COBALT NEWS

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THE COBALT DEVELOPMENT INSTITUTE
167 High Street, Guildford, Surrey, GU1 3AJ, UK
Tel: (0)1483 578877 Fax: (0)1483 573873
e-mail: info@thecdi.com
Website: www.thecdi.com
Editor: D. Weight – Production: I. Porri
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COMMENT

This edition of the Cobalt News marks my first 12-months with the CDI and what a year it has been.

Picking up the reigns on the CDI REACH developments has been a major learning curve for everyone, but I am pleased to say that we have finalised the cobalt REACH Consortium Agreement and have identified at least three Consortia that need to be formed. When the substance lists have been completed, we will make a formal announcement and get on with the job of guiding the cobalt industry through Pre-Registration in the first place and then on through Registration. Please see the accompanying article in the Cobalt News.

Volatility has now become a global phenomenon, spreading across all markets, not only affecting base metal markets, but basically anything else that trades, which would indicate we could be in for some extremely interesting times, as I suspect a number of hedge funds have already discovered! Cobalt is not immune and there is plenty of interest in what is happening with this speciality metal. Availability remains constrained due to the moratorium on the export of raw material from the DRC and demand in China, the global commodity and investment driver, remains buoyant. The statistics in this edition of the Cobalt News show that availability is pretty much the same as this time last year and prices, despite softening in the mid-year holiday season, have quickly snapped back into reality on the back of improved Asian demand.

There is an impressive line-up of new cobalt production projects set to come on stream in the next five years and we await updates on progress with interest.

Information is paramount so don't forget the WBMS/CDI *"World Cobalt Statistics 2004 – 2006"* which can be purchased online at this website or through the office of either the CDI or WBMS.

First Half Production Statistics

Table 1 – CDI First Half Refined Cobalt Production Statistics (Tonnes)

	2000	2001	2002	2003	2004	2005	2006	2007
BHP Billiton	720	1,035	910	920	1,000	900	500	900
Chambishi Metals	893	1,222	2,184	2,541	1,826	1,883	1,643	1,147
CTT	600	600	620	500	650	824	709	742
CVRD/Inco	780	830	790	517	750	817	919	1,065
Eramet	109	111	94	112	98	105	151	153
ICCI	1,460	1,386	1,537	1,610	1,632	1,740	1,558	1,772
Norilsk	1,782	1,709	1,700	2,300	2,265	2,325	2,311	2,201
OMG	3,560	3,745	3,900	3,800	3,990	3,930	4,160	4,220
Sumitomo	126	171	167	199	197	227	453	543
Umicore	600	540	590	600	1,250	1,737	1,422	1,475
Xstrata	2,075	1,469	2,103	2,300	2,261	2,555	2,531	1,919
TOTAL	**12,705**	**12,818**	**14,595**	**15,287**	**15,919**	**17,043**	**16,357**	**16,137**

Production

Table 1 illustrates refined cobalt production from CDI members for the first six months of each calendar year from 2000 to 2007.

At 16,137 tonnes the 2007 total refined production from CDI members is 220 tonnes less than in the same period in 2006, resulting from decreases in production from Xstrata, Norilsk and Chambishi. The decreases from these operations were offset to some extent by significant increases in production from BHP Billiton, ICCI, CVRD/Inco, and Sumitomo. The figure for Umicore includes production from their Ganzhou Hengsheng subsidiary in China.

Table 2 summarises refined cobalt production from other producers together with deliveries from the DLA stockpile. The table also includes a revised figure for Chinese production in the first half of 2006 following a reassessment of Chinese cobalt production for that period.

Total production from non-members of the CDI in the first half of 2007 was 10,105 tonnes, which is 107 tonnes higher than in the first half of 2006.

The main contributions to this increased availability have been from Tocantins (Brazil), Gécamines (DRC), Mopani (Zambia), and Minara (Murrin Murrin, Australia) mainly as a result of increased nickel and copper mining activity.

Table 2 – First Half Refined Cobalt Availability

	2000	2001	2002	2003	2004	2005	2006	2007
Bulong	57	88	0	0	0	0	0	0
China	600	*600	700	1,824	*3000	5,250	6,350	6,205
Gecamines	1,470	1,673	964	560	330	304	300	347
India	60	75	*75	75	270	398	665	600
Kasese	182	295	331	0	173	298	330	338
Mopani	400	823	900	960	1,019	877	769	850
Murrin Murrin	327	753	889	876	890	773	1,005	1,062
RSA	191	*155	160	139	116	141	131	*135
Tocantins	340	436	452	552	546	581	448	568
TOTAL	**3,627**	**4,898**	**4,471**	**4,986**	**6,344**	**8,622**	**9,998**	**10,105**
DLA Deliveries	1,493	1,324	740	1,386	1,450	604	69	200
TOTAL	**5,120**	**6,222**	**5,211**	**6,372**	**7,794**	**9,226**	**10,067**	**10,305**

** Estimates*

Table 3 – CDI First Half Total Refined Cobalt Availability (Tonnes)

	2000	2001	2002	2003	2004	2005	2006	2007
CDI Members	12,705	12,818	14,595	15,287	15,919	17,043	16,357	16,137
Others	5,120	6,222	5,211	6,372	7,794	9,226	10,067	10,305
Total	**17,825**	**19,040**	**19,809**	**21,659**	**23,713**	**26,269**	**26,424**	**26,442**

Chinese production which was adversely affected in 2006 by a reduction in raw material supply from the Democratic Republic of Congo (DRC) continues to be constrained in 2007, reducing by about 145 tonnes compared to the same period in 2006.

