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COVER This genetically modified mouse lacks the receptor for capsaicin (the pungent ingredient in chili peppers) and no longer avoids the spicy Habanero pepper. These mice also exhibit a reduction in their ability to detect protons or heat under normal or pathophysiological conditions, illustrating a requirement for the capsaicin receptor in detecting diverse modalities of pain-producing stimuli. [Photo: G. Hollopeter and A. DePace]



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This Week in *Science*

edited by PHIL SZUROMI

SALTY INTERFACE

Reactions between the atmosphere and sea salt aerosols are important for many tropospheric processes. Conventional gas and bulk aqueous phase chemical models have been unable to explain the observed chemistry of these particles, however. Knipping et al. (p. 301; see the Perspective by Seinfeld) have now combined experimental observation, computational kinetic modeling, and molecular dynamic and quantum mechanical calculations to show how the production of chlorine gas must occur from NaCl aerosols in the presence of OH⁻. Their results demonstrate that the concentration of chloride ions is enhanced at the aerosol surface and that reactions at the air-water interface must dominate.

BURNING QUESTIONS

Carbon monoxide is a pervasive atmospheric pollutant, and identifying its sources is important not only for scientific reasons but for questions related to environmental policy as well. Forest fires are one known source, and anthropogenic fossil fuel burning is another. Wotawa and Trainer (p. 324) have combined ground-based and aircraft measurements with a transport model to identify the origin of an episodic pollution event that affected the southeastern United States in the summer of 1995. By tracing the source of the carbon monoxide to emissions from forest fires in Canada, they show that boreal fires can be important contributors to the pollution budgets of mid-latitude regions.

HISTORY IN TITANIA

The mineral phases within a rock can provide clues to its previous environments. Hwang et al. (p. 321) have uncovered a nanometer-sized inclusion of TiO₂ (titania) with an α -PbO₂-type structure sandwiched between two rutile crystals in the diamond-bearing ultrahigh pressure metamorphic rocks of the Erzgebirge in Germany. This phase of titania has not been observed previously in nature, and its recognition provides an important temperature and pressure indicator for the history of deformation in metamorphic rocks (for example, the diamonds in these rocks could have formed over a wider range of pressures and temperatures). This finding indicates that the massif experienced a rapid subduction and burial to depths of greater than 200 kilometers, one of the deepest recorded by any mineral phase, and then was rapidly exhumed.

THE NANOMECHANICS OF RECOGNITION

Intermolecular forces arising from the adsorption of molecules on surfaces are known to induce surface stress. Fritz et al. (p. 316) exploit this effect to transduce molecular recognition into nanomechanical responses. Cantilevers were functionalized with biomolecules such as DNA. Molecular recognition of a ligand—such as a complementary DNA strand-was measured as a differential nanomechanical response between differently functionalized cantilevers. This method, which was also demonstrated for protein-protein recognition, does not require labeling, optical excitation, or external probes, is compatible with silicon technology, and may easily be run in parallel.

SELF-CONTAINED OXIDE GROWTH

The layers of silicon dioxide that are used in the gates of MOSFETs (metal-oxidesemiconductor field-effect transistors) cease to be good insulators if they made only a few atomic layers in thickness. Further downsizing of these devices should be possible if other metal oxides with higher permittivity, such as alumina or zirconia, could be used as a dielectric, but if silicon is oxidized during their deposition, the lower capacitance of the silica layer will limit the effectiveness of this approach. Ritala *et al.* (p. 319) modified the method of atom layer deposition so that the reaction chemistry requires no separate oxygen sources. They can deposit thin layers of high-permittivity alumina and other oxides on silicon without forming an intermediate layer of silica.

CAN TAKE THE HEAT

The "heat" in hot peppers or from an acid burn turns out to be due to the triggering of one of the same receptors that contributes to the sensation of painful heat. Caterina et al. (p. 306; see the cover and the news story by Vogel) have constructed transgenic mice that are lacking the VR1 receptor, a cation channel selectively found in neural ganglia that mediate pain, which opens when activated by capsaicin or protons. These mice can eat chili peppers without painful consequences. The ability of these mice to sense noxious heat is impaired, but not completely eliminated, which suggests that other systems also contribute to heat detection. The VR1 receptor likely integrates stimuli released from tissue damage (such as protons) with the sensation of painful heat to send a rapid danger signal to the brain to remove the animal from the stimulus.

