

Scientific paper

# Carboxylic Acid Reduction over Silica Supported Cu, Ni and Cu<sub>2</sub>In, Ni<sub>2</sub>In Catalysts

György Onyestyák\* and Szabolcs Harnos

Institute of Materials and Environmental Chemistry, Research Centre for Natural Sciences,  
Hungarian Academy of Sciences, Magyar tudósok körútja 2., Budapest, Hungary, H-1117

\* Corresponding author: E-mail: onyestyak.gyorgy@ttk.mta.hu

Tel.: +36-1-382-6844

Received: 04-04-2014

## Abstract

Hydroconversion of caprylic acid as model compound was studied in a flow-through fixed-bed reactor at 21 bar total pressure and 240–360 °C reaction temperature over various hydrogenating active phases: pure metal (Cu, Ni) and intermetallic compound (Cu<sub>2</sub>In, Ni<sub>2</sub>In) nanoparticles. Different silicas produced by dissimilar methods and a commercial  $\gamma$ -alumina were compared as appropriate supports. Catalyst precursors were activated in reducing H<sub>2</sub> flow at 21 bar and 450 °C as routine pretreatment. Catalysts of high activity and selectivity for alcohol production can be obtained by varying the supports, the main metals and their indium modified bimetallic forms. Diversity of catalytic behavior reflects the complexity of the surface reactions. Caprylic alcohol formation was substantiated to proceed through caprylic aldehyde intermediates, however it can be also dehydrated to dicaprylic ether or octenes over alumina support. Silica supports, especially a less compact variant seem to be more inert for side reactions than alumina. Different morphology of studied silicas can highly influence the catalytic performances taking place over different metal particles.

**Keywords:** Carboxylic acids; alcohols; hydrogenation; indium co-catalys

## 1. Introduction

Heterogeneous catalysts applying bimetallic phases seem to gain more and more significance in the biomass upgrading technologies.<sup>1,2</sup> Hydroprocessing to valuable products seems to be a challenge, where various metallic composites as reducing agents can play important role.<sup>1</sup> There is a sore need for development of alternative catalysts for more facile hydrogenation of organic acids than the conventional copper chromite (Adkins-type) catalysts.<sup>3</sup> Such catalysts should be active in the reduction of carbonyl group to methylene group, but shows low activity in alcohol dehydration and hydrogenolysis of C-C bonds resulting in high selectivity for alcohol production.

The patent literature describes catalysts for carboxylic acid reduction to alcohols comprising of one or more noble metals of Group VIII dispersed on Group III or IV metal oxides. Vanice et al. studied a series catalysts carrying platinum on TiO<sub>2</sub>, SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> and Fe<sub>2</sub>O<sub>3</sub> supports and catalyst Pt powder without support.<sup>4</sup> Hydrodecarbonylation and decomposition reactions of acetic acid do-

minated on Pt powder, Pt/SiO<sub>2</sub> and Pt/Al<sub>2</sub>O<sub>3</sub> similarly to that we found and reported about for Ni/Al<sub>2</sub>O<sub>3</sub> catalyst.<sup>5</sup> A recent study concerns the performance of various commercial supported noble metal catalysts (Ru/C, Pd/C, Pt/C, Ru/Al<sub>2</sub>O<sub>3</sub>, Pd/Al<sub>2</sub>O<sub>3</sub> and Pt/Al<sub>2</sub>O<sub>3</sub>) in aqueous phase hydrogenation of acetic acid.<sup>6</sup> These catalysts were shown to be just as poor as the supported Pt catalysts used by Vanice et al.<sup>4</sup> A systematic catalytic study of commercial supported noble metal, and Raney Ni or Cu catalysts combined with density functional theory calculations also showed to be most advantageous Ru/C catalyst, however alkane production was still significant.<sup>7</sup> Manyar et al.<sup>8</sup> found most efficient Pt/TiO<sub>2</sub> catalyst for steric acid hydrogenation applying various supports similarly to Vanice et al.<sup>4</sup> and the selectivity was further improved by Re admission. Mentioned results clearly show the importance of data gathering about support effects in the hydrodeoxygenation catalysis. Appearance of bimetallic catalysts seems to be advantageous for hydrogenation of various carboxylic acids (PtSn/SiO<sub>2</sub> for selective reduction of acetic acid<sup>9</sup> and RuSn/Al<sub>2</sub>O<sub>3</sub> for dicarboxylic and fatty acids<sup>10</sup>). As long as the effect of Sn addition on the catalytic properties

of Pt/Al<sub>2</sub>O<sub>3</sub> has been investigated in numerous studies (among them for acetic acid hydroconversion<sup>9</sup>), the promoting effect of the neighbouring indium has received much less attention.<sup>11–13</sup>

