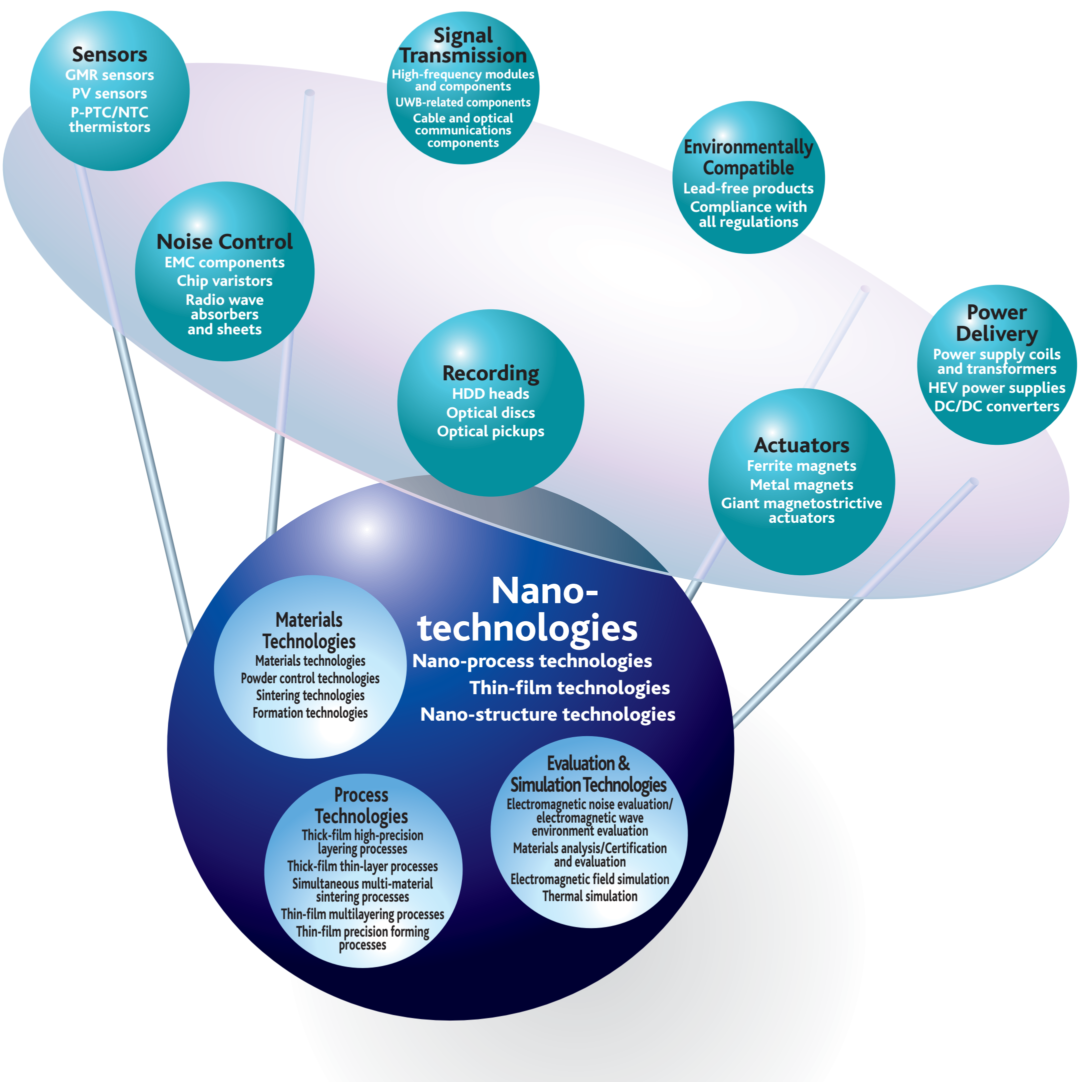
Fusing Core Technologies With Nanotechnology to Accelerate Growth

TDK's Nanotechnology—Creating a New Technology Paradigm

Today, all manner of high-tech fields are embracing the technological concepts and techniques of nanotechnology. This groundbreaking technology is poised to take a major leap forward to an exciting new stage.

The word nanotechnology first appeared in the mass media around 2000. The U.S. was first to position nanotechnology as a strategic research field of national importance with the aim of revitalizing manufacturing industries that were being hollowed out. In Japan, nanotechnology is now regarded as one of four important fields of science alongside IT, biotechnology and the environmental technology.

