

## Reduction Of Copper Oxide By Formic Acid Qucosa

The Reduction of Copper Oxide by Carbon Monoxide and the Catalytic Oxidation of Carbon Monoxide in Presence of Copper and of Copper Oxide  
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A Dissertation (Classic Reprint)  
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Copper electrodes were made with three different types of surfaces: copper metal, cuprous oxide, and cupric oxide. The metal electrode was made from a polished and chemically etched sheet, while the oxides were made by varying the thermal treatment of the copper metal in air. The electrodes were characterized by X-ray Photoelectron Spectroscopy and X-ray Diffraction. Background voltammetric behavior was consistent with theory as indicated by the Pourbaix diagram for Cu in aqueous media. The electrodes were then tested for activity toward catalytic electroreduction of carbon dioxide, CO<sub>2</sub>. Cyclic voltammetry with and without CO<sub>2</sub> gave similar results, so that it was determined that any CO<sub>2</sub> reduction was occurring within the voltage range for H<sub>2</sub> evolution, which started at -0.7 V versus Ag/AgCl. Photoelectrochemical experiments were performed using a Xe arc light source. Cyclic voltammetry and chronoamperometric studies showed enhanced current behavior in the light. While chronoamperometry at -1.0 V generally showed current decay with time, the CuO electrode actually rose, supporting currents in excess of 100 mA after 10 min. Electrolyte samples taken after extended amperometry over an hour's time and tested via Infrared Spectrometry showed a reduction product or products possessing O-H and C-H bonds.

Direct desulfurization of syngas is an important measure to further increase the efficiency of IGCC systems. Solid-phase, metal oxide adsorbents which sequester the sulfur by converting H<sub>2</sub>S to a metal sulfide are the only desulfurization technology capable of withstanding the combustion temperatures present at the outlet of the gasifier. Copper oxide is of particular interest due to its favourable thermodynamics across a wide range of temperatures. Cu-ETS-2 is a copper exchanged form of the sodium titanate ETS-2 and functions analogously to CuO for the conversion of H<sub>2</sub>S into CuS at temperatures ranging from ambient to 950 °C. The results of this study show that Cu-ETS-2 is capable of removing H<sub>2</sub>S from H<sub>2</sub>S/He mixture to concentrations below a mass spectrometer's detection limit at temperatures as high as 950°C. Temperature is, however, only one of the challenges facing a direct-desulfurization adsorbent; high concentrations of H<sub>2</sub> and water vapour are present in the syngas stream which can influence the oxidation state of the metal and the efficiency of H<sub>2</sub>S removal. In an attempt to prevent reduction of CuO, Chromium was successfully used to stabilize the oxidation state of copper oxide and maintain constant adsorption capacity throughout the whole temperature range. While several studies have examined the effect hydrogen in the feed, there are few studies exploring the influence of water vapour on the efficiency of H<sub>2</sub>S removal and none that explore the effect of water vapour at elevated temperatures. This study can be considered the only study to investigate the influence of water vapour on the desulfurization of a dilute H<sub>2</sub>S stream at temperatures between 350 and 950 °C using copper oxide-based adsorbents. The findings demonstrate that the presence of water vapor promotes production of H<sub>2</sub>, resulting in faster reduction of CuO to Cu<sub>2</sub>O and elemental copper, leading to less adsorption capacity. In the final chapter, the ability of the adsorbent for regeneration and use as a multi-cycle adsorbent was investigated. The results indicate that the adsorbent is capable of regeneration for at least four times with no sign of reduction in capacity. The results also indicate that the exothermic nature of oxidation reaction results in temperatures up to ~1700°C causing the partial melting of the quartz glass tube. However the adsorbent can withstand such high temperatures and does not lose adsorption capacity after the first oxidation step. This phenomenon is due to having nanotitanate ETS-2 as the support in the adsorbent.

