Influence of Pd codeposition on the magnetic properties of Co particles on alumina/NiAl(110)

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Changes of the magnetic properties of ferromagnetic Co particles deposited at room temperature on a thin alumina film grown on a NiAl(110) substrate were investigated as a function of Pd coverage by subsequent deposition of Pd onto deposited Co particles. From previous x-ray photoelectron spectroscopy, IR, and temperature programmed desorption experiments it was concluded that Pd forms a shell on top of Co particles. However, the current experiments indicate that Pd does induce structural rearrangements within the Co particles which may also involve the intermixing of small amounts of Pd into the Co particles. The latter is inferred from a change in the g-value for small particles. The impact of a larger intermixture of Co and Pd on the magnetic properties will be emphasized by a reversed deposition order where Pd particles were deposited first and subsequently covered by Co. The reversal of the deposition order increases the magnetic anisotropy of the particles considerably. © *2008 American Institute of Physics.* [DOI: 10.1063/1.2975332]

I. INTRODUCTION

Nanometer scale bimetallic particles have gained considerable interest over the past years. This interest is on the one hand driven by the prospects these systems have to improve technologically important applications and on the other hand these systems pose a variety of important problems for fundamental science. Bimetallic Co systems, in particular, multilayered structures of Co/Pt and Co/Pd, have been investigated in a large number with respect to their magnetic properties because of the perpendicular orientation of the magnetization, but only recently microscopic insight into the correlation of structural and magnetic properties have been obtained (e.g., Refs. 1–3). Bimetallic Co/Pd particles have gained particular attention in the field of heterogeneous catalysis because it was shown that supported Co/Pd particles show a better selectivity as well as conversion toward the direct reaction of methane to higher hydrocarbons[4] as well as the hydrogenation of CO (the Fischer–Tropsch reaction)[5] than either of the single component systems alone. To gain more insight into the microscopic properties of this complex system, a model system was prepared using a well defined thin alumina surface, which was proven to be a suitable for this kind of catalytic model systems.[6] Co and Pd were deposited onto this substrate under UHV conditions and the properties of the particles was previously explored using x-ray photoelectron spectroscopy (XPS), scanning tunneling microscopy (STM), temperature programmed desorption (TPD), and IR spectroscopy for different preparation conditions.[7–9] From the above-mentioned experiments it was concluded that Pd grown on top Co particles form a shell

while the reversed deposition order gives rise to a substantial intermixture of Pd and Co due to the tendency of Pd to segregate to the surface of the particles. In the present investigation we want to look again into this growth using the magnetic properties as a sensitive probe to investigate the structural and magnetic properties of the abovementioned bimetallic particles.

II. EXPERIMENT

The ferromagnetic resonance (FMR) experiments were carried out in a specially designed UHV apparatus which has been described previously.[10] The thin aluminum oxide film was grown on a NiAl (110) single crystal as described in detail elsewhere.[11] The structure of the film was monitored by means of its characteristic low energy electron diffraction pattern. Metal was deposited by an electron beam evaporator (Focus/Omicron EFM3). The particles were grown at 300 K with a deposition rate of 1 Å/min as calibrated by a quartz microbalance. Note that the sample was biased to the voltage of the evaporation material to avoid an acceleration of metal ions onto the surface. The pressure during metal evaporation never rose above 6×10^{-10} mbar and the base pressure in the apparatus was better than 2×10^{-10} mbar. The coverage given in Ångstrøm throughout this paper is meant as the height of a hypothetical homogenous metal film on the alumina surface. All FMR spectra shown throughout this paper are taken at room temperature with the static magnetic field being oriented in the surface plane unless stated otherwise.

III. RESULTS

Figure 1 shows FMR spectra obtained after deposition of 2, 4, and 10 Å of cobalt on freshly prepared alumina films at 300 K. The spectrum observed for the 2 Å deposition exhibits a single line at 296 mT. The line shape is asymmetric with a broader tail in the low field region of the spectrum and

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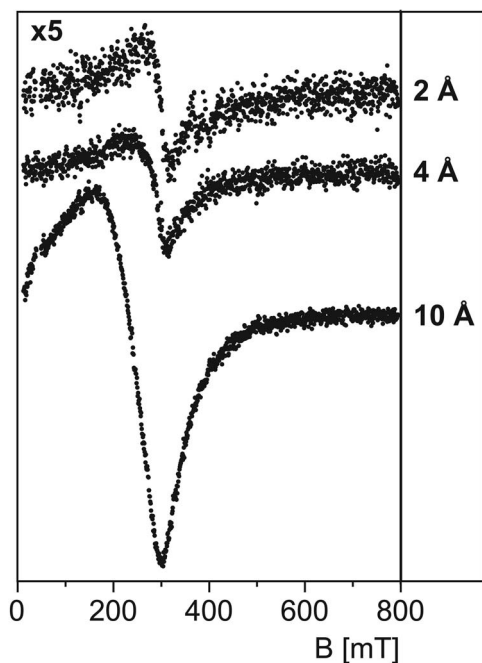b)Author to whom correspondence should be addressed. Electronic mail: risse@fhi-berlin.mpg.de.