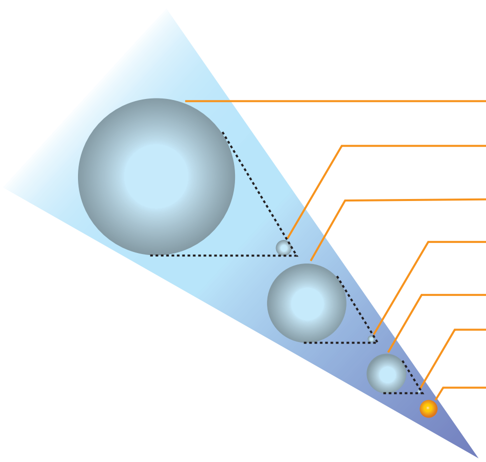
But nanotechnology is not a fleeting trend. Rather, it is a momentous technology paradigm that will define progress over the next century. In the 20th century, electronics emerged as a new technology paradigm straddling the disciplines of physics and engineering. Now, nanotechnology is creating a paradigm that cuts across myriad fields, sweeping aside barriers created by past segmentation and specialization. Nanotechnology has two contrasting aspects. On the one hand, it is a microscopic technology of the atomic and molecular level. On the other, it is a macroscopic technology with the potential to solve environmental and energy problems on a world scale. Nanotechnology may even have the potential of bringing about innovations even more radical than those sparked by the industrial revolution. Long an innovator in materials, TDK is determined to make nanotechnology an even greater driving force of its own growth.



The development of new products and technologies imbuing value that anticipate market needs drives growth in manufacturing industries. Aiming to be a consummate e-material solution provider, TDK is improving and bolstering its organizational structure. Guiding these activities is the catchphrase "Join all our forces together and strengthen the growth power."

Value-added products that are competitive in the international arena are not developed overnight. They are borne of sophisticated technologies created over many years. One of TDK's greatest strengths is its expertise in three core technologies: materials technologies accumulated over many years, and its exclusive process technologies and evaluation & simulation technologies built on this foundation.

Nanotechnology will alter existing technologies as the creative force for new ideas and lateral thinking, serving as the springboard for new breakthroughs. It harbors boundless potential. TDK is determined to unlock this potential to add to its storehouse of core technologies and to develop next-generation technologies and products that were once the stuff of dreams.



Making Core Businesses Even Stronger—The Latest Advances Stemming From TDK's Nanotechnology

TDK aims to use nanotechnologies to refine its wealth of core technologies, which are the cornerstone of the company's businesses, to make these technologies even stronger. TDK's nanotechnologies allow us to capture even greater synergies in fields where we are unrivaled and to innovate for a new tomorrow. This section showcases just some of the latest accomplishments of our new product and technology development efforts.

The Dream of Perpendicular Recording Technologies Comes to Life in TDK's HDD Heads

Today, HDDs are found in an increasing array of digital home appliances other than computers, such as HDD/DVD players, digital audio equipment and car navigation systems. Incorporating a variety of nanotechnologies, HDDs are a cutting-edge technology. Rapid advances are being made in raising the recording capacity of HDDs while making them more compact. This progress will increasingly see HDDs become a common feature in mobile phones and other mobile devices.

TDK manufactures magnetic heads, vital components of HDDs. In fact, we are the world's leading head supplier, commanding a global market share of 30%. As the preeminent company in the field, we have opened up new technological frontiers in magnetic HDD heads. Some of our many accomplishments include development of thin-film magnetic heads replace of bulk heads, MR heads that make use of the magneto-resistive (MR) effect, and the even more advanced Giant-MR (GMR) and tunneling-MR (TMR) heads.

TDK's leading-edge nanotechnology continues to create breakthroughs in HDD head technology. Perpendicular magnetic recording (PMR) heads that transcend the boundaries of longitudinal recording are a case in point. This is a development much awaited by the industry.

Perpendicular magnetic recording was first proposed as a theoretical possibility in the 1970s. However, the complexity of this high-density magnetic recording technology prevented its commercial development by manufacturers the world over. This method demands highly sophisticated thin-film process technologies to form microscopic single poles between multiple thin layers. Beyond that, a number of complex issues arise when trying to miniaturize single poles. One particularly difficult problem is overcoming pole erasure, the deletion of magnetic data due to remanent magnetization at the tip of the pole.