The CDI understands that production is being maintained through the utilisation of imported hydrometallurgical intermediate cobalt products as raw material and a slight improvement in concentrate import since the second half of 2006.

The continued constraint in availability of raw material from the DRC could affect the second half production, though current indication is that production may be maintained at these levels for the balance of the year. Of the Chinese total, Jinchuan produced about 3,000 tonnes.

It is emphasised that Chinese production shown in Table 2 does not include Umicore's production in China which is included in Table 1.

Sales from the USA Defence Logistics Agency (DLA) have been much reduced on previous years although there were some 200 tonnes of deliveries in the first six months of 2007 compared to 69 tonnes during the same period in 2006. At the end of June 2007, uncommitted DLA stocks stood at about 1,030 tonnes.

The total availability of refined cobalt in the first half of the year from 2000 to 2007 is shown in Table 3. The figures show that overall availability in the first half of 2007 was virtually the same as the same period in 2006, being just 18 tonnes lower.

As in the past, we emphasise that the figures do not include production of refined cobalt from companies treating various cobalt-containing intermediate products and scrap that do not report their figures.

Demand

The CDI has published supply and apparent demand data in the WBMS/CDI book "World Cobalt Statistics 2004-2006". The data were derived from worldwide import/export figures. The publication details apparent worldwide refined cobalt demand by geographical location. It can be purchased from either the CDI or WBMS.

In 2006, apparent worldwide demand totalled 54,685 tonnes, a decrease of about 3.9% over that of calendar year 2005. A small decrease in apparent demand was seen in Europe, and Chinese apparent demand figures were still being adversely affected by the constrained availability of raw material. However, the Americas showed an improvement in apparent consumption of better than 4% compared to 2005

Figures for the first half of 2007 are not finalised but initial data indicate that apparent demand is slightly up on that in the first half of 2006, with the main improvements noted in China and SE Asia while the Americas and Europe are slightly down.

Price

At the beginning of 2007, the average MB bid/offer spread cobalt price stood at about US$25.00/lb and US$22.00/lb for high and low grade metal respectively, an increase of about US$12.00/lb from the beginning of 2006. Prices continued to increase during 2007 and reached a peak of US$30.75/lb in May for higher grade and US$29.50/lb for lower grade before drifting off through the mid-year to a MB low of about US$25.00/lb for high grade and US$24.00/lb for the lower grade. However prices have quickly reversed a softening trend over the summer period and have firmed up considerably. Current (late September) prices are around US$30.00/lb for high grade and US$27.00/lb for low grade.

The EU REACH Regulation & the CDI

As you will be aware, the EU's new Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) entered into force on 1st June 2007. It is designed, using the principle of 'no data, no market', to shift onto industry the responsibility for assessing any risks relating to the substances it places on the EU market.

Manufacturers and Importers

All manufacturers and importers of chemical substances in the EU, including metals and metal compounds, in quantities exceeding one tonne per year will be required to submit a registration to the new European Chemicals Agency.

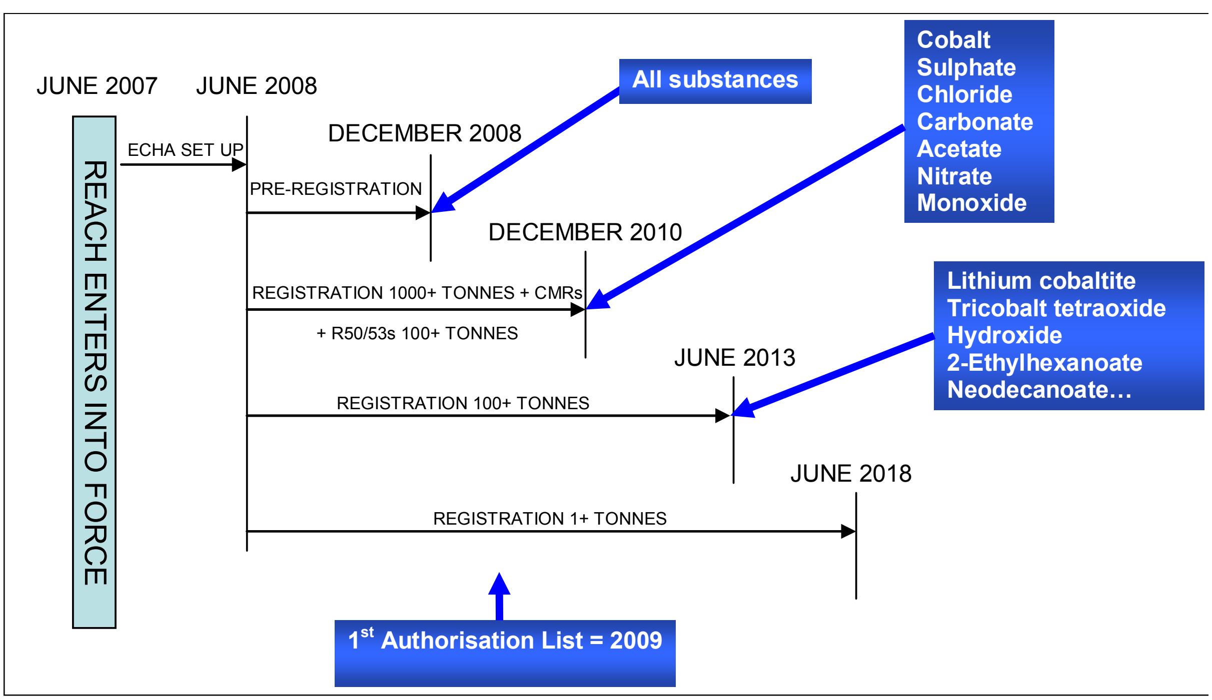
The registration dossier will contain detailed information on the substance, including a full chemical safety assessment and proposals for classification and labelling.