Recent studies concern the hydroconversion of carboxylic acids over catalysts obtained by reduction and In-modification of Cu- and Ni-zeolites.<sup>14–18</sup> Although the zeolite based samples proved to be efficient, the regular microporous systems did not come up to expectations in formation of reactive metal clusters inside the highly ordered aluminosilicate crystals. Applying only one of the zeolite components as support, higher efficiency can be attained over alumina loaded with Cu or Ni and modified with indium guest metal.<sup>19,5</sup> Indium-additive doping Ni host metal was found to suppress the total hydrogenation and hydrodecarbonylation reaction – both resulting in hydrocarbons – and promote selective alcohol formation.<sup>19–20</sup>

Properties of such hydroprocessing catalysts are basically determined by the type and the state of active metal phase. However, the support can significantly influence the formation of active metal particles, hence the quality of catalytically efficient surface. Recent paper showing promotional effects over a series of bimetallic Ni-Fe catalysts for CO<sub>2</sub> hydrogenation reflects great differences applying alumina or silica supports of exactly same specific surface area.<sup>21</sup> Cu and Ni hydrotreating agents, especially with indium doping are highly efficient in H<sub>2</sub> activating processes for step-by-step reduction of carboxylic acids. Pioneering research on indium doping is continued: the aim of present work was to investigate the change of the support from one component (Al<sub>2</sub>O<sub>3</sub>) of earlier profoundly investigated crystalline aluminosilicates, zeolites for the second one (SiO<sub>2</sub>). Two intrinsically different types of silica were picked up together with a commercial alumina, as well-known catalyst support using caprylic acid (CAC) of medium carbon-chain, as model reactant. It seems to be practical to compare the novel, chromium-free catalyst composites with the highly efficient, but old-fashioned Adkins contact, which was developed for selective reduction of fatty acid esters to aliphatic alcohols nearly one century ago.

## 2. Experimental

### 2.1. Catalyst preparation

Commercial silica gel (Grace) /SI1/ (BET: 302 m<sup>2</sup>/g) is an efficient conventional adsorbent. Commercial CAB-O-SIL M-5 (Cabot Corp.) /SI2/ is a fumed silica (BET: 200 m<sup>2</sup>/g) with a still much wider mesopore distribution consisting of agglomerated amorphous, colloidal silicon dioxide particles. These different silica samples and activated  $\gamma$ -Al<sub>2</sub>O<sub>3</sub> (Ketjen CK 300, Akzo-Chemie, BET 199 m<sup>2</sup>/g) /AL/ were applied as supports to prepare catalysts by the incipient wetness impregnation method with

aqueous solution of NH<sub>3</sub> (Reanal, Hungary) of Ni(acetate)<sub>2</sub> (Aldrich) or Cu(acetate)<sub>2</sub> (Aldrich), dried at 120 °C, and calcined at 550 °C in air. The sample designation, e.g., 9Ni/SI1 formula represents a catalyst preparation containing 9 wt.% Ni on SI1. Bimetallic catalysts were prepared by adding indium (III) oxide (Aldrich) to the calcined in air, NiO containing, 9Ni/silica or 9Ni/alumina samples in amounts to attain Ni<sub>2</sub>In or Cu<sub>2</sub>In stoichiometric composition of metallic phase and the mixture was grinded in an agate mortar. Each catalyst precursor (both containing one or two metal oxides) was reduced in hydrogen flow *in situ* in the reactor at 450 °C for 1 h in order to generate active supported metal prior to the catalytic test.

For comparison a commercial Adkins catalyst (consisting of 72 wt.% CuCr<sub>2</sub>O<sub>4</sub> and 28 wt.% CuO) was also tested applying the same activation and reaction conditions as for the catalysts of the present study.

### 2.2. Characterization

Nitrogen adsorption measurements were carried out at –196 °C using Quantochrome Autosorb 1C instrument. Before measurements, the samples were outgassed under vacuum at 350 °C for 24 h. The specific surface area was determined by the Brunauer-Emmet-Teller (BET) method. The pore size distribution was calculated from desorption branch of the isotherms by the Barrett-Joyner-Halenda (BJH) method.

The XRD patterns of the catalysts were recorded by Philips PW 1810 diffractometer applying monochromatized CuK<sub>α</sub> ( $\lambda = 0.15418$  nm) radiation (40 kV, 35 mA) at elevated temperatures in hydrogen flow using a high temperature XRD cell (HT-XRD). The crystalline phases were identified using the JSPDS ICDD database. The main size of active metallic particles was determined by the Scherrer equation evaluating the full width at half maximum (FWMH) values with profile fitting method.