Drawing on its nano-level thin-film multilayering and processing technologies and other skills, TDK has cleared the innumerable technological hurdles one by one. By incorporating original ideas in the shape of the head pole, its materials, the shield structure and other areas, TDK solved the vexing problem of pole erasure. This achievement enabled TDK to win the global race to establish technology for mass producing PMR heads (for recording) that boast a high signal/noise ratio and outstanding reliability. In 2004, TDK achieved an areal recording density of 133Gbpsi (Giga bit per square inch) with a GMR/PMR head. This combination GMR head (for playback) and PMR head has already proven its reliability in HDDs. Adding to these successes, a TDK-developed TMR/PMR head that incorporates a next-generation TMR head (for playback) has achieved an areal recording density of over 150Gbpsi.

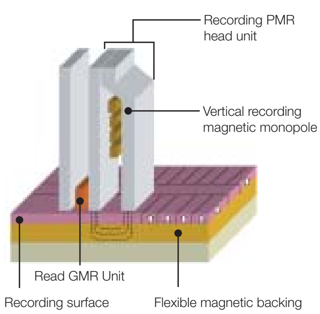
By providing a way to make HDDs much smaller and dramatically raise areal recording density, the PMR head has opened up the possibility that one day, in the not too distant future, people will watch videos on their mobile phones. This will redefine forever the role of mobile devices in our lives.

Targeting the upcoming terabit age (1Tbpsi=1,000Gbpsi), TDK is now taking up the challenge of developing groundbreaking technologies that will lead to more innovation in magnetic recording.

Gbpsi (Giga bit per square inch): A measure of recording capacity per square inch.
GMR (Giant Magnetoresistive) heads: The most commonly type of magnetic heads currently used in hard disk drives.
TMR (Tunneling Magnetoresistive) heads: A type of read head with higher sensitivity and resolution than GMR heads.
PMR (Perpendicular Magnetic Recording): A method of magnetizing recording elements in the direction of the thickness of the recording layer. PMR is expected to achieve much higher recording densities than the longitudinal magnetic recording currently in use.

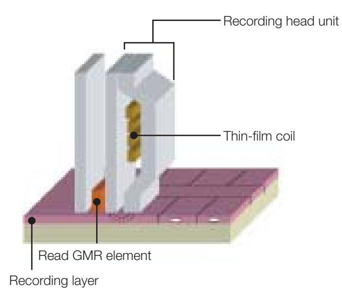
Comparison of PMR and LMR Recording Methods

Perpendicular Magnetic Recording (PMR)



The magnetic field generated by the monopole forms a U-shaped magnetic path that goes through the flexible magnetic backing, and the magnetic field that goes through the recording layer is used, making perpendicular magnetic recording possible.

Longitudinal Magnetic Recording (LMR)



The LMR recording method uses magnetic field that leaks between a gap in the recording heads. The magnetic field passes through the interior of the recording layer in the shape of a circular arc, so longitudinal magnetic recording is parallel to the recording surface.

The Industry's Long Wait Is Almost Over—Discrete Track Media Promises to Open Up the Terabit Era

Moore's Law holds that transistor density in integrated circuits will increase at an annual rate of 50%. Since the mid-1990s, the annual rate of increase in the areal recording density of HDDs has been 100%, outpacing Moore's Law.

However, magnetic interference from adjacent tracks grows as recording tracks become narrower. Another problem is "thermal fluctuation"* caused by the microscopic size of the crystals of magnetic material in the top layer. Discrete track media eliminates these problems. This epoch-making technology physically separates recording tracks by forming minute grooves in the recording layer, thereby reducing the magnetic interference from adjacent tracks. This opens the possibility of a dramatic leap forward in surface recording density.

At TDK, we study magnetic recording media in parallel with the development of magnetic heads. Discrete track media is one of the products of this cooperative research effort. In developing this media, we employed electron-beam (EB) lithography to achieve nanometer-order control, as well as precision dry-etching processing, proprietary surface planarizing technology and other state-of-the-art nanotechnologies. With a track pitch of 90nm achieved through ultra-fine processing, this next-generation magnetic recording media makes possible a surface recording density of over 200Gbpsi.

The development of new products before markets for those products emerge is a driving force behind TDK's growth. We are determined to build on our overwhelming competitive edge in magnetic head technology. At the same time, we will vigorously pursue research at the vanguard of the industry, namely discrete bit media and the application of spintronics, to make possible even higher density recording.

*Thermal fluctuation: Refers to the change in magnet polarization of the microscopic magnets that form the magnetic layer due to fluctuations in ambient temperature, even at room temperature. This causes data errors in HDDs.