Copper is widely known as a very important material due to its applications in our daily life, such as electrical devices and heating appliances. It is not so common knowledge that copper is not found in its metallic form, but mixed with other metals and elements like sulphur and oxygen. The process to obtain pure copper nowadays implies a strong impact on the environment. Regarding copper sulphides, its reduction to metallic copper is based in the oxidation of the ore products which forms sulphur dioxide (SO<sub>2</sub>), amongst others. Although SO<sub>2</sub> is sent to sulphuric acid production, there are still emissions to the environment. Since the reduction of contaminant emissions has become of a primary concern, several alternatives have been studied to replace the current process. One of the alternatives that is gaining strength is the leaching or bioleaching, where poor ores are treated with solvents (chemical leaching) or with bacteria (bioleaching). The advantages of this process is that low pressures and temperatures are needed, but long times are required. However, a high pressure and temperature version exists to reduce the leaching retention time. Another option is the so – called mechanochemical reactions. These are based in applying high energy by grinding and milling a small amount of the sample. The main disadvantages are that the reaction is slow and small amounts can be treated at a time. This choice is taken where tiny particle size is required, since copper of nano size can be prepared. In addition, it is used as a pre – treatment for the leaching/bioleaching process, because the milling activates the reactivity of the solid and shortens the leaching times. The process that has attracted more attention is the reduction with hydrogen (H<sub>2</sub>) gas. If feasible, a similar system as it exists nowadays could be adapted to the H<sub>2</sub> flow. Regarding the particular case of copper sulphides, several authors have already investigated the reaction. Among their conclusions, the reaction is not thermodynamically favourable unless another material is added to capture the hydrogen sulphide (H<sub>2</sub>S) produced in the reducing reaction. Numerous studies have based the good conversion results of this reaction by the addition of a considerable amount of another substance, practically in all cases, lime, i.e. calcium oxide. The role of this compound is to react with the H<sub>2</sub>S produced in the reduction, forcing the reaction to the production of metallic copper. The purpose of this thesis was to provide more information about this particular case, the H<sub>2</sub> reduction, because it seems to generate more interest due to its good results. This process can apply to both copper oxides and sulphides; however, this project was focused only in the reduction of copper (I) sulphide (Cu<sub>2</sub>S), commonly known as chalcocite. In addition, a new attempt to improve the bare reaction is made by mixing metallic copper on one set of experiments and copper (II) oxide (CuO) in another. Moreover, the modelling of the process was approached basing the mathematical solution on the development made by H. Y. Sohn for reactions between porous solids and gases. The materials used to perform the experiments were Cu<sub>2</sub>S, metallic copper and CuO, and the reactant gas was a mixture of 4% H<sub>2</sub> and 96% argon (Ar). The rate of conversion was measured by weight loss in a conventional thermo gravimetric analysis (TGA) set up for the bare reduction reaction. In this particular set up, experiments with loose powder at different reaction temperatures were carried out, as well as experiments in the pellet form and mixtures with copper. These last cases were performed only at a concrete isotherm. A differential scanning calorimetric (DSC) set up was used to perform the same

experiments as in the TGA set up, but in pellet shape, to confirm that no oxidation was affecting the results. The experiments mixing CuO were only completed in this set up. The results from the loose powder experiments gave low sulphur removal conversions, at a low partial pressure of reactant gas ( $H_2$  partial pressure is 0.04 MPa). The isotherm values showed different mechanisms for the high (750 – 850°C) and the low (600 – 700°C) temperature range studies. An attempt to determinate the kinetics of the chemical reaction was done taking the very first values of the reaction, where diffusion was not playing an important role. The findings were that the kinetics followed the shrinkage core model in the whole range, while the activation energy for the reaction was 61 kJ/mol for the low range and 8 kJ/mol for the high temperature range. Diffusion became strong quite fast after the chemical reaction stage. Its effect was studied by means of performing the exact same experiment in pellet shape. Since the porosity of the pellet is lower, diffusion was expected to be harder and lead to a lower value, but instead the sulphur removal from became higher. The action of compressing the powder introduced defects into the powder, making it more active which could explain this discrepancy. A step forward to previous experiments in the field was to add a certain amount of metallic copper with the idea of set nucleation spots for the copper production. All mixture conversions turned out to be lower than that for the simple  $Cu_2S$  reduction, which might be due to a thicker product layer and faster shrinkage of the copper formed, which prevents the reactant gas to go further. Another approach was to produce the copper spots for nucleation in situ, with the reduction of CuO by  $H_2$  before the main reduction. In the test conditions, the experiment with lower CuO content (1 wt %) generated noticeably better overall conversion results than the normal reduction. On the contrary, mixtures with a higher content (e.g. 10 CuO wt %), in the test conditions, were not able to reduce the CuO completely before heading to the isothermal conditions of the main reduction, which lead to the production of  $SO_2$ . As a result, the improvement in the conversion cannot be taken into account. An important part of the project is focused on the application of the model developed by H. Y. Sohn et al to describe the experimental results obtained from the isotherms. A first attempt considering only chemical reaction and diffusion effects fairly represented the conversion values in the intermediate region. The first stage is clearly controlled by chemical reaction, while flat slope of the latest period indicated the effects of mass transfer. The second attempt was to add the resistance of the gas film surrounding the pellet to the model. The new conversion curves were closer to the slope at the end of the experimental results, but differed deeply from the initial values. As main conclusions, it was seen that the temperature affected extremely to the mechanism of the reaction. The shrinkage core model described fairly well the chemical reaction controlled part, while the addition of diffusion or mass transfer gives better approximations to the latest stages of the process. The addition of metallic copper turned out to be badly for the sulphur removal because the product sinters faster, while the addition of CuO seems to improve the reaction, although more experiments should be done regarding the latter.