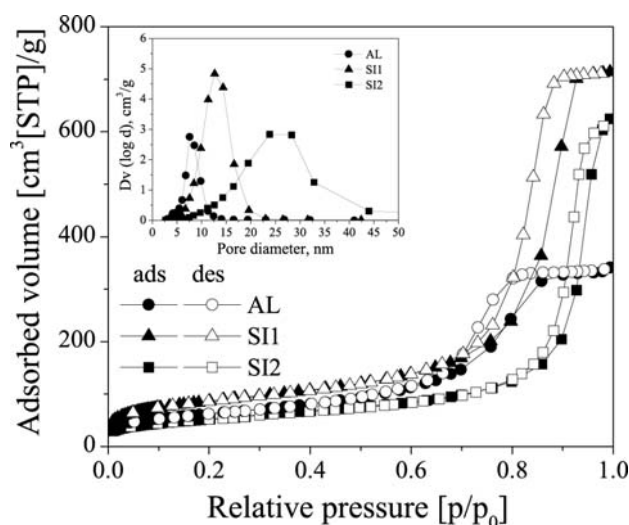
The reducibility and the extent of reduction of the samples were examined by temperature-programmed H<sub>2</sub>-reduction (H<sub>2</sub>-TPR) using a flow-through quartz micro-reactor. About 30 mg catalyst was pretreated in a flow of 30 ml min<sup>-1</sup> nitrogen at 350 °C for 1 h. The pre-treated sample then cooled to room temperature in the same N<sub>2</sub> flow before was contacted with a 30 cm<sup>3</sup> min<sup>-1</sup> flow of 9.7 % H<sub>2</sub>/N<sub>2</sub> mixture. The reactor temperature was ramped up at a rate of 10 °C min<sup>-1</sup> to 800 °C and maintained for 1 h at latter temperature. The effluent gas was passed through a liquid nitrogen trap and a thermal conductivity detector (TCD). Data were recorded and processed by computer. Calculation of the corresponding hydrogen consumptions based on the peak areas was carried out by using the calibration value determined with the H<sub>2</sub>-TPR of CuO reference material. All samples could be reduced completely under the condition of investigations, that is, hydrogen consumptions are equal with the amount of loaded reducible metals.

### 2. 3. Investigation of Catalytic Properties

The catalytic hydrogenation of CAC was carried out in a high-pressure fixed bed flow-through reactor at 21 bar total pressure in the temperature and space time ranges of 240–360 °C and 0.3–2 h, respectively. The reactor effluent was cooled to room temperature and the liquid and gas phase products were separated. The liquid was analyzed by a gas chromatograph (GC, Shimadzu 2010) equipped with flame ionization detector and a CP-FFAP CB capillary column. The gas was analyzed by an on-line GC (HP 5890) equipped with thermal conductivity detector and Carboxen 1006 PLOT capillary column. The activity and the selectivity of the catalysts were characterized by product distributions represented by stacked area graphs. In this representation, the distance between two neighboring curves gives the yield of the specified product in weight percent.

### 3. Results and Discussion

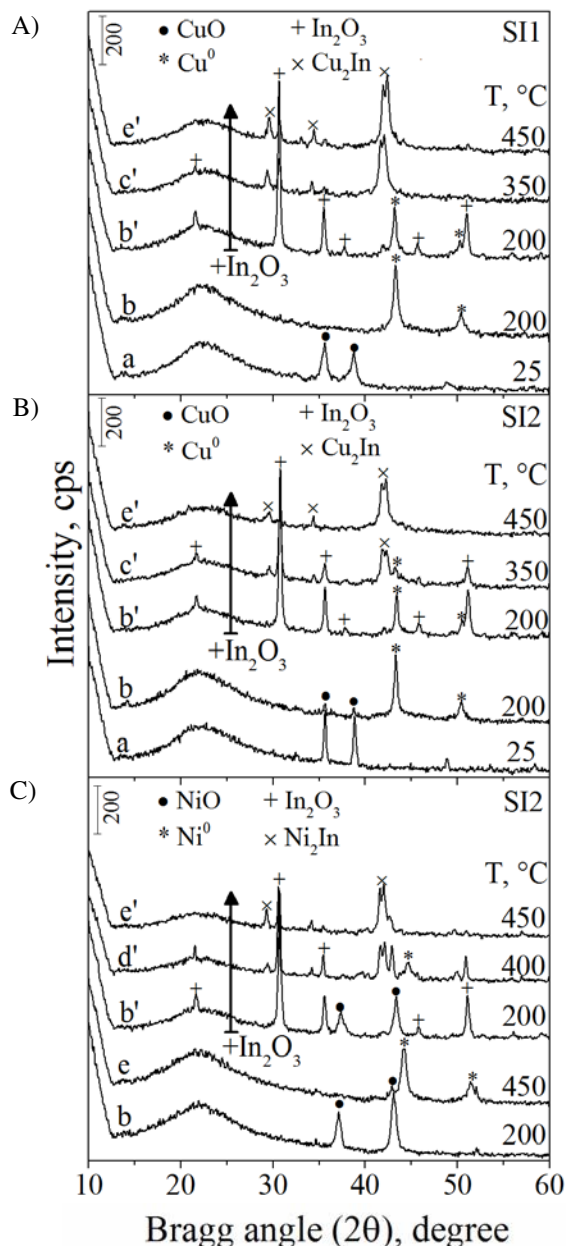
The parent silicas and alumina used as supports in this study are mesoporous materials as reflected by the nitrogen ad- and desorption isotherms and the pore size distributions shown in Fig. 1. These substrates are significantly different following different manufacturing. The specific surface areas are nearly related, however these samples have diverse pore size distributions around 8 nm /AL/, 13 nm /SI1/ and 27 nm /SI2/ with strikingly different width. This feature can determine fundamentally the formation, consequently the quality of active metallic particles and the mass transport properties in the prepared catalyst highly influencing the catalytic properties under reaction conditions. Isotherms of all derivatives (precursors, mono- or bimetal loaded forms too) are practically overlapping (so only the