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FIG. 1. FMR spectra of different amounts of Co deposited at room temperature on $Al_2O_3/NiAl(110)$.

FIG. 2. FMR spectra of Pd deposited at room temperature on top of 4 Å Co on $Al_2O_3/NiAl(110)$.

is characterized by a peak to peak line width of 55 mT in agreement with earlier published results.[12] The FMR spectra observed for 4 and 10 Å Co deposited on the $Al_2O_3/NiAl(110)$ surface show a strong increase in the FMR intensity as compared to the 2 Å case. The apparent resonance position shifts monotonously toward lower fields with increasing amount of Co being 231 mT for the 10 Å deposit. Concomitantly, the line shape becomes more asymmetric which is also reflected by the increase in the linewidth which is 141 mT for the 10 Å deposit. For this amount of Co the spectrum extends almost to zero field, in contrast to the other preparations discussed here. Note that the line shape of the 4 Å deposits shows a shoulder around 300 mT which is caused by the incoherent superposition of resonance lines of particles with different sizes.

Figure 2 shows the changes of the FMR spectra of 4 Å Co upon subsequent deposition of Pd at 300 K. The addition of 1 Å Pd results in an increase in the linewidth from 80 to 96 mT and is accompanied by a shift of the apparent resonance position from 285 to 245 mT (see Table I). Furthermore, the integral intensity of the spectrum increases by about 40%. The FMR intensity increases further upon addition of Pd and levels off after addition of about 3 Å Pd. At this point the intensity has approximately doubled (see Fig. 3). The addition of 2 Å Pd narrows the linewidth again to 80 mT and the apparent resonance position shifts back to higher fields. Further addition of Pd leads to a slight increase in linewidth as well as the resonance position which then remains constant for deposition of more than 4 Å Pd. It is important to notice that the change of the line shape is almost exclusively determined by the changes in the low field maximum, while the high field minimum shows only marginal changes in position. Particles prepared by deposition of 2 Å Co share this feature of the line shape. However, the degree of line broadening and shift of the apparent resonance posi-
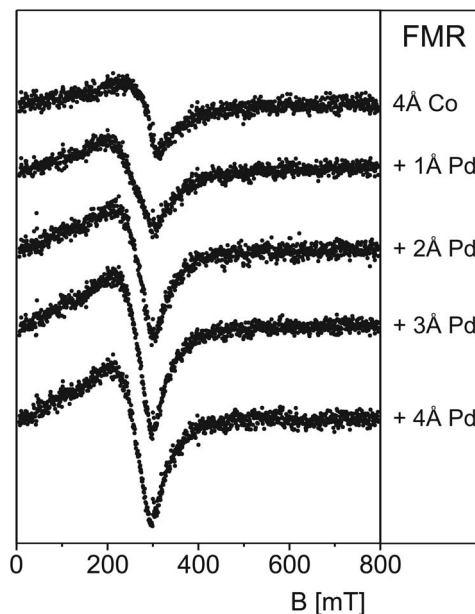
tion are less pronounced (see Table I). The system shows a maximum of linewidth and asymmetry after addition of 1 Å Pd. The change in asymmetry results in a continuous shift of the apparent resonance position, while the peak to peak linewidth shows the abovementioned maximum for 1 Å Pd. For 6 and 10 Å Co a substantial broadening of the signal is observed and the resonance is shifted monotonously toward lower field values. While the high field minimum of the spectrum shifts only slightly toward lower fields for the 6 Å case, this shift is substantial for the 10 Å deposits. In addition, the latter shows a large zero field absorption which renders a determination of a linewidth of the spectra impossible. Despite these differences in the changes in resonance position and linewidth upon Pd codeposition, the relative intensities of all systems discussed so far behave rather similar. Figure 3 shows the changes in the normalized intensity, as determined by proper double integration of the FMR spectra, with respect to the added amount of Pd for the different
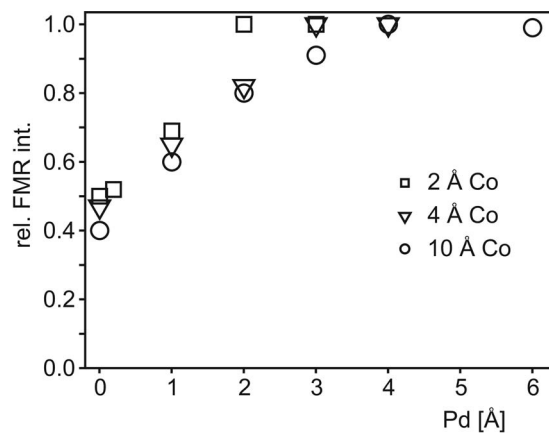