LEAVING TOGETHER

The loss of evolutionary history and biodiversity incurred with the loss of entire genera of threatened animal species is very much worse than if extinction strikes at

STELLAR REMNANTS

Titanium carbide grains, enclosed in amorphous graphite, have been described in meteorites and inferred to be evolved from asymptotic giant branch (AGB) stars. Von Helden et al. (p. 313) now provide a more direct link between these grains and the ejection of a carbonand titanium-rich superwind from a post-AGB object after the death of the star. They measured the infrared wavelength spectra of TiC clusters in the laboratory and found a 20.1-micrometer peak with a similar width and intensity as the 20.1-micrometer peak that has only been detected in post-AGB objects by the Infrared Space Obser-



vatory. Combining meteoritic and spectral observations, they calculate the density and mass loss rate of the superwind coming from these post-AGB objects.

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random, as is commonly assumed. Purvis *et al.* (p. 328) show that extinction risk is, in fact, unusually high for bird and mammal species that have few close relatives, and they also show that closely related species have unusually similar risks of extinction.

CHAPERONE SELECTION

Secretory and plasma membrane proteins begin their life with cotranslational translocation into the endoplasmic reticulum (ER). Inside the ER, the correct folding of newly synthesized proteins is assisted by a group of chaperone molecules including binding protein (BiP) and the lectins calnexin and calreticulin. Molinari and Helenius (p. 331) found that chaperone selection occurs cotranslationally and describe some of the criteria that select for a particular chaperone. The position of carbohydrate chains in the nascent chain of the protein diverted it from an interaction with BiP to an interaction with calnexin and calreticulin.

TOXIN AND PHAGE SECRETION

Cholera toxin is secreted from Vibrio cholerae bacteria harboring the filamentous bacteriophage CTX ϕ . Davis *et al.* (p. 333) examined the requirements for release of new phages from infected bacteria and discovered that a protein known to be involved in secretion of cholera toxin, EpsD, was also required for phage release. This finding is unexpected given the different size and nature of a protein toxin versus a protein-coated DNA molecule.

EXECUTING THE EXECUTIONER

Amyotrophic lateral sclerosis (ALS) is characterized by rapid death of motor neurons in the brain and spinal cord and results in paralysis and death, usually within 5 years of disease onset. The discovery of mutations in the SOD1 gene, which encodes a copper zinc superoxide dismutase, in a familial form of the disease enabled the creation of a mouse model of ALS in which the mice overexpress a mutant version of human SOD1. Li et al. (p. 335; see the Perspective by Gurney et al.) now demonstrate that motor neurons in the ALS mice die by apoptosis. By blocking the activity of caspase enzymes, the cell's executioners during apoptosis, with the inhibitor zVAD-fmk, they dramatically prolonged survival of the ALS mice. These findings suggest that caspase inhibitors may be beneficial in the treatment of ALS, particularly if combined with other neuroprotective drugs.

AN EVOLVING VIEW OF HCV INFECTION

Infection with hepatitis C virus (HCV) is a major public health problem that affects 170 million individuals worldwide. The vast majority of infected individuals develop chronic disease that can remain stable over many decades, whereas others successfully clear the virus soon after infection. To identify factors that might contribute to these diverse clinical outcomes, Farci et al. (p. 339) examined the evolution of sequences in the HCV envelope genes at early stages of infection. In patients who developed chronic disease, HCV evolved rapidly and showed a much greater genetic diversity than did HCV from patients who cleared the virus. These results suggest that analysis of viral sequence changes early in infection may be a useful tool for predicting clinical outcome.

DIVIDING UP THE WORK PLACE

During development, areas of the mammalian neocortex acquire specialization and thus different tasks, such as interpreting touch or directing reach, are parceled out to different areas. At least some of the specialization is directed by input from other regions of the brain. Bishop et al. (p. 344) now show that the specialization is not entirely dependent on neuronal input-rather, some component of the areal specialization is determined by genes expressed in the cortical cells themselves. Two genes, Emx2 and Pax6, act in opposition to determine the rostral-caudal pattern of neocortical areas, thus establishing the basics of cortical areal specification.