For all substances manufactured or imported in quantities of 1,000 tonnes per year per registrant, a registration dossier must be submitted before 1 December 2010. The same deadline applies to substances, such as cobalt sulphate and cobalt dichloride, which are classified as carcinogenic, mutagenic or toxic to reproduction (CMR) category 1 or 2, and substances, such as cobalt monoxide and cobalt sulphide, classified as dangerous for the environment and manufactured or imported in quantities of 100 tonnes per year.

Non-classified substances manufactured or imported in quantities of 100 tonnes per year per registrant will require registration before 1 June 2013, and non-classified substances manufactured or imported in quantities of 1 tonne per year per registrant will require registration before 1 June 2018.

In order to benefit from the phase-in regime described above, all potential registrants will need to pre-register their substances between 1 June

Timelines



and 1 December 2008.

The pre-registration step involves the provision of some very basic information such as the identity of the substance, and does not commit companies to submit a registration, and therefore it is recommended that all companies with an interest in cobalt or cobalt compounds pre-register to ensure access to the market after 1 December 2008.

All companies that pre-register the same substance will become members of a Substance Information Exchange Forum (SIEF) for that substance. It is envisaged that the members of a SIEF will share existing data, and they must agree a classification for their substance.

Downstream Users

Downstream users of cobalt and cobalt compounds do not have to register, however there are requirements relating to the provision of information on their uses. As part of the registration dossier, manufacturers and importers are required to generate 'Exposure Scenarios' covering all uses of their substances. However information on exposure that is required to develop the Exposure Scenarios will need to be provided to the manufacturers by the downstream users.

Authorisation

Substances that come under the authorisation regime will require positive authorisation for continued use. Substances classified as CMR category 1 or 2, such as cobalt sulphate and cobalt dichloride, will almost certainly be added to a 'candidate list' of substances that are *liable to* authorisation.

During 2009 the European Commission will publish proposals for a first list of substances that become *subject to* authorisation.

Both manufacturers/importers and downstream users may apply for authorisations for their uses, and authorisations will be granted to specific companies for specific uses depending on the demonstration of adequate control of risks to human health and the environment, and on the availability of suitable alternatives.

CDI Activities

The REACH Regulation strongly encourages the joint submission of a large proportion of the registration file through a consortium.

The CDI is currently working to establish Consortia with the purpose of preparing the registration dossiers for cobalt and cobalt compounds. The agreements governing the Consortia are expected to be available for signature in September/October 2007.

Although much information on the exposure and effects of cobalt and cobalt compounds is already available, it is anticipated that a significant amount of further research will be required in order to carry out the chemical safety assessments required under REACH.

The research programme will be coordinated by working groups within the relevant consortia, and the costs shared according to principles laid down in the Consortium Agreements.

Downstream users of cobalt and cobalt compounds will be welcome to join the cobalt consortia as associate members for the purposes of data exchange, and to join any Technical Working Groups that are set up to develop Exposure Scenarios on the production and uses of cobalt substances.

Please also refer to the REACH section of the CDI website at http://www.thecdi.com

If you would like to know more about the requirements of REACH or the cobalt consortia, please contact Dr Paul Marsh at the CDI (email pmarsh@thecdi.com, tel: +44 1483 510472).

Delicate Relation between Single Spins

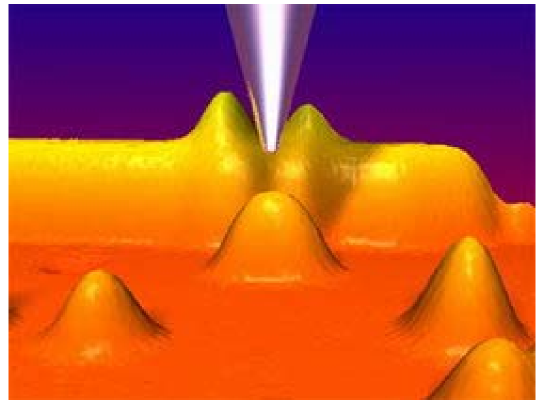
Probing the magnetic interaction between single atoms is no longer a dream. Using a scanning tunnelling microscope, the interaction of the spins of two neighbouring cobalt atoms adsorbed at a copper surface has been measured as a function of their distance with atomic precision. This development opens up new possibilities to probe the quantum nature of magnetic phenomena and to explore the physical limits of magnetic data storage.

It is a vision of information technology to store data in the smallest available units - single atoms - thus enabling the development of novel mass storage devices with huge capacities but compact dimensions. It is crucial to understand the mutual interaction and dynamics of individual spins, both for realising such a visionary device as well as to explore the limits of conventional mass storage media. New insights into these interactions can find direct application in the advancement of magnetic recording techniques as well as in the development of novel spin-based information technologies such as quantum computers.

Max-Planck researchers from Stuttgart and Halle in collaboration with colleagues from the CNRS in Grenoble have succeeded in accessing the interaction between single magnetic adatoms on a metal surface by comparing experimental results obtained with a scanning tunnelling microscope with a detailed theoretical analysis. The interaction between single magnetic adatoms has been theoretically analyzed already in the middle of last century and the predictions could now for the first time be compared with experiments on single atoms.