FIG. 3. Integral intensity of FMR spectra as a function of Pd (300 K) for different amounts of Co deposited on $Al_2O_3/NiAl(110)$.

TABLE I. Apparent resonance positions and linewidth for different amounts of Co and subsequent addition of Pd.

	Pristine Co		1 Å Pd		2 Å Pd		2 Å Pd		4 Å Pd	
	H_{res} (mT)	ΔH (mT)	H_{res} (mT)	ΔH (mT)	H_{res} (mT)	ΔH (mT)	H_{res} (mT)	ΔH (mT)	H_{res} (mT)	ΔH (mT)
2 Å Co	296 ± 2	55 ± 5	294 ± 2	64 ± 5	293 ± 2	58 ± 5	290 ± 2	58 ± 5	⋯	⋯
4 Å Co	285 ± 2	80 ± 5	245 ± 3	96 ± 5	258 ± 2	80 ± 5	258 ± 2	82 ± 5	253 ± 2	88 ± 5
6 Å Co	267 ± 3	93 ± 5	232 ± 3	110 ± 5	228 ± 3	135 ± 5	228 ± 3	143 ± 5	228 ± 3	173 ± 5
10 Å Co	231 ± 3	141 ± 5	200 ± 3	⋯	178 ± 3	⋯	171 ± 3	⋯	171 ± 3	⋯

systems. The FMR intensity increases by a factor of 2 for the 2 Å deposits to a factor of 2.5 for the 10 Å case after addition of 2 and 4 Å Pd, respectively.

To elucidate the origin of the intensity gain after addition of Pd, pristine Co deposits grown at 300 K are compared to systems which were subsequently annealed to 840 K prior to Pd deposition. This annealing step results in significant change in the structure of the particles. First, the particle size increases to some extent (the particle height increases by about 30%; the increase in the width is more difficult to interpret due to tip convolution effects) and concomitantly the particle density as well as the total amount of metal on the alumina surface are reduced as compared to the pristine deposits.[13] In addition, a change in the internal structure of the particles take places which can be monitored by reduction in the g-value from 2.22 for the pristine deposits to 2.18 for the annealed system.[12] This is consistent with the expectation of the redistribution toward thermodynamically favored crystalline particles. Figure 4 shows the change in the FMR signal upon annealing of a 3 Å Co deposit to 840 K and subsequent deposition of Pd. First, a reduction in the FMR intensity is observed, in line with expectations due to the reduced metal amount on the surface. In addition, the

linewidth of the signal is reduced from 61 to 38 mT and the resonance position shifts to higher field. Deposition of 1 Å Pd gives rise to an increase in the linewidth and a shift of the apparent resonance position to lower magnetic field. Upon deposition of 2 and 3 Å Pd, the line narrows slightly, while the apparent resonance position changes only very slightly (see Fig. 4). While this behavior is similar to the one observed for the pristine deposits, the integral intensity of the spectra is almost constant during the whole deposition series in sharp contrast to the pristine deposits.

For all the abovementioned experiments Pd was deposited on top of Co particles. However, it is interesting to compare this situation to particles grown by a reversal of the deposition order which gives rise to a change in the distribution of the two metals within the particles due to the tendency of Pd to segregate to the surface.[14] In the case of a reversed deposition order, it is necessary to take the different nucleation behavior of Pd into account. At 300 K Pd tends to form larger crystalline islands predominantly at the line defects of the alumina film due to its larger mobility. The
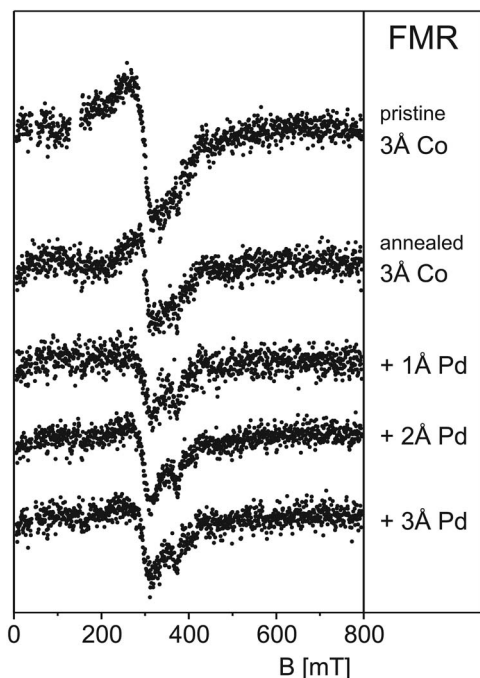