Proceedings of the NATO Advanced Study Institute on Desulfurization of Hot Coal with Regenerable Metal Oxide Sorbents: New Developments, held in Kusadasi, Turkey, July 1996

Advances in electrolytic and gas sensing technologies continue to be driven by careful selection and engineering of materials. Copper oxides--both cuprous oxide,  $Cu_2O$ , and cupric oxide,  $CuO$ --are abundant, environmentally friendly, and highly versatile. An attractive feature unique to both copper oxides is the ease of synthesis through a one-step thermal oxidation of copper foil in ambient environment, yielding various oxide compositions and morphologies according to the oxidation temperature and time. There are many possible applications for the copper oxide materials, including pigments in ceramics, catalysts, sensors, solar cells, and batteries, to name a few. This work presents applications in electrochemical cells, more specifically photocatalytic water splitting and  $CO_2$  reduction, and gas sensors. The synthesis processes of copper oxides are characterized in terms of processing parameters and inspected with X-ray diffraction measurements and scanning electron microscope (SEM). Three kinds of copper oxides were investigated for photocatalytic testing: 1 micrometer-thick, and 5 micrometer-thick  $Cu_2O$  films via 0.5 hr and 10 hr oxidation at 300 °C, respectively, and a 10 micrometer-thick  $Cu_2O$  film with 8 micrometer tall vertically-aligned  $CuO$  nanowire array on top via a 2 hr oxidation at 500 °C. Under AM 1.5 illumination, photocurrents of 0.8, 1.3, and 1.7 mA/cm<sup>2</sup>, respectively, were recorded for these samples, exceeding the performance of previously reported as-synthesized, co-catalyst-free copper oxide photocathodes. Possible explanations for the observed performance based on increased minority carrier diffusion length and enhanced surface electric field are discussed. Future prospects of highly photoactive and stable copper oxide-based photocathodes are also explored. The effectiveness of surface passivation for the copper oxide photocathodes using pristine and hydrogenated  $TiO_2$  thin films are quantified through prolonged photoelectrochemical testing. Photocathodes protected with  $TiO_2$  films of 50 nm thickness deposited by atomic layer deposition exhibited excellent stability, but the photocurrent dropped to ~0.06 mA/cm<sup>2</sup>. The results of  $CO_2$  reduction using electrochemically reduced Cu sites from copper oxide electrodes as precursors for  $CO_2$  reduction is also demonstrated. The proportion of reaction products  $H_2$ ,  $CO$ ,  $HCOOH$ , and  $CH_3COOH$  is shown to be tunable according to the surface morphology and composition of the original oxide electrode. Therefore, these electrodes exhibit the potential for highly selective liquid fuel production, including a measured  $H_2/CO$  product ratio of ~2.6 for maximized production of liquid fuels using the Fischer-Tropsch process. A simple gas sensing architecture taking advantage of the vertically-aligned growth of  $CuO$  nanowires is demonstrated. Complete devices are formed instantly following  $CuO$  nanowire synthesis by affixing a pair of electrode pads of a second substrate on top of the nanowire array to form a complete electrical circuit. This device architecture offers simple and facile integration of nanowires into a working device. A resistance change  $R/R_0$  of ~6 was observed for 8.1%  $H_2$  concentration increasing to ~26 for 25.5%  $H_2$  concentration. Recovery time is excellent at ~0.5 min or less. A description for the formation of facile microheater-integrated devices is outlined as a promising next step. A process flow to fabricate this device along with heat transfer analysis to predict the temperature distribution in the device is provided and the power consumption may be further minimized with a proposed pulsed heating strategy.