**Figure 1.** Ad- and desorption isotherms of nitrogen at  $-196\text{ °C}$  and pore size distribution of parent alumina (AL) and silica (SI1 /gel/ and SI2 /fumed/) supports.

parent samples are shown in Fig. 1) resulting in nearly the same specific surface area. This means that there is no significant influence of mono- or bimetal particle formation for accessibility of full volume inside the catalyst particles. The reason is that these three-dimensional, quite capacious pore structures exclude the pore blocking effect. The fumed silica /SI2/ has the most opened pore structure which can be highly advantageous from catalytic point of view.

The HT-XRD patterns given in Fig. 2 represent the formation of silica supported active metal particles. The step-by-step reduction of added host (copper or nickel)



**Figure 2.** HT-XRD patterns of the indium free (a, b, e) and In loaded catalysts (b', c', d', e') recorded on 9Cu/SI1 (A), 9Cu/SI2 (B) and 9Ni/SI2 (C) precursors with and without 10 wt%  $\text{In}_2\text{O}_3$  admixed, treated in  $\text{H}_2$  flow for 30 min at various reducing temperatures.

and guest (indium) metal oxides to the active hydrogenating mono- or bimetallic phases is shown similarly than for nickel in ref. 5 and copper in ref. 19 on alumina support. Reductive treatment is completely reducing the CuO or NiO phases of the 9Cu/ or 9Ni/SI1 and /SI2 catalyst precursors up to 450 °C, which is the routine pretreatment temperature and generates small Cu or Ni metal particles (Fig. 2 A-a,b, B-a,b, C-b,e). CuO is completely reduced up to 200 °C on each support (Fig. 2 A-b, B-b) and in this case, there is no any difference using alumina or silica supports. The average size of Cu particles (calculated by the Scherrer equation) is 20 nm formed on alumina.<sup>19</sup> Significantly higher values were obtained on silicas /26 nm on SI1 and 35 nm on SI2/. Higher porosity of silicas means smaller diffusional resistance that can result in aggregation of copper atoms into somewhat bigger particles especially in the more porous fumed silica.

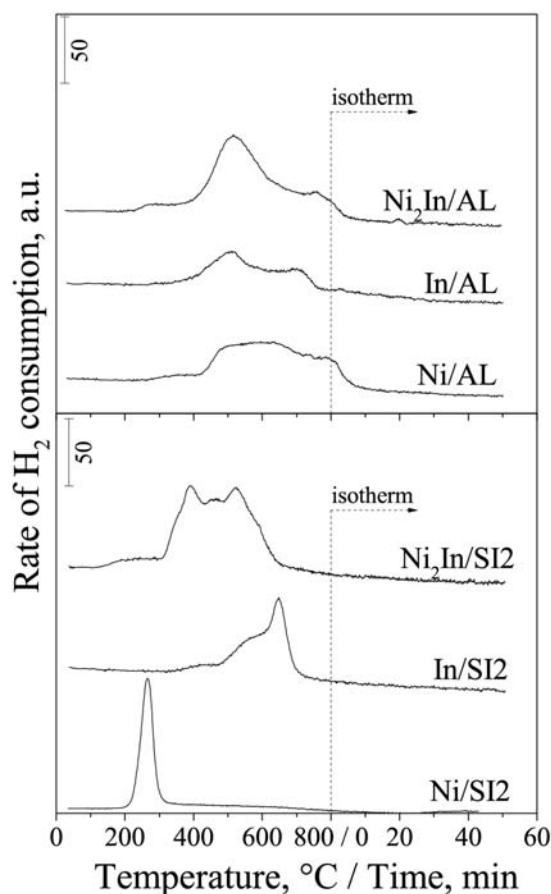
The intensity of nickel diffraction lines are still increasing up to 450 °C formed the metal phase at much higher temperature than copper. The reduction temperature of host metal oxides is increasing in the next order: Cu < Ni and on silica < alumina. The lower reduction temperature of NiO on silicas compared to alumina can come from the weaker oxide-oxide interaction and/or lower diffusional resistance in the less compact silicas. The average size of Ni particles is 8 nm formed on alumina and two times bigger (21 nm) particles were obtained on the more porous SI2.