The metallic tip of a scanning tunnelling microscope passes over a conducting surface thereby giving access to an atomic scale height map. In order to measure the tiny magnetic effects, the researchers had to cool their microscope to low temperatures (-267°C or -448.6°F) and conduct the experiments in a vibration-isolated and sound-proof environment. The low temperature on the one hand freeze the motion of the atoms which enables the investigation of single atoms in the first place, on the other hand the spectroscopic resolution of the experiment is increased. The atomic arrangements in which the interactions have been studied were prepared by selectively dissociating single molecules containing cobalt atoms with the tip of the scanning tunnelling microscope.

As a probe for the magnetic interactions the



Artist's view of the measurement set up with the metallic tip of the scanning tunnelling microscope on top of a chain made out of three cobalt adatoms on a copper surface. The bump to the left is a single cobalt atom. *Credit: Max Planck Institute for Solid State Research*

researchers have exploited an electronic many body effect, the Kondo effect. This effect is due to the interaction of the spin of a magnetic adatom with the electrons of the metallic substrate. The effect can (at low temperatures) be detected by the scanning tunnelling microscope as resonance in the local electronic density of states. By a detailed analysis of the dependence of the Kondo resonance on the distance between two adjacent cobalt adatoms on a copper surface, the researchers were able to probe their magnetic interactions. This enabled for the first time a direct comparison of theoretical calculations for the magnetic interaction between single atoms on a metal surface with experimental data. The researchers also observed a novel magnetic state for a chain of three cobalt adatoms, which is a correlated state of the spins of the three constituting atoms.

The results of the Max-Planck researchers are promising first steps toward developing new pathways for manipulating and engineering materials and nanostructures on the atomic scale by exploiting the quantum nature of magnetism. At the same time the results improve our understanding of the fundamental interactions between single spins.

Citation: P. Wahl, P. Simon, L. Diekhöner, V.S. Stepanyuk, P. Bruno, M.A. Schneider, and K. Kern, Exchange Interaction between Single Magnetic Adatoms, Phys. Rev. Lett. 98, 056601 (2007)

Source: Max Planck Institute for Solid State Research

Thermomechanical Treatments of Aluminium Alloys

Thermomechanical processes are defined in the broadest sense to include any combination of thermal or deformation processes that give rise to interactive microstructural features. The varieties of mechanisms involving the creation, rearrangement and elimination of dislocations and grain boundaries are reviewed to show the range of possibilities in microstructure and property production.

The interactions of dislocations and grain boundaries with solutes and second phase particles are examined, and the opportunities for synergistic combinations are discussed. The primary concern is for aluminium alloys, but attention is paid to contrasting and comparative alloy systems. The processes result in improvements in yield strength, toughness and resistance to stress corrosion cracking, fatigue and creep.

Traditionally the thermal treatment and deformation processing of metals were kept separate in both practice, and theory. This arose on one hand because austenitising completely eradicated any worked structure and on the other because the martensitic steel vas very difficult to work.

Non-ferrous alloys were largely not heat-treatable and the introduction of ones that were did not immediately change preconceived notions. The shaping of metals, especially hot working, was considered solely as a mean of changing shape and metallurgical effort was directed at improving size capability, rate of processing and yield. Cold working and annealing were recognized as means of controlling the strength and the grain size but were considered techniques reserved for metals that were not heat treatable.

As knowledge grew of properties, microstructures, substructures, and mechanisms active during heat treatment and during deformation, and as the concept of strengthening mechanisms developed, the idea sprang up of superimposing mechanistic effects by combining processes. The term “thermomechanical processing” was coined to cover manufacturing in which a heat treatment and deformation were combined so that microstructural changes wrought by each interacted.

For the purposes of this paper, thermomechanical processing includes all combinations of thermal and mechanical treatments, irrespective of their order, which produce microstructural changes that do not obliterate each other. Another aspect which distinguishes such processing from simple forming operations is that the primary goal is product microstructure and properties, with the shape production and flow stresses being secondary. The microstructures produced by forming processes over a broad range of temperatures are examined. This includes the effects on dynamic restoration mechanisms of solute, particle dispersions and massive second phase.

Cold and Warm Working. Deformation at room temperature is a simple technique which can be carried out with great precision and good surface finish. Even with good lubrication, very high forces are developed at high strains and, depending on the process, there are limits to ductility. When the rate of working is increased, adiabatic heating may raise the temperature so that warm working ensues. The limits of warm preheating for forging or impact extrusion are, set by the lubricant stability.

Hot Working - Dynamic Recovery. Deformation at temperatures above 0.5 Tm, above which dynamic recovery is dependent on climb and vacancy migration, gives rise to a polygonised substructure. During the initial strain-hardening phase, dislocations accumulate in regular tangles and sub-boundaries. In distinction from cold or warm working, stable equiaxed subgrains form and persist through steady state deformation (temperature, strain rate and stress constant) without change in size or wall density. As the temperature is raised or the strain rate lowered, the steady state subgrains become larger and more perfect. As the degree of dynamic recovery increases, the hot flow stress decreases and the ductility increases.

Hot Working - Dynamic Recrystallisation. The degree of high temperature dynamic recovery depends upon the stacking fault energy of the metal much as in cold working. Thus, for metals such as α-Fe and Zr, the substructures are very similar to those of Al. On the other hand, metals such as Ni and Cu have much smaller less perfect subgrains which have a higher dislocation density.

The recrystallisation results in work softening to a new steady state in which the microstructure consists of equiaxed grains with a distribution of sizes. The larger grains are those which nucleated the longer time and strain before the point of observation and consequently have developed a high density dynamically recovered substructure. The preferred orientation after dynamic recrystallisation appears to be the same as that developed with only dynamic recovery because of the continuing deformation. The yield strength at room temperature follows the normal Petch relationship for grain size, but is stronger than recrystallised material of the same grain size because of the substructure.