This handbook is a comprehensive guide to the selection and applications of copper and copper alloys, which constitute one of the largest and most diverse families of engineering materials. The handbook includes all of the essential information contained in the ASM Handbook series, as well as important reference information and data from a wide variety of ASM publications and industry sources.

The manufacture and use of the powders of non-ferrous metals has been taking place for many years in what was previously Soviet Russia, and a huge amount of knowledge and experience has built up in that country over the last forty years or so. Although accounts of the topic have been published in the Russian language, no English language account has existed until now. Six prominent academics and industrialists from the Ukraine and Russia have produced this highly-detailed account which covers the classification, manufacturing methods, treatment and

properties of the non-ferrous metals ( aluminium, titanium, magnesium, copper, nickel, cobalt, zinc, cadmium, lead, tin, bismuth, noble metals and earth metals). The result is a formidable reference source for those in all aspects of the metal powder industry. \* Covers the manufacturing methods, properties and importance of the following metals: aluminium, titanium, magnesium, copper, nickel, cobalt, zinc, cadmium, noble metals, rare earth metals, lead, tin and bismuth. \* Expert Russian team of authors, all very experienced \* English translation and update of book previously published in Russian.

Basic studies of the kinetics of the reduction of copper oxide were made to establish the effect of the solid phase on the over-all reaction kinetics The reaction  $\text{CuO} + \text{H}_2$  at the only rea  $\text{Cu} + \text{H}_2\text{O}$  consisted of an induction stage, an acceleration or autocatalytic stage terminating at about 35% reduction of the oxide, and a decreasing-rate stage The reduction rates for each stage were dependent on the nature of the initial oxide, the degree of subdivision of the oxide, and the temperature but were independent of the mass of the oxide phase. Addition of the reaction product copper had no measurable effect on the reaction. Water vapor in concentrations of 25 mg per liter of  $\text{H}_2$  prevented reduction at 112 cton prod- C The inhibiting effect decreased rapidly as the temperature was increased and disappeared entirely at 190 cton prod- C. Once reduction had started. water vapor had practically no effect The acceleration and decay stages were very closely approximated by a semiempirical equation based on the initial reaction occurring on certain active nuclei followed by a rapid growth of these nuclei by a branching-chain mechanism. The reduction rate reached a maximum and subsequently decreased as considerable interference occurred among the branching nuclei. Arrhenius plots gave an activation energy- of 13.5 plus or minus 1.2);cal for the reduction. (auth).

The origins of raku can be traced back hundreds of years to Japan, where it was used as the traditional method of creating clay bowls for the tea ceremony. Over the years potters have embraced and adapted the methods, celebrating the remarkable but unpredictable results achieved using raku techniques. The author, who has specialized in raku for over twenty years, considers the origins of raku before offering over 300 glaze recipes. A selection of other potters also share their ideas, and with one hundred photographs of raku-fired pieces, Fired Up With Raku offers inspiration to all potters and is an invaluable source of information and advice for all ceramicists. Includes over 300 glaze recipes. Superbly illustrated with one hundred colour photographs of raku-fired pieces. Irene Poulton has specialized in raku firing for over twenty years and her work is exhibited in both Australia and the USA.

This study explored how different parameters affect the additive expansion by the reduction of oxides (AERO) method to create copper foams in order to simplify the process for future work. Summary of Investigation Copper metal foaming by the reduction of oxides was studied. Room temperature high-energy ball milling was used to disperse copper oxide (CuO) in copper (Cu). Different parameters, CuO particle size, milling time, and the use of a process control agent were tested to determine the effects on the resulting foams. The greatest percent increase in porosity (exceeding 40%) was attained from the Cu-CuO alloy milled with the microscale CuO for 30 min and annealed at 800o and 600o, with and without the process control agent, respectively. The findings in this study suggested that room temperature milling can be used to substitute cryogenic milling for metal foaming, allowing for large scale metal foam production using this method.

"It is known that the addition of titanium to certain types of brasses and bronzes gives them additional valuable properties. The copper-titanium master alloy which is the natural addition agent for making these brasses can not, however, be used if it has been made aluminothermically. It appears that aluminum in the master alloy makes it useless for the above purpose. It should, therefore, be worth while to determine if it is possible to produce a copper-titanium alloy by some method which eliminates the contamination by aluminum, and which would give a copper-titanium which could be used with advantage as an addition-agent for brasses. The problem of this thesis is to investigate the possibilities of producing a copper-titanium alloy from rutile-copper-oxide mixtures by reduction with magnesium, to study the effect of addition agents to form a suitable slag, and to investigate the feasibility [sic] of using an inert atmosphere in the reduction vessel"--Introduction, leaf 1.