All admixed In<sub>2</sub>O<sub>3</sub> seem to be converted to indium atoms up to 450 °C in hydrogen flow indicated by disappearance of its diffraction lines from the HT-XRD patterns (Fig. 2 A, B, C) and that can form immediately new Ni<sub>2</sub>In or Cu<sub>2</sub>In bimetallic phases (see similarly for alumina support in ref. 5 and ref. 19). The support and the presence of host metal can significantly influence the reduction of the admixed In<sub>2</sub>O<sub>3</sub> phase as demonstrated later in Fig. 3. Copper particles are already ready for alloying at 200 °C and can catalyze the reduction of the guest metal indium which can immediately form the bimetallic particles around 350 °C alike in both silica (see Fig.2 A-c' and B-c'). In silica support NiO can be reduced at a shade lower temperature (350–400 °C) than In<sub>2</sub>O<sub>3</sub> being also ready for alloying with nascent indium atoms. In this system the guest metal indium can be reduced between 350 and 450 °C needed higher temperature or longer time for the complete formation of bimetallic phase from pure nickel particles (see Fig. 2 C-d' and C-e'). The formed indium (as metal phase can be detectable by XRD only below 156.6 °C, the melting temperature of indium metal /not shown/) can be consumed in the reaction attaining the Ni<sub>2</sub>In stoichiometry with the host metal for longer contact time than half hour (compare Fig. 2 C-d' and C-e'). Excess indium cannot be detected excluding the formation of intermetallic compounds with higher Ni-content /Ni<sub>4</sub>In, Ni<sub>3</sub>In/. Furthermore applying more amount of In<sub>2</sub>O<sub>3</sub> NiIn or Ni<sub>2</sub>In<sub>3</sub> were also not formed. In the case of Cu or Ni

host metals, formation of Cu<sub>2</sub>In and Ni<sub>2</sub>In phases were clearly detected in numerous studies.