RECOGNIZING LANGUAGE

Although there might be general agreement that language, as commonly understood, is an ability limited to humans, it may nevertheless rely upon component skills that could be present to some extent in nonhuman primates. Ramus et al. (p. 349; see the Perspective by Werker and Vouloumanos) provide evidence for at least one of the skills using parallel training and testing paradigms to assess the comparative abilities of human newborns and tamarin monkeys. They find, replicating earlier work, that newborns can discriminate between rhythmically distinct languages when spoken forward but not backward. Surprisingly, the monkeys are equally adept, indicating that they do possess processing skills that help identify a sequence of sounds as language.



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Atomic Layer Deposition of Oxide Thin Films with Metal Alkoxides as Oxygen Sources

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A chemical approach to atomic layer deposition (ALD) of oxide thin films is reported here. Instead of using water or other compounds for an oxygen source, oxygen is obtained from a metal alkoxide, which serves as both an oxygen and a metal source when it reacts with another metal compound such as a metal chloride or a metal alkyl. These reactions generally enable deposition of oxides of many metals. With this approach, an alumina film has been deposited on silicon without creating an interfacial silicon oxide layer that otherwise forms easily. This finding adds to the other benefits of the ALD method, especially the atomic-level thickness control and excellent uniformity, and takes a major step toward the scientifically challenging and technologically important task of replacing silica as the gate dielectric in the future generations of metal oxide semiconductor field effect transistors.

The continuous shrinkage of microelectronic devices during the past 30 years according to the predictions and guidance of the Moore's Law (1) has led to a situation in which the materials used since the beginning of the integrated circuit technology are approaching their fundamental limits (2-4). The replacement of aluminum with copper has already begun, and high- and low-permittivity dielectrics are being examined as substitutes for SiO₂. For example, the thickness of SiO_2 as the gate oxide in metal oxide semiconductor field effect transistors (MOSFET), the dominant device in today's integrated circuits, is projected to be scaled down to 1 nm by the year 2010(2, 4). The gate oxide capacitively couples the gate electrode to the channel region between the source and drain regions of the MOSFET. By applying a voltage on the gate electrode, the conductivity of the channel region may be controlled, and the transistor is thereby switched on and off. However, when thinned to 1 nm, which corresponds to only four to five atom layers, SiO₂ no longer serves as an insulator because of the tunneling current that runs through it (3-5). Therefore, alternative materials with a permittivity higher than that of SiO_2 (3.9) are needed to be able to use thicker gate dielectrics in achieving the required capacitances (6) without tunneling currents, and thereby continue the evolution toward higher integration densities.

The replacement of SiO₂ with high-permit-

tivity dielectrics is a major challenge in which the basic research and the near-future needs of the semiconductor industry merge. To benefit from a high-permittivity substitute, it must be deposited on silicon in a way that an interfacial layer of SiO₂ only one or two molecular layers thick is formed. This requirement is illustrated by the concept of equivalent thickness d_{eq} , which is the thickness of such a SiO₂ layer that would give the same capacitance density C/A as the material under consideration, where C is the capacitance and A is the area of the capacitor. For a dielectric layer with a permittivity ε and thickness d, $d_{eq} = (\varepsilon_{SiO2}/\varepsilon)d = (3.9/\varepsilon)d$. Highpermittivity dielectrics are required in realizing equivalent thicknesses of 1.0 nm and less. However, silicon has a high affinity toward oxygen, and therefore a thin interfacial SiO₂ layer is easily formed between silicon and the dielectric layer. In such a case, the resulting double-layer insulator structure corresponds to two capacitors in series, and the total equivalent thickness is a sum of the SiO₂ layer thickness and d_{eq} of the dielectric layer: $d_{eq,tot} = d_{SiO2} + d_{eq}$. Thus, every 0.1 nm of SiO₂ will be away from the thickness of the high-permittivity dielectric, thereby requiring a use of thinner layers with a concomitant risk of higher leakage currents. In other words, the interfacial SiO₂ layer sets the lower limit for the achievable

 $d_{eq,tot}$. The interfacial SiO₂ layer may be formed by two mechanisms: (i) a reaction between silicon and the high-permittivity oxide and (ii) oxidation of the silicon surface during the oxide deposition. To avoid the first mechanism, oxides that appear to be thermodynamically stable in contact with silicon should be chosen, such as Al₂O₃ and ZrO₂ (7). To improve interface characteristics, some silicon may be incorporated to the high-permittivity oxide, thereby forming silicates (8). Another option is to use carefully tailored interface structures, like in the epitaxial structure grown by molecular beam epitaxy (MBE) in which one monolayer of strontium silicide was placed at the silicon- $SrTiO_3$ interface (9). However, there is major concern over whether this MBE-based approach can be scaled up to a cost-effective production. Avoiding the second possible mechanism for the interface layer formation, i.e., the oxidation of the silicon surface by the oxygen containing atmosphere during the film deposition, requires careful consideration of the deposition conditions, and will be focused on here.