Hot Working-Effects of Alloying. Solid solution alloying is likely to decrease the amount of dynamic recovery as it lowers the stacking fault energy as observed in Cu-Zn and Zr-Sn alloys. The effect on microstructure is not nearly so clear in other cases where a well defined substructure is produced, e.g. Al-Mg alloys, ferritic Fe-Si, Fe-Cr and Fe-Ni alloys, austenitic stainless steels, and nickel superalloys.

In the case of Al-Mg alloys the substructure depends on the absence or presence of dynamic strain aging. If the alloy composition, thermal history and deformation temperature and strain rate are such that the impurity atoms interact dynamically with the dislocations, they inhibit subgrain formation and change the activation energy. Somewhat similar effects are observed in Al-Cu alloys and in α-Fe -C-N alloys. Solute addition frequently delays dynamic recrystallisation to higher strains since it inhibits grain boundary migration. Fine, well-distributed particles can interact with the dislocations increasing their density, pinning the cell walls and in some cases may define the substructure. In hot working, the effect is more noticeable than in cold working, since the metal, without the particles, would have much larger subgrains. Particles which shear may prevent the formation of a substructure. Dynamic precipitation may also occur with one or other of the effects already mentioned. Fine particles on the sub-boundaries stabilize them slowing static recovery, and delaying or preventing static or dynamic recrystallisation.

Static Recovery and Substructure Strengthening. If a metal containing a substructure is heated, the stored energy gives rise to static restoration processes. Recovery involves individual dislocation motions within the existing grains whereas recrystallisation involves displacements of grain boundaries which eliminate the deformed structure entirely. Recovery usually always occurs first to some degree but can be the sole mechanism if a critical stored energy dependent on the annealing temperature is not reached. This critical stored energy is higher for metals which have dynamically recovered more at higher temperatures.

Product Strengthening by Recovered Substructure. Cold deformation followed by static recovery is a thermomechanical process used in industry mainly for stress relief anneals in which extensive recovery is not the object. It does appear, however, that in preparation for deep drawing of aluminium cans, annealing to polygonise the cold work substructure is employed to raise the strain hardening coefficient. Hot working is almost always followed by static recovery during the period after deformation until the temperature is too low for vacancy migration. In Al-alloys and ?-Fe alloys, the dynamically recovered structure is such that moderate rates of cooling can avoid recrystallisation and permit static recovery that is limited to annihilation of the dislocations within the sub-grains.

Deformation Substructures and Precipitates. Precipitates or dispersed particles can be present at the start of deformation and help to define the substructure. The powder metallurgy pressing and sintering of Ni-ThO2 alloys and the internal oxidation of Cu-Al2O3 alloys are the initial phases of thermomechanical treatments. To improve high temperature stability, CuAl2 has been precipitated in Al-Cu alloys and Fe-Al6 and (FeCo)Al9 have been included in aluminium prior to working and annealing. However, as an example of a different possible phenomenon, the Cu precipitates in Fe-Cu alloys prevent the formation of a substructure. Precipitates may form on a substructure created in the first step of a thermomehanical treatment, e.g. Cu precipitates on the dislocations of a cold worked and recovered substructure in Fe. The prior deformation usually accelerates the precipitation by providing more sites for heterogeneous nucleation, e.g. in austenite the rate of precipitation of Nb is increased an order of magnitude.

Thermomechanical Treatments for High Strength Aluminium Alloys. These processes have been called ITMT, intermediate thermomechanical treatments. The research in this area also indicates that improved properties can be achieved by extending structure control to earlier stages of processing.

Rapid cooling produces very fine dendrite arm spacing and thus finer inclusions and constituent particles which do not reduce the toughness as do coarser distributions. Powder metallurgy fabrication also reduces the problems of inclusions and large dendrite spacing. High purity alloys with reduced inclusion contents exhibit improved ductility, toughness, and resistance to fatigue and stress corrosion cracking. For many years, a simple press heat treatment has been practiced, in which the hot working served as the solution treatment and the hot worked product had to be rapidly quenched. This gave fairly satisfactory results for Al-Cu (2000 series) and Al-Mg-Si alloys (6000 series) but was in general inappropriate for the Al-Zn-Mg-Cu alloys (7000 series with exception possibly of 7005 and 7039). The problems arise from three areas:

1. the hot working is not of adequate duration and precision for a solution treatment;
2. the quenching rates, because of the forming process are not rapid enough and
3. the heterogeneous nucleation on dislocations supplants the very fine uniform, partially-coherent precipitate needed for highest strength.

The high strength aluminium alloys of the Zn-Mg-Cu and Zn-Mg classes can have their toughness and resistance to fatigue and stress corrosion cracking improved by what is known as FTMT, final thermomechanical treatment. This consists of solution, preaging, deformation and final aging.

The preaging plays a very important role: carried out near or slightly below the temperature and time for normal aging, it provides a set of uniformly distributed nuclei which guarantees that homogeneous nucleation can compete with heterogeneous nucleation on dislocations during final aging. Such preaging also provides for more uniform deformation in contrast to the heavy narrow slip bands which occur in slightly aged material. The deformations utilized have been in the range 10-50% and may be cold or warm. The substructure produced by the working should be uniform with slight cellularity being acceptable. The optimum appears to be deformation at or slightly above the aging temperature to strains of about 20%. Without the final aging the strength would be superior to simple aged material with ductility and toughness the same.