Significant work has been done by the investigators on the cerium oxide-copper oxide based sorbent/catalysts for the combined removal of sulfur and nitrogen oxides from the flue gases of stationary sources. A relatively wide temperature window was established for the use of alumina-supported cerium oxide-copper oxide mixtures as regenerable sorbents for SO<sub>2</sub> removal. Preliminary evaluation of these sorbents as catalysts for the selective reduction of NO(subscript x) gave promising results with ammonia, but indicated low selectivity when methane was used as the reductant. Since the replacement of ammonia by another reductant is commercially very attractive, in this project, four research components will be undertaken. The investigation of the reaction mechanism, the first component, will help in the selection of promoters to improve the catalytic activity and selectivity of the sorbents in the SCR with methane. This will result in new catalyst formulations (second component). If this research is successful, the combined SO<sub>2</sub>-NO(subscript x) removal process based on alumina-supported copper oxide-ceria sorbent/catalysts will become very attractive for commercial applications. The objective of the third component of the project is to develop an alternative SCR process using another inexpensive fuel, residual fuel oil, instead of natural gas. This innovative proposal is based on very scant evidence concerning the good performance of coked catalysts in the selective reduction of NO and if proven to work the process will certainly be commercially viable. The fourth component of the project involves our industrial partner TDA Research, and the objective is to evaluate long-term stability and durability of the prepared sorbent/catalysts. In the first year of the project, the catalysts were investigated by the temperature-programmed reduction (TPR) technique. The results from TPR indicated that the interaction with support appears to promote reduction at lower temperatures. Copper oxide in excess of monolayer coverage reduces at temperatures close to the reduction temperature of the unsupported copper oxide. Increased dispersion increases the support effect. Low activity of ceria in NO reduction may be due to its resistance to reduction at low temperatures.

Excerpt from Outlines of Inorganic Chemistry Withdrawal of Oxygen from Air by Hydrogen and by other Substances. Preparation of Oxygen by heating Mercury Oxide. Properties of Oxygen. Preparation of Oxygen by heating Potassium Chlorate and Manganese Dioxide. Burning of Charcoal, Sulphur, Phosphorus, in Oxygen. Burning of Steel in Oxygen. Burning of Hydrogen in Oxygen. Oxyhydrogen Blowpipe. Calcium Light. Explosion of Mixtures of Hydrogen and Oxy gen. Oxides. Oxidation and Oxidizers. Reduction and Reducers. Re duction of copper Oxide by Hydrogen, and Oxidation of Copper by Air. Reduction of Iron Oxide by Hydrogen, and Oxidation of Iron by Air. About the Publisher Forgotten Books publishes hundreds of thousands of rare and classic books. Find more at [www.forgottenbooks.com](http://www.forgottenbooks.com) This book is a reproduction of an important historical work. Forgotten Books uses state-of-the-art technology to digitally reconstruct the work, preserving the original format whilst repairing imperfections present in the aged copy. In rare

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Excerpt from The Reduction of Copper Oxide by Carbon Monoxide and the Catalytic Oxidation of Carbon Monoxide in Presence of Copper and of Copper Oxide: A Dissertation  
The following investigation attempts to extend our know ledge oi these simple processes by a thorough study of the reduction of copper oxide by carbon monoxide and of the catalytic combination of carbon monoxide and oxygen in presence of copper oxide and of reduced copper. It will be seen that these reactions show striking similarities in certain aspects to the corresponding reactions with hydrogen: At the same time there are marked and fundamental differences, which, as will be shown, are of great importance in processes. About the Publisher Forgotten Books publishes hundreds of thousands of rare and classic books. Find more at [www.forgottenbooks.com](http://www.forgottenbooks.com) This book is a reproduction of an important historical work. Forgotten Books uses state-of-the-art technology to digitally reconstruct the work, preserving the original format whilst repairing imperfections present in the aged copy. In rare cases, an imperfection in the original, such as a blemish or missing page, may be replicated in our edition. We do, however, repair the vast majority of imperfections successfully; any imperfections that remain are intentionally left to preserve the state of such historical works.

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