ALD is a gas-phase thin-film deposition method that is unique because the film growth proceeds through self-limiting surface reactions (10-13). As a consequence, ALD offers excellent large-area uniformity and conformality (14) and enables simple and accurate control of film thickness and composition at an atomic layer level. All these characteristics make ALD an important film deposition technique for future microelectronics.

In ALD of oxides, one deposition cycle consists of an exposure to a metal precursor, a purge period, an exposure to an oxygen precursor, and another purge period. Typical metal precursors include halides, alkyls, alkoxides, and beta-diketonates, whereas water, hydrogen peroxide, ozone, and, in few cases, molecular oxygen has been used as an oxygen source (10). Oxide films made by ALD show good insulator properties, as evidenced by their use in commercial thin-film electroluminescent displays, and especially good insulators are obtained by constructing nanolaminate structures (10, 11). The major problem in ALD of high-permittivity oxides on silicon is that only a monolayer of the metal compound lies on the silicon surface when it is exposed to the oxygen source for the first time. Under typical growth conditions, this monolayer does not protect the silicon against oxidation, and therefore a thin SiO₂ interface layer is easily formed.

We now show a chemical approach to ALD of oxides without the use of the common oxygen sources listed above, thereby making it possible to create sharp silicon-metal oxide interfaces with no interfacial silicon oxide layer (Fig. 1). Instead of using a separate oxygen source, two metal compounds are used such that at least one of them is an alkoxide $[M(OR)]_{n}$, where M = metal and R = alkyl group] in which the oxygen of the ligand is directly bonded to a metal. In alkoxides, the metal-oxygen bonds are strong and short, implying multiple-bond character due to the π -bonding of the oxygen p-orbital to the metal d-orbital. Because oxygen is strongly bonded to metals that often have a higher free energy of oxide formation than SiO₂, it is reasonable to expect that metal alkoxides would be less oxidizing toward silicon than water, not to mention

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hydrogen peroxide or ozone.

Reactions of metal halides and alkoxides into oxides and alkyl halides are known from sol-gel processes under nonhydrolytic conditions, i.e., in absence of water (15, 16)

$$M(OR)_{a} + MX_{a} \rightarrow 2MO_{a/2} + aRX (1)$$

$$bM(OR)_{a} + aM'X_{b} \rightarrow$$

$$M_b M'_a O_{(a+b)/2} + (a+b) RX$$
 (2)

where a and b are the oxidation states of the metals M and M', respectively, and X represents a halide.

The metals in the two compounds may be either the same (Eq. 1) or different (Eq. 2), the latter resulting in the formation of mixed oxides. The reaction mechanism involves coordination of an oxygen atom of the alkoxy group to the metal center of the halide, followed by a nucleophilic cleavage of the O-R bond (16). Therefore, the cationic character of the alkyl group is important; the more stabilized the cleaving carbonium ion is, i.e., the more branched R is, the more facile the reaction is (16).

Reactions of metal alkoxides and halides in solutions at temperatures close to room temperature are slow, typically taking hours



Fig. 1. High-resolution transmission electron microsope image of an interface between a silicon substrate and an Al_2O_3 film made from $AlCl_3$ and $Al(O^{1}Pr)_3$ at 300°C.



Fig. 2. Elemental depth profiles determined by TOF-ERDA for a Zr-Si-O film deposited from $ZrCl_4$ and $Si(O^{n}Bu)_4$ at 500°C (ⁿBu, *n*-butyl) at. %, atomic %.

or days to reach equilibrim. But they are completed in seconds or minutes when carried out at 300°C in heptadecane or tricotylphosphine oxide, respectively (17). Therefore, the reactions appear promising for ALD where the achievement of high deposition rates requires that each monomolecular layer surface reaction step is completed in less than a second. The reactions may be accelerated by increasing the temperature, but an upper limit is set by the thermal self-decomposition of the alkoxides because the key feature of ALD, the self-limiting film growth, would then be ruined (10, 11).