The second aging is frequently an overaging which lowers the strength to the normal value but increases the resistance to stress-corrosion cracking thus being somewhat similar to the second in a double aging treatment. Similar treatments have been worked out for Al-Mg-Si (6000 series), with similar restrictions on acceptable deformation structures. The Al-Cu alloys can usually be improved by working after the solution treatment but the conditions are not as restrictive as for the alloys with Zn and Mg.

In examining potential thermomechanical treatments, it is useful to include processing which involves only dislocation accumulation and restoration. Through manipulation of many variables, they are capable of yielding a spectrum of product microstructures either as complete processes or in conjunction with phase transformations. Some of these dislocation and grain boundary manipulating treatments have been applied to Al-alloys, the most important being:

- preservation of the hot worked substructure to strengthen non heat-treatable alloys,
- use of a particle stabilized subgrain structure to influence the evolution of the substructure during cold drawing and annealing to produce electrical wire with improved resistance to thermal softening,
- the establishment through control of ingot homogenization, rolling and annealing of an equiaxed microstructure with well distributed constituent particles which on further rolling to plate gives improved short transverse properties.

The high strength aluminium alloys can have their ductility, toughness and resistance to stress corrosion cracking greatly improved by a special preaging, warm working and post aging which does not detract from the normal precipitate distribution.

This entry was posted on Industry Metal Articles on Thursday, March 15th, 2007 at 5:40 am and is filed under Aluminum Alloys.

Korean Researchers Build New MRAM Technology

The Ministry of Science & Technology announced on Monday that a research team led by Professor Kim Bong-soo of the Korea Advanced Institute of Science and Technology has developed a new kind of magnetic RAM, which is a next-generation computer chip.

MRAM is expected to be the next big thing in chips because it has larger data storage capacity and can handle data from one hundred times to a thousand times faster than existing semiconductors.

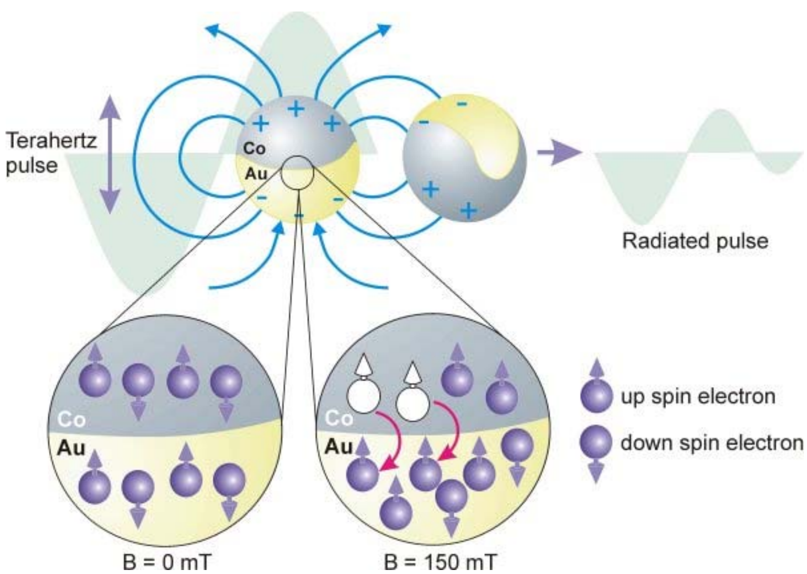
"We proved for the first time that cobalt silicon, which is not naturally magnetic, can be made strongly magnetic if it is produced in ultra-microscopic nanometer-size lines," said Professor Kim. By closely arranging the nano-lines, the researchers are able to make three-dimensional MRAM. The research was published Monday on the Nano Letters website, which is a world-renowned nano-technology journal.

The next generation of computer chips will read the 0s and 1s of digital information by using magnetic properties. MRAM is expected to be able to handle data one thousand times faster than existing flash memory chips.

Spins Turn Light Off

Researchers in Canada and the US have unveiled a new material that can switch a light beam on and off by varying the spin-polarization of electrons in the material. The material is made up of tiny magnetic particles of cobalt that are partially coated with gold.

According to the researchers, it could one day be used in devices for processing information that exploit both light and electron spin (*Phys. Rev. Lett.* 98 133901).



Terahertz light is partially transmitted through the material via plasmons on the surface of cobalt particles, which are partially coated with gold (top). If the cobalt is magnetized by an applied magnetic field, electrons can be spin polarized by the light (bottom). This reduces the amount of light that is transmitted through the material. *(Courtesy Abdul Elezzabi, University of Alberta).*

Many researchers are trying to develop "spintronic" devices that use the spin of the electron as well as its electrical charge to store and process information.

Others, meanwhile, are trying to exploit the interaction between light and the collective oscillations of electrons on the surfaces of metals (called plasmons) to create “plasmonic” devices for processing and transmitting data.

Now, Abdul Elezabbi and Kenneth Chau at the University of Alberta, along with Mark Johnson at the Naval Research Laboratory in Washington, DC, have created a material that combines spintronics and plasmonics to switch a beam of terahertz light.

When their material is exposed to an external magnetic field, the electrons in the micrometre-sized cobalt particles become spin polarized. If light in the terahertz frequency range is shone on the material, the electromagnetic field associated with the light drives some spin-polarized electrons from the cobalt into the partial gold coating (see figure).

This leads to an electrical resistance between the gold and cobalt called anisotropic magnetoresistance (AMR).

With the magnetic field turned off, there is no AMR and much of the light is transmitted through the material via plasmons. However, as the field is turned on, the increased resistance brought on by AMR impedes the flow of plasmons and the light transmission drops by over 70% in some samples.

Elezabbi told *Physics Web* that the team has observed this switching effect in other magnetic materials and is currently trying to find materials that enhance the effect.