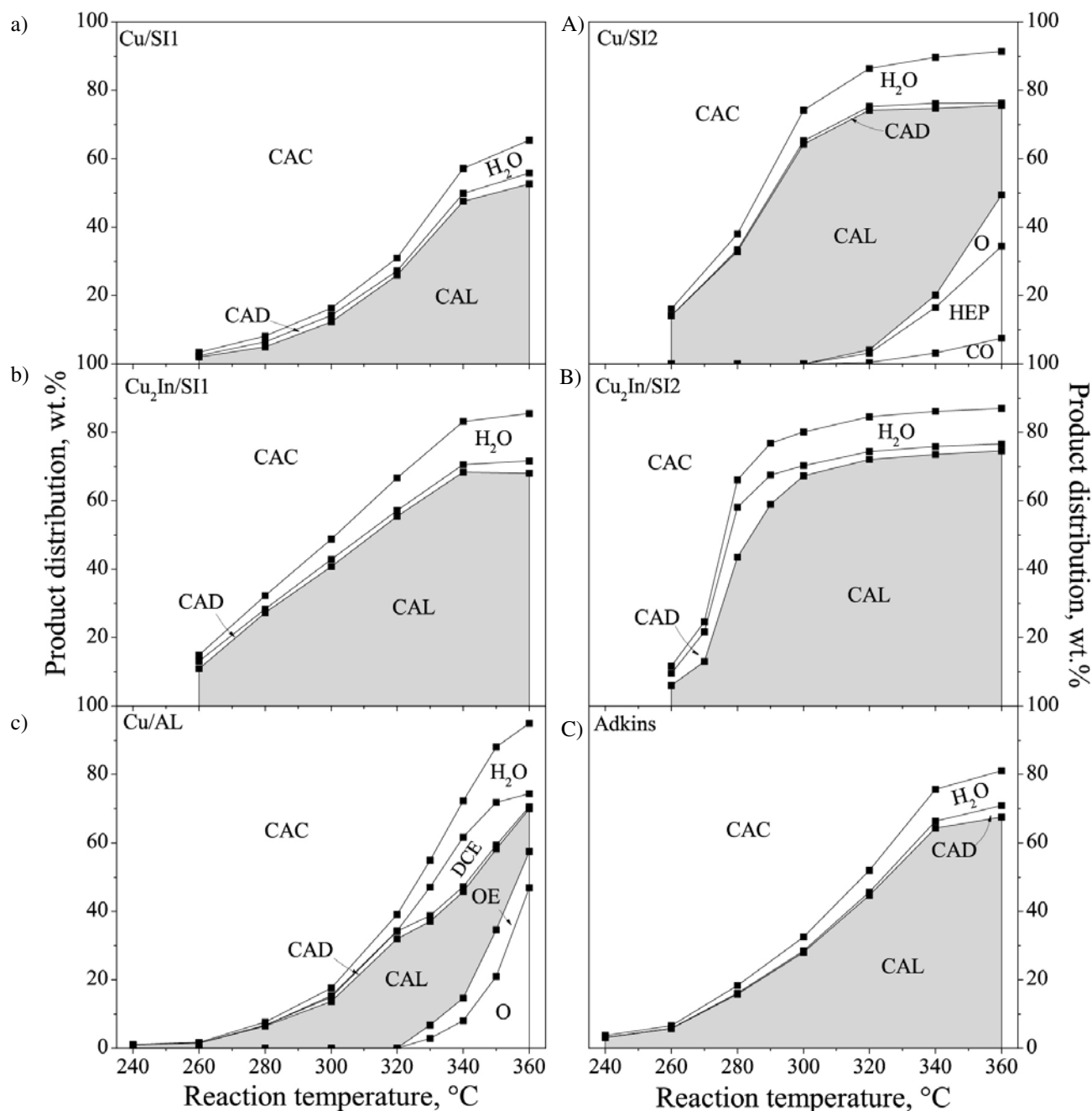
One reason of the significantly lower activity of alumina supported catalysts compared with silica based samples can be the much slower reduction of NiO bound solidly on the alumina surface compared to the more inert silica. The H<sub>2</sub>-TPR curves recorded on alumina /AL/ and the highly mesoporous silica /SI2/ (compare in Fig. 3) in accord with HT-XRD findings reflect important differences induced by diverse supports. Complete reduction of all precursors was found in the measured temperature range on the base of mass balances of added metal oxides and hydrogen. Applying identical linear heating up program for varied oxide precursors in hydrogen flow, the obtained H<sub>2</sub>-TPR curves demonstrate that presence of alumina can affect intensely the reduction of supported oxides (NiO or In<sub>2</sub>O<sub>3</sub>).

Contrary, NiO loading on SI2 can be completely reduced into pure nickel phase at low temperature below 300 °C and in a very narrow range without appearance of two possible oxidation steps. Just the opposite is the behavior of In<sub>2</sub>O<sub>3</sub> (containing larger particles than 100 nm), which simply admixed to SI2 powder by grinding can be



**Figure 3.** H<sub>2</sub>-TPR curves demonstrating the reduction of NiO and In<sub>2</sub>O<sub>3</sub> by itself, and jointly supported on alumina (A) and fumed silica (B).