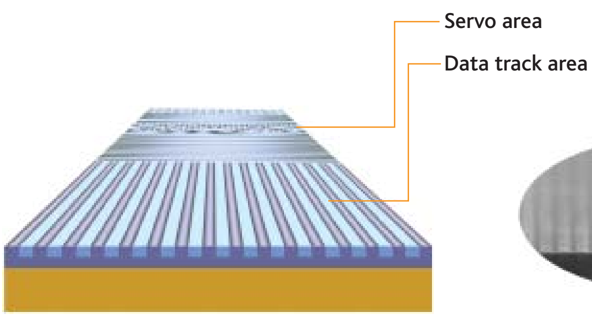
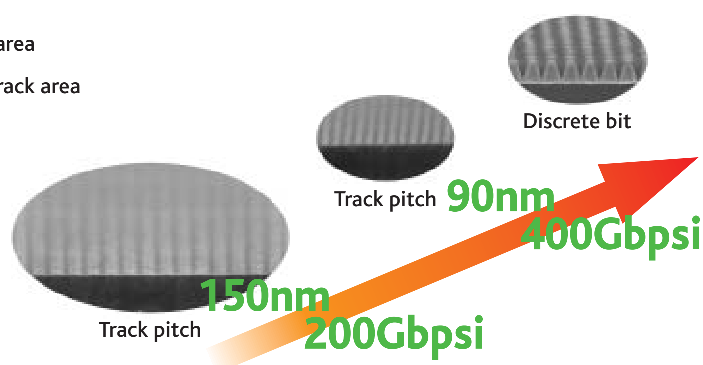


Diagram of discrete track media with a track pitch of a mere 90nm



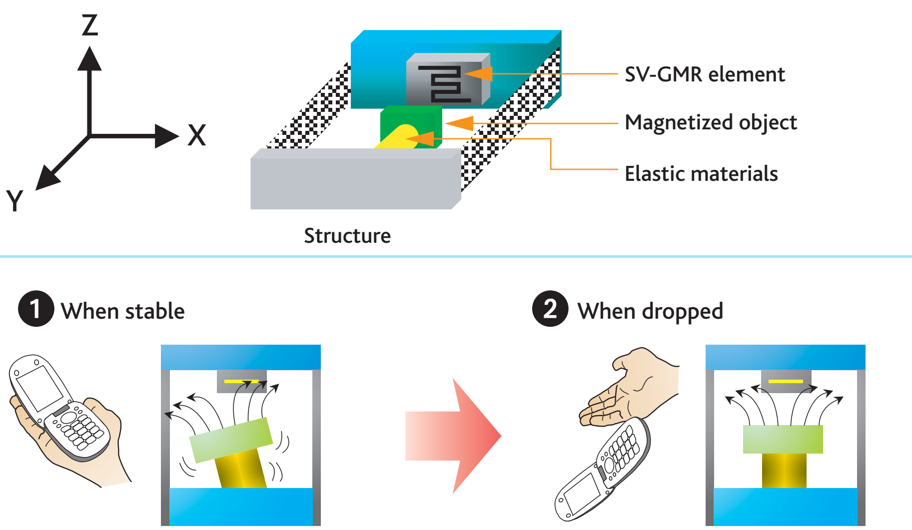
Discrete bit media, the next stage of progress after discrete track media, will enable a surface recording density of 400Gbpsi

Highly Sensitive Sensors Applying Magnetic Head Technology—GMR Sensor/Drop Sensor

The GMR sensor is a newly developed magnetic sensor that combines GMR head technologies, TDK's thin-film and nano-process technologies. Due to the compact size and ultra-high sensitivity of this sensor, researchers looked beyond rotation and angle sensors to explore applications such as current sensors in automobiles and robots and bio sensors that detect antibodies in blood.

Another possibility is making multi-GMR chips by lining up many GMR elements on a substrate. These chips are attracting attention as a new type of highly sensitive magnetic sensor with almost unlimited applications. One possible application is as a line sensor for non-destructive surface testing to detect metal defects in aircraft, nuclear power plants, chemical plants and other plants and machinery.

More and more HDDs are used in mobile devices thanks to progress in the miniaturization of these drives. An example of a pioneering application of the GMR sensor, this unique, compact sensor combines GMR elements and tiny magnets. The sensor can quickly detect the falling motion of a mobile phone or other device, such as when it is accidentally dropped, and automatically retracts the magnetic head before impact, protecting the HDD from damage. TDK's drop sensor can immediately detect motion along three axes (X-Y-Z). In addition, its ultra-compact profile enables it to be placed directly inside a HDD.