He said that in principle the effect is not restricted to terahertz light – which is sandwiched between the ultraviolet and microwave bands – but it would be difficult to achieve at higher (microwave) frequencies because the light’s electric field oscillates so rapidly that spin-polarized electrons would not accumulate in the gold coating.

Elezabbi also said that the group are in the process of filing a patent related to several devices based on the effect.

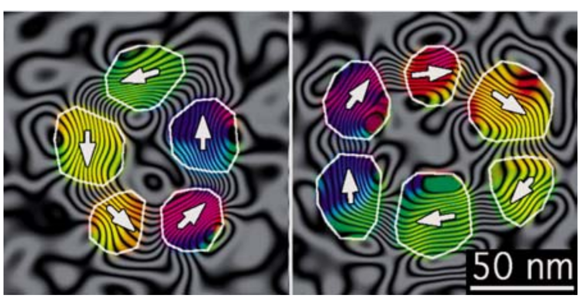
Hamish Johnston, editor, Physics Web, 9 April 2007 (http://physicsweb.org/articles/news/11/4/5/1)

Purdue's self-assembled 'nanorings' could boost computer memory

Recent nanotechnology research at Purdue University could pave the way toward faster computer memories and higher density magnetic data storage, all with an affordable price tag.

Just like the electronics industry, the data storage industry is on the move toward nanoscale. By shrinking components to below 1/10,000th the width of a human hair, manufacturers could make faster computer chips with more firepower per square inch. However, the technology for making devices in that size range is still being developed, and the smaller the components get, the more expensive they are to produce.

Purdue chemist Alexander Wei may have come up with a surprisingly simple and cheap solution to the shrinking data storage problem. Wei's research team has found a way to create tiny magnetic rings from particles made of cobalt. The rings are much less than 100 nanometers across – an important threshold for the size-conscious computer industry – and can store magnetic information at room temperature. Best of all, these "nanorings" form all on their own, a process commonly known as self-assembly.



Cobalt Nanoparticles (caption below)

"The cobalt nanoparticles which form the rings are essentially tiny magnets with a north and south pole, just like the magnets you played with as a kid," said Wei, who is an associate professor of chemistry in Purdue's School of Science. "The nanoparticles link up when they are brought close together. Normally you might expect these to form chains, but under the right conditions, the particles will assemble into rings instead."

The research appeared as a "Very Important Paper" in the November issue of the chemistry journal *Angewandte Chemie*. Wei collaborated with lead author Steven Tripp and Rafal Dunin-Borkowski, an electron microscopist at the University of Cambridge.

The magnetic dipoles responsible for nanoring formation also produce a collective magnetic state known as flux closure. There is strong magnetic force, or flux, within the rings themselves, stemming from the magnetic poles each particle possesses. But after the particles form rings, the net magnetic effect is zero outside. Tripp developed conditions leading to the self-assembly of the cobalt nanorings, then initiated a collaboration with Dunin-Borkowski to study their magnetic properties. By using a technique known as electron holography, the researchers were able to observe directly the flux-closure states, which are stable at room temperature.

"Magnetic rings are currently being considered as memory elements in devices for long-term data storage and magnetic random-access memory," Wei said. "The rings contain a magnetic field, or flux, which can flow in one of two directions, clockwise or counterclockwise. Magnetic rings can thus store binary information, and unlike most magnets, the rings keep the flux to themselves. This minimizes crosstalk and reduces error during data processing."

When you turn on your computer, it loads its operating system and whatever documents you are working on into its RAM, or random-access memory. RAM is fast, enabling your computer to make quick changes to whatever is stored there, but its chief drawback is its volatility – it cannot perform without a continuous supply of electricity. Many people have experienced the frustration of losing an unsaved document when their computer suddenly crashes or loses power, causing all the data stored in RAM to vanish.

"Nonvolatile memory based on nanorings could in theory be developed," Wei said. "For the moment, the nanorings are simply a promising development."

Preliminary studies have shown that the nanorings' magnetic states can be switched by applying a magnetic field, which could be used to switch a nanoring "bit" back and forth between 1 and 0. But according to Wei, perhaps the greatest potential for his group's findings lay in the possibility of combining nanorings with other nanoscale structures.

"Integrating the cobalt nanorings with electrically conductive nanowires, which can produce highly localized magnetic fields for switching flux closure states, is highly appealing." he said. "Such integration may be possible by virtue of self-assembly."

Several research groups have created magnetic rings before but have relied on a "top-down" manufacturing approach, which imposes serious limitations on size reduction.

"The fact that cobalt nanoparticles can spontaneously assemble into rings with stable magnetic properties at room temperature is really remarkable," Wei said. "While this discovery will not make nonvolatile computer memory available tomorrow, it could be an important step towards its eventual development. Systems like this could be what the data storage industry is looking for."

Wei's group is associated with the Birck Nanotechnology Center, which will be one of the largest university facilities in the nation dedicated to nanotechnology research when construction is completed in 2005. Nearly 100 groups associated with the center are pursuing research topics such as nanometer-sized machines, advanced materials for nanoelectronics and nanoscale biosensors. Funding for Wei's research was provided in part by the National Science Foundation and the Department of Defense.

Photo Caption: Shown are cobalt nanoparticles that have self-assembled into bracelet-like "nano-rings." The rings' magnetic flux can be oriented in one of two directions – clockwise or counterclockwise – a characteristic that could represent binary numbers in magnetic memory devices. Because the flux direction remains even without a constant power supply, it is possible these rings could lead to so-called "non-volatile" computer memory, which would not be wiped out in the event of a system failure. (Graphic/VCH Publishers).