Results of our experiments (18) on growing oxides by ALD with the use of only metalcontaining precursors are summarized in Table 1. The results demonstrate that the metal chloride-metal alkoxide chemistry is effective, resulting in the growth of uniform films from various precursor combinations, provided that a threshold temperature is exceeded. The threshold temperature is lower when the alkyl group is more branched. For example, no film is obtained from the AlCl₃-Al(OEt)₃ combination at 300°C, whereas the AlCl₃-Al(OⁱPr)₃ combination gives a deposition rate of 0.80 Å/cycle (ⁱPr, isopropyl). Thus, like the solution-phase studies (16), the cationic character of the alkyl group is important also here. The deposition temperatures were chosen so that no thermal self-decomposition of the alkoxides occurred. This was verified experimentally by observing that no film growth occurred when only the alkoxide was pulsed into the reactor at a given temperature.

One remarkable result of this new chemical approach is the incorporation of silicon into oxide mixtures. Until now, no facile chemistry has been found for depositing SiO_2 by ALD. All the reported processes have been based on long reaction times of at least tens of seconds

(12, 13) and therefore have been far from costeffective. With the current chemistry, large amounts of silicon were uniformly incorporated into Zr-Si-O mixtures (Table 1, Fig. 2), a material with a great potential for gate oxides (8). On the other hand, all the attempts so far to deposit binary SiO₂ have failed with this chemical approach. Also, this finding parallels the sol-gel studies in which reactions between SiCl₄ and Si(OR)₄ with primary or secondary R groups require metal chloride catalysts to proceed (19).

In the mixed-oxide films, the metal ratio often does not correspond to the ratio expected on the basis of Eq. 1, thereby implying that more complex overall reactions are involved. For example, the $HfCl_4 + Ti(O^iPr)_4$ combination leads to a metal ratio of Hf/(Hf+Ti) = 0.24 instead of the expected 0.50. This can be understood by the thermodynamically (20) facile etching reaction in which TiO₂ on the film surface is partially replaced by HfO_2

$$TiO_2(s) + HfCl_4(g) \rightarrow HfO_2(s) + TiCl_4(g)$$

$$\Delta G(300^{\circ}C) = -73 \text{ kJ/mol}$$
(3)

where ΔG is the change in Gibb's free energy.

In general, the processes presented here result in higher deposition rates than those obtained in the conventional metal halide– water or metal alkoxide–water ALD processes (10). In these new processes, both precursor pulses deposit metal ions into the film, whereas in the conventional approach only one of the precursors deposits metal. Time-of-flight–elastic recoil detection analysis (TOF-ERDA) studies showed that the films deposited with this chemistry at 300°C and above contained less than 1 atomic % carbon and hydrogen. On the other hand, the films do contain some chlorine residues, typically 1 to 2 atomic %, and thus it is evident that the removal of the chlo-

Table 1. Summary of the film growth experiments. Me, methyl.

Precursors	Temperature (°C)	Growth rate (Å/cycle)	Metal ratio	Chlorine residues (atomic %)
$AlCl_2 + Al(OEt)_2$	400	0.7		2.6
3 (/3	300	No growth		
$AlCl_{2} + Al(O^{i}Pr)_{2}$	300	0.8		2.0
AlMe ₃ + Al(O ⁱ Pr) ₃	300	1.3		
AlMe ₂ + Ti(O ⁱ Pr)	300	No growth		
AlCl ₃ + Ti(OEt)	300	No growth		
$AlCl_{3} + Ti(O^{i}Pr)_{4}$	300	2.3	Al/(Al+Ti) = 0.80	4.0
$ZrCl_{A} + Al(OEt)_{3}$	400	0.45	Zr/(Zr+Al) = 0.28	1.8
45	300	No growth		
HfCl₄ + Al(OEt)₃	400	0.6	Hf/(Hf+Al) = 0.33	1.0
4	300	No growth		
ZrCl₄ + Ti(O ⁱ Pr)₄	300	1.2	Zr/(Zr+Ti) = 0.45	0.8
HfCl₄ + Ti(O'Pr)₄	300	0.5	Hf/(Hf+Ti) = 0.24	0.8
$TaCl_{5} + Ta(OEt)_{5}$	275	0.5		2.0
$ZrCl_4 + Si(OEt)_4$	500	0.5	Zr/(Zr+Si) = 0.39	1.5
	350	No growth		
ZrCl4 + Si(O ⁿ Bu)4	500	1.3	Zr/(Zr+Si) = 0.30	0.8
	250	0.7	Zr/(Zr+Si) = 0.53	8.3
$SiCl_4 + Si(O^nBu)_4$	500	No growth		
$SiCl_4 + Si(OEt)_4$	500	No growth		