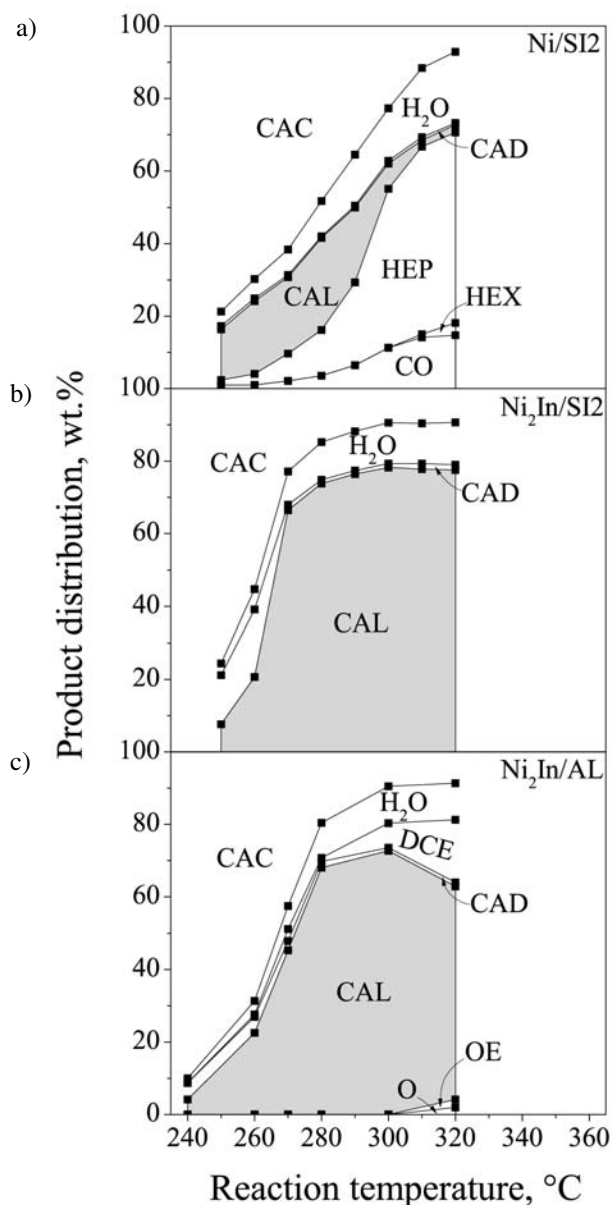




**Figure 4.** Stacked area graphs of product distributions obtained from the hydroconversion of CAC over catalysts (a) Cu/Si1, (b) Cu<sub>2</sub>In/Si1, (c) Cu/AL, (A) Cu/Si2, (B) Cu<sub>2</sub>In/Si2 and (C) commercial Adkins catalyst as a function of reaction temperature. The total pressure was 21 bar and the WHSV of CAC was 2 h<sup>-1</sup>. Legend: CAC: caprylic acid, H<sub>2</sub>O: water, CAD: caprylic aldehyde, CAL: caprylic alcohol, O: octane, OE: octenes, HEP: heptane, CO: carbon monoxide, DCE: dicaprylic ether.

talyst (compare ref. 10 and Fig. 5A). Indium doping shows the already well-known, never-failing efficiency to improve of Ni/Si2 to a fully alcohol selective catalyst (see Fig. 5B), which is significantly more active than the Cu-form. Catalytic performance of Ni<sub>2</sub>In/Si2 and formerly studied Ni<sub>2</sub>In/AL catalysts can be compared in Fig. 5B and 5C.<sup>5</sup> In these most active catalysts, the efficiency of the metallic component in the consecutive CAC reduction

to CAL seems to be commensurable independently on the support. The difference of supports loaded with the alcohol selective Ni<sub>2</sub>In phase clearly manifests itself in ability of dehydration of product CAL. It is evidenced that dehydration activity of acidic sites of alumina cannot be influenced (acidic centres are not poisoned) by indium admission, therefore the inert silica surface is really more advantageous as support.



**Figure 5.** Stacked area graphs of product distributions obtained from the hydroconversion of CAC over catalysts (a) Ni/SiO<sub>2</sub>, (b) Ni<sub>2</sub>In/SiO<sub>2</sub> and (c) Ni<sub>2</sub>In/Al as a function of reaction temperature. The total pressure was 21 bar and the WHSV of CAC was 2 h<sup>-1</sup>. Legend as in Fig. 4. In addition: HEX: hexane.

## 4. Conclusions

Novel indium doped Ni catalysts were found to be outstandingly efficient for selective reduction of carboxylic acids to alcohols. Over Ni<sub>2</sub>In intermetallic compound, – where the host metal is diluted with the guest metal indium in this favorable composition, – hydrogen cannot cut the C–C bond, and can attack the C–O bonds, and can saturate the C=C bond of vinyl alcohol, the tautomer of aldehyde, to generate alcohol. This study reveals that the role of novel highly efficient bimetallic phases is decisive.

However, the properties of the supports seem to be also quite significant. Highly mesoporous fumed silica was proven to be advantageous of overriding. Nature of silica surface excludes side reactions (e.g. mono- or bimolecular dehydration), which are characteristic for alumina. Beside the surface properties of the silica supports, their pore structure and morphological feature was turned out a success. Loading fumed silica support with the less active hydrogenating copper metal, the properties of the more active nickel catalysts can be explicitly approached. Variety of the most suitable catalysts for hydroconversion of bioacids is expanded and a further improvement can be attained by optimization of the support and the catalyst preparation technique. These findings reflect that by future preparation of well-defined ordered silica structures the efficiency of the *in situ* formed active metallic phase can be effectively controlled.

## 5. Acknowledgement

The authors wish to express their appreciation to Mrs. Ágnes Farkas Wellisch for her technical assistance. Thanks is due to the Hungary-Slovakia Cross-border Cooperation Programme (Project registration number: HUSK/1101/1.2.1/0318) for supporting this research. Thanks to the European Union and the State of Hungary co-financed by the European Social Fund in the framework of TÁMOP 4.2.4. A/2-11-1-2012-0001 National Excellence Program' for the further support.