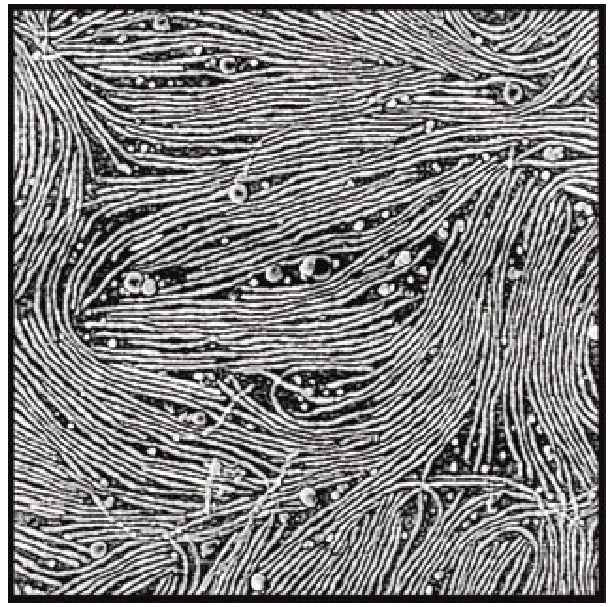
Reference:

Flux Closure in Self-Assembled Cobalt Nano-particle Rings, *Steven L. Tripp, Rafal E. Dunin-Borkowski, and Alexander Wei, Angewandte Chemie, Nov. 2003.*

First published in Purdue News: Purdue News Service: +1 765 494-2096 purduenews@purdue.edu

Battery Powered by Viruses

Popular Science always seem to have interesting things on their website, where this time I found an article by Michael Stroh on virus powered batteries. Michael spoke to Angela Belcher, who is the MIT materials scientist leading the effort, and who made Popular Science's 'Brilliant 10′ list in 2002.



MIT researchers are developing a new razor-thin and transparent lithium-ion battery that looks like a piece of tape and will be more potent than current power cells, storing three times the energy of a conventional electrode. Such design will open a new dimension in the world of gadgets, including computing.

The secret behind the slimness and power of the new battery is a (harmless) virus called M13. It was genetically engineered to attract metal ions and then "bathed in a solution of cobalt oxide and gold, metals known for their superior energy-storage properties. Coating the viruses onto a charged polymer film created an electrode 40 times as thin as a human hair". The technology should be commercially available within five years.

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Novel magnetic nanofilms

A new laminate oxide nanostructure could be ideal for high-frequency micromagnetic devices

An international team of researchers has made a novel laminate oxide nanostructure that may suit high-frequency micromagnetic devices, such as thin film inductors, transformers and flux-gate sensors. The material, which consists of cobalt, iron, hafnium and oxygen, was synthesized using RF sputtering techniques and has excellent soft magnetic properties as well as high electrical resistivity.

Magnetic thin films are widely used for a large number of technology applications, including sensors and media for magnetic recording and in the automotive and aerospace industries. They are also one of the most important tools for preparing multifunctional materials.

Recently there has been an emerging demand for magnetic thin films in high-frequency applications, such as in magnetic recording write-heads, soft underlayers for perpendicular recording media and thin-film wireless inductor cores. However, these applications need thin films with high electrical resistivity (to minimize energy loss due to eddy currents), a large saturation magnetization and a so-called hard-axis anisotropy field to increase the magnetic switching capacity at high frequencies.

Until now, however, most of the materials proposed have had low electrical resistivity and are unable to work in the technologically important gigahertz frequency range.

Now, an international team of scientists, including Manh-Huong Phan of Bristol University in the UK, Nguyen Duy Ha of Leiden University in the Netherlands and Chong Oh Kim of Chungnam National University in Korea, may have come up with a solution to the problem. The researchers have shown that they can make single-layer magnetic oxide thin films from cobalt iron hafnium oxide (CoFeHfO) using an RF sputtering technique.

Using magnetic hysteresis measurements, the team has shown that the nanostructure has excellent magnetic properties with a large saturation magnetization of 18–21 kG and a large hard-axis anisotropy field of 30– 84 Oe. Moreover, the material has a high electrical resistivity of 1400– 3600 μΩ. According to Phan and co-workers, these properties make CoFeHfO an ideal candidate for high-frequency micromagnetic devices.

The team has also revealed that the laminate structure, which consists of nanocrystalline α-Fe(Co)-rich layers separated by amorphous HfO_2-rich layers, can be considered as a [Fe(Co)-rich/HfO2-rich]n multilayer, where "exchange coupling" of Fe–Fe(Co) takes place between two neighbouring ferromagnetic layers through an insulating HfO_2-rich amorphous layer.

This indicates that CoFeHfO is itself a tunnelling multijunction, which means that it could be developed for use in advanced spintronic applications, where the spin of the electron is exploited as well as its charge. "Since the CoFeHfO thin films are insensitive to oxygen at interfaces, they can ideally be used as free layers for the fabrication of spin-dependent tunnelling junctions and as electrode layers for tunnelling magnetoresistive (TMR) junction applications," says Phan.

Phan added that the RF sputtering technique employed in this new work could also help to design other smart, nanostructural magnetic thin-film materials. The method allows a high degree of control over the thin film's growth, allowing its chemical composition, and so its properties, to be optimized.

And if all this was not enough, the team has also discovered that the CoFeHfO thin films show a giant magnetoimpedance (GMI) effect. This means that the material could find use in magnetic recording heads using GMI sensing technology.

Belle Dumé
belle.dume@physics.org

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Nguyen Duy Ha et al. 2007 Nanotechnology ***18*** *155705*