1.57 % through the use of nano-fillers. Moreover, the nano-particles create a network effect within the matrix that increases tensile strength, edge stability and abrasion resistance.

A further phenomenon that contributes to aesthetic dental restoratives is the translucency of disperse nano-particles. Since the particles are smaller than the wavelength of visible light, absorption does not occur and light shines through them as it does through glass.

On the right: a resin with 38% micro-filler yields a fissured mass. On the left: the same resin with 40% nano-filler remains a liquid.



A polymer filled with nano-particles is clear and translucent, where one filled with macro-fillers is opaque.

Since a higher filler content, good integration and a limited amount of shrinkage can be achieved through nano-technology, additional properties, such as opacity, tackiness and flow characteristics of the composite can be adjusted without technical compromises by varying the micro-fillers. The handling properties thus can be optimised on demand and the material can be processed faster and safer.

The employment of nano-technology as part of the material concept thus effectuates high physical strength, decreased shrinkage, improved aesthetics and simultaneously enables the requirements for consistency and handling to be met.

Is nanotechnology dangerous?

Three are always two factors involved in a possible risk from nano-particles. One factor to consider is the chemical composition, especially if toxic materials are involved. The other factor here is how and whether these particles can be released from the preparation; thus how their mobility should be rated. If only one of the hazard requirements of toxicity and mobility is not met, then the potential for damaging effects to the health from dental restorative material is sufficiently implausible.

Evaluation of the mobility

The nano-scaled fillers in Grandio are imbedded in the plastic-resin matrix and not present as airborne dusts or aerosols, as are found in sprays. Ultimately, the nano-particles are covalently bonded to the resin when polymerised with light, i.e. they are polymerised to substantially larger molecules. There are thus no more existing, isolated nano-particles in the placed filling after polymerisation.

Even the grinding dust from Grandio during finishing does not differ from the grinding dust from micro-composites. Nano-particles, however, are always found in the grinding dust from hard materials; thus, even with the polishing and finishing of metal, ceramic or a real tooth. As a rule of thumb, it can be considered that the harder the material is, the finer the grinding dust will be. Grinding should be conducted under water, especially when it comes to grinding tooth enamel and ceramic; not only for heat transmission reasons, but also to bind the dust.

Evaluation of the toxicology

The nano-particles in Grandio are comprised of pharmaceutical, pure silicon dioxide (quartz), the main component of nearly all glasses and natural minerals. Silicon dioxide is nontoxic and used as the negative standard in toxicological analyses. Biologically, nano-scaled silicon dioxide appears in some living organisms as a cytoskeleton (diatoms, radiolarians). Apart from its use as a remedy in the form of healing crystals, healing earth or dietary supplements, its effectiveness is scientifically questionable. It is found (E 551) in numerous foods, in addition to objects of daily use, such as drinking glasses and bottles.

Nano-particles in Grandio are neither toxic nor mobile. Thus there is no risk from it. Since the material was the first type of dental filling material in this range, numerous tests were conducted as a precaution by a certified, independent laboratory. As anticipated, Grandio was unremarkable and classified as toxicologically safe. Several million fillings have been placed with Grandio to date and even in the dental surgery there has not been a single case where the material's toxicological safety came into question.

Conclusion: The integration of nano-particles into dental materials imparts these extraordinary physical properties, both in referenced to the stability and durability of the restoration and also the processing of the material. These advantages, however, are only found with the use of "genuine" nano-particles: Everyone can say nano, but not everyone really has it!

[1] Ottersbach P, Schmitz C, Averdung J, Heinrich L, Gutsch A: Von der Höhlenmalerei zur Schlüsseltechnologie. *Chemie in unserer Zeit* 2001; 4: 230-237.
[2] Hollemann, Wiberg, *Lehrbuch der anorganischen Chemie*, 91.-100. Auflage, Walter de Gruyter, Seite 765.