## 6. References

1. D. M. Alonso, S.G. Wettstein, J. Dumesic, Chem. Soc. Rev. **2012**, *41*, 8075–8098.
2. J. C. Serrano-Ruiz, R. Luque, A. Sepúlveda-Escribano, Chem. Soc. Rev. **2011**, *40*, 5266–5281.
3. T. Turek, D.L. Trimm, N.W. Cant, Catal. Rev. Sci. Eng. **1994**, *36*, 645–683.
4. W. Rachmady, M.A. Vannice J. Catal. **2000**, *192*, 322–334
5. Gy. Onyestyák, Sz. Harnos, D. Kalló, Catal. Comm. **2011**, *16*, 184–188.
6. H. Wan, R. V. Chaudary, B. Subramaniam, Energy & Fuels **2013**, *27*, 487–493
7. H. Olcay, L. Xu, Y. Xu, G.W. Huber. Chem. Cat. Chem. **2010**, *2*, 1420–1424
8. H. G. Manyar, C. Paun, R. Pilus, D.W. Rooney, J. M. Thompson, C. Hardcore Chem. Commun. **2010**, *46*, 6279, 62–81.
9. R. Alcalá, J.W. Shabaker, G.W. Huber, M.A. Sanchez-Castillo, J. A. Dumesic J. Phys. Chem. B. **2005**, *109*, 2074–2085.
10. M. Toba, S. Tanaka, S. Niwa, F. Mizukami, Zs. Koppány, L. Gucci, K. Cheah, T. Tang Appl. Catal. A. **1999**, *189*, 243–250.
11. F. B. Passos, D. A. G. Aranda, M. Schmal J. Catal. **1998**, *178*, 478–488.

12. C. Mohr, H. Hofmeister, J. Radnik, P. Claus J. Am. Chem. Soc. **2003**, *125*, 1905–1911.
13. F. Haass, M. Bron, H. Fuess, P. Claus Appl. Catal. A. **2007**, *318*, 9–16.
14. Gy. Onyestyák, Sz. Harnos, D. Kalló, in: Indium: Properties, Technological Applications and Health Issues; H.G. Woo, H.T. Choi, Eds.; Nova Science Publishers, New York, **2013**, pp. 53–80.
15. Sz. Harnos, Gy. Onyestyák, J. Valyon, Appl. Catal. A. Gen. **2012**, *31*, 439–440.
16. Sz. Harnos, Gy. Onyestyák, D. Kalló, Microp. Mesop. Mater. **2013**, *167*, 109–116.
17. Sz. Harnos, Gy. Onyestyák, R. Barthos, M. Štolcová, A. Kaszonyi, J. Valyon, Centr. Eur. J. Chem. **2012**, *10*, 1954–1962.
18. Sz. Harnos, Gy. Onyestyák, Sz. Klébert, M. Štolcová, A. Kaszonyi, J. Valyon, Reac. Kinet. Mech. Cat. **2013**, *110*, 53–62.
19. Gy. Onyestyák, Sz. Harnos, D. Kalló, Catal. Comm. **2012**, *26*, 19–24.
20. Gy. Onyestyák, Sz. Harnos, A. Kaszonyi, M. Štolcová, D. Kalló, Catal. Comm. **2012**, *27*, 159–163.
21. D. Pandey, D. Goutam, J. Mol. Catal. A. **2014**, *382*, 23–30.

## Povzetek

Konverzijo kaprilne kisline, kot modelne spojine, smo študirali v pretočnem reaktorju pri tlaku 21 barov in temperaturi reakcij med 240 in 360 °C z uporabo različnih aktivnih faz: čiste kovine (Cu, Ni) in nanodelci intermetalnih spojin ( $\text{Cu}_2\text{In}$ ,  $\text{Ni}_2\text{In}$ ). Primerjali smo tudi ustreznost različnih nosilcev katalizatorja: silicijeve spojine pripravljene z različnimi metodami in  $\gamma$ -aluminijev oksid. Katalitske prekursorje smo predhodno aktivirali v reduktivni atmosferi  $\text{H}_2$  pri 21 barih in 450 °C. Katalizatorje za proizvodnjo alkohola, ki imajo tudi visoko aktivnost in selektivnost, lahko pripravimo s spreminjanjem nosilca, kovine in modifikacijo indijevih intermetalnih spojin. Raznolikost katalitskega obnašanja je posledica kompleksnosti reakcij na površini. Predvidevamo, da nastanek kaprilnega alkohola poteka preko aldehidnega intermediata, vendar lahko pride tudi do dehidracije in nastanka dikapril etra ali oktena pri uporabi  $\text{Al}_2\text{O}_3$  nosilca. Nosilci na osnovi silicija, zlasti manj kompaktni, so bolj inertni, z manj stranskih reakcij. Različna morfologija nosilcev močno vpliva na katalitske sposobnosti kovinskih delcev.