The principle of the drop sensor: Instant detection of a free fall to protect the HDD.

Nanomaterials Make Multilayer Ceramic Chip Capacitors Smaller While Raising Capacitance

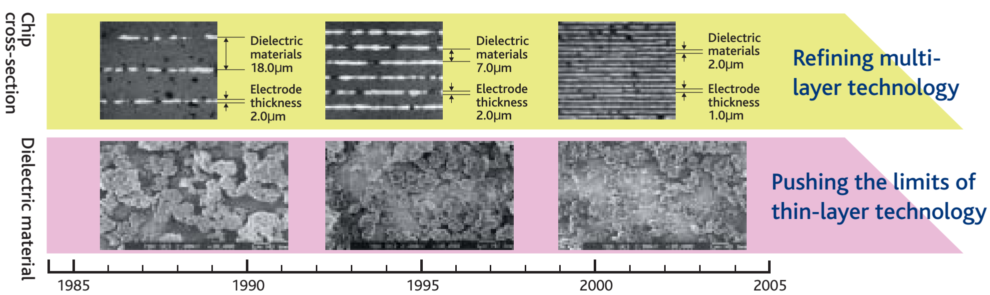
Since many multilayer ceramic chip capacitors are used in mobile devices, making capacitors smaller is vital to reducing the size of these devices. Applying nano-material technologies to its wealth of fine multilayering technologies, TDK is exploring ways to make dielectric material sheets and internal electrodes that are even thinner. These efforts culminated in the development of a 3216-size (3.2x1.6mm) high-capacitance 100μF capacitor.

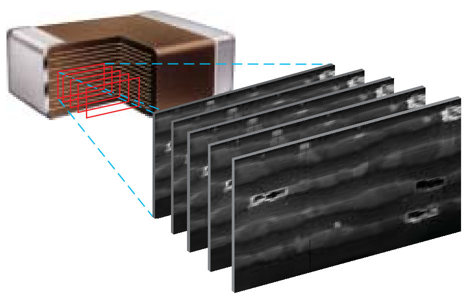
TDK has almost completed development of manufacturing technology for 2012-size (2.0x1.2mm) 100μF multilayer ceramic chip capacitors by drawing on a host of new technologies. These include newly developed high-precision screen technologies, revolutionary irregularity elimination technologies for press formation, and technology that can gently peel off even ultra-thin 1-micron sheets of dielectric materials with no damage.

When the gap between layers of a multilayer ceramic chip capacitor falls below 1 micron (μm), the particle size of barium titanate, a dielectric material, must be smaller than 100 nanometers, a feat that requires highly sophisticated powder technology. TDK has developed titanium oxide barium nano-particles that enable the formation of even thinner layers. Now TDK is applying high-quality nickel alloy high dispersion slurry technology, dry-electrode lithography processes and other techniques, as it takes up the challenge of advancing capacitor technology to uncharted territory. We plan to reduce the size of capacitors from 0402 to 0201 and then 01005. Another goal is making a chip capacitor with 1,000 layers, which would raise capacitance to level of an aluminum electrolytic capacitor.

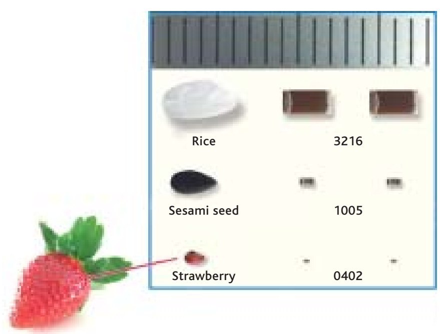
TDK is determined to adopt advanced nanotechnologies to drive new advances in its powerful fine multilayering technologies.

Advances in the miniaturization of dielectric materials and multilayering have reduced the gap between layers to under 1 micron (μm).





A composite 3D image based on a two-dimensional image



Shown here, in actual size, is the smallest multilayer ceramic chip capacitor on the market today. Now TDK is developing manufacturing technology to reduce the size from 0402 (pictured here) to 0201 and then 01005.

In this section, we showcased a few of the new products and technologies that highlight TDK's advanced nanotechnologies. Our nanotechnologies are not ideas for products of the near future. They can be found today in a host of electronic components and devices. Nanotechnology will continue to be a key driving force behind advances in TDK's core materials, process and evaluation & simulation technologies.

Nanotechnology is a world harboring boundless potential and a wellspring of myriad applications. TDK is determined to add to its reservoir of nanotechnologies, with the aim of creating a new technology paradigm. Our R&D efforts will be relentless.