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rides is more difficult than that of the alkoxo ligands. Nevertheless, the permittivities of these films are only slightly lower than those of the corresponding materials deposited by the conventional ALD processes, and their leakage current properties are nearly identical (21). For removal of the chloride residues, proper postdeposition annealing conditions must be looked for in which the chlorides are replaced by oxygen but the underlying silicon is not yet oxidized. In contrast, the use of metal iodides with weaker binding energies than the chlorides offers a potential way to decrease the halide residues. Yet another scheme might be to use this new process only for the interface formation and then continue with the conventional ALD processes, which leave fewer residues.

Whereas the reactions between the halides and alkoxides were known from the solution studies, the success of depositing Al_2O_3 from aluminium isopropoxide and trimethyl aluminium was more surprising. Most likely this reaction mechanism involves formation of *tert*-butane

 $Al(CH_3)_3 + Al(OCH(CH_3)_2)_3$

 \rightarrow Al₂O₃ + 3 CH₃CH(CH₃)₂ (4)

The most important finding related to this ALD chemistry is that there is no interfacial silicon oxide layer between the silicon substrate and an Al₂O₃ film (Fig. 1). Before depositing this film, the silicon surface was etched with a dilute aqueous HF solution to remove the native oxide and to leave the surface hydrogen terminated. Whether the thin light zone at the interface is real or is an artifact is impossible to distinguish. However, even if the interface does have oxidized silicon, it is only one monolayer thick and, thus, represents an atomic-level interface between Al₂O₃ and Si, which is oxidized only from its topmost layer. The absence of a thicker interfacial layer implies that ALD with the use of alkoxides as oxygen sources is a viable technique for gate oxide deposition for the future-generation integrated circuits. The other requirements for the gate oxide deposition method, i.e., accurate thickness control and uniformity over the large silicon wafers, are inherently fulfilled by ALD because of its self-limiting film growth process.

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Nanometer-Size α-PbO₂–Type TiO₂ in Garnet: A Thermobarometer for Ultrahigh-Pressure Metamorphism

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A high-pressure phase of titanium dioxide (TiO₂) with an α -PbO₂-type structure has been identified in garnet of diamondiferous quartzofeldspathic rocks from the Saxonian Erzgebirge, Germany. Analytical electron microscopy indicates that this α -PbO₂-type TiO₂ occurred as an epitaxial nanometer-thick slab between twinned rutile bicrystals. Given a V-shaped curve for the equilibrium phase boundary of α -PbO₂-type TiO₂ to rutile, the stabilization pressure of α -PbO₂-type TiO₂ should be 4 to 5 gigapascals at 900° to 1000°C. This suggests a burial of continental crustal rocks to depths of at least 130 kilometers. The α -PbO₂-type TiO₂ may be a useful pressure and temperature indicator in the diamond stability field.

Coesite or diamond inclusions in garnet are important indicators of ultrahigh-pressure (UHP) metamorphism [above 2.5 to 2.7 GPa for the production of coesite (1)] in orogenic belts such as the western Alps (2), the Kokchetav Massif in Kazakhstan (3, 4), Dabie Shan in central China (5), the western Gneiss Region in Norway (6), and recently the Saxonian Erzgebirge in Germany (7). UHP metamorphism is important to our understanding of continental collision zones and the mantle dynamics attending subduction (1). For example, the source rocks in the Kokchetav Massif (4) and the Saxonian Erzgebirge (7) are acidic crustal rocks, and as such they imply burial to the mantle depths before exhumation to the surface. In general, inclusions larger than several micrometers in diameter can be identified using optical microscopy, Raman probe, or electron probe microanalysis, as well as methods for polishing thin rock sections to quanti-

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