FIG. 4. FMR spectra of Pd deposited at room temperature on top of 3 Å Co deposited at previously annealed to 840 K. Spectrum of pristine 3 Å Co deposit is shown for comparison.
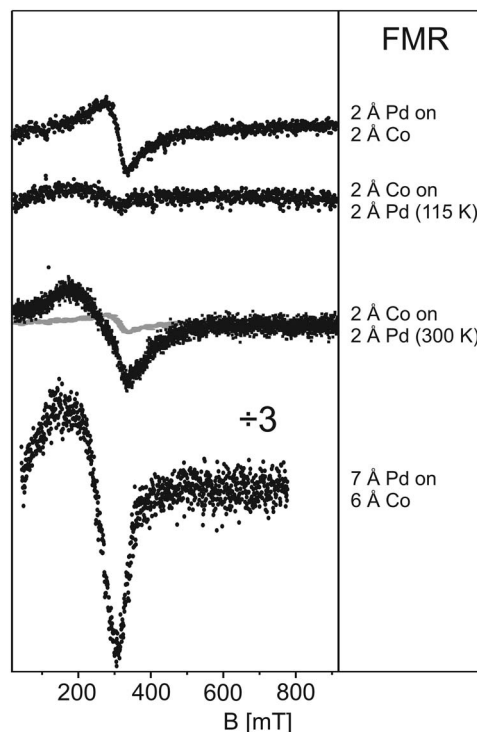

FIG. 5. FMR spectra for Co deposited at 300 K on top of Pd/Al₂O₃/NiAl(110) (115, 300 K). FMR spectra of Pd deposited at 300 K on top of Co particles grown at 300 K. Deposited amounts as given in the figure.

evaporation of 2 Å Pd leads to a cluster density which is 15%–20% of the corresponding Co density. A postdeposition of Co onto these Pd particles gives rise to pure Co particles in between the Co/Pd islands. From the difference in cluster density the number of the pure Co particles is about 25% of the number of particles for Co deposited on a pristine surface.[9] The nucleation density of Pd can be strongly enhanced by deposition at lower temperatures. At about 100 K Pd shows a similar nucleation behavior as Co at 300 K, and it was confirmed earlier that the islands remain stable up to 300 K.[15] Thus, Pd deposits at lower temperatures allow for the formation of mixed Co/Pd particles with approximately the same mixing ratio as for the reversed deposition order, but different metal distributions within the particles. In Fig. 5 FMR spectra for 2 and 4 Å Co covered with 2 Å Pd are opposed to particles prepared by deposition of 2 Å Pd at 115 K and subsequent addition of 2 or 4 Å Co at 300 K. In addition, FMR spectra measured after depositing 2 Å Co on top of Pd particles (2 Å) prepared at 300 K are shown for comparison. The spectra change significantly upon inversion of the deposition order. Comparing the two topmost situations [(1) 2 Å Pd on top of 2 Å Co; (2) 2.2 Å Co (300 K) on top of 2 Å Pd (115 K)] a strong decrease in the signal amplitude is observed upon reversal of the deposition order. Furthermore, the line shifts toward lower field and becomes more asymmetric due to a broader tail at lower fields. The spectrum observed for deposition of 2 Å Co on 2 Å Pd grown at 300 K shows the same qualitative trend, namely, a shift toward lower fields and a broadening of the FMR line. However, the FMR intensity is significantly larger as compared to the situation of Co on the Pd particles grown at 115 K. It is important to notice that the number of Co atoms per Co/Pd island is significantly larger than in both of the other cases. The part of the signal related to pure Co particles formed, because of the different mobilities of Co and Pd on the alumina surface, can be estimated from the abovementioned structural considerations and the corresponding signal is overlaid (see Fig. 5). The lowest spectrum was measured for 7 Å Pd deposited on top of 6 Å Co both grown at 300 K. This corresponds to a situation where the number of Co atoms per particle as well as the Pd/Co ratio is the same as for 2 Å Co deposited on top of 2 Å Pd grown at 300 K. However, the number of particles is a factor of 3 larger, thus the original spectrum has been scaled by a factor of 3 to account for the different total amounts.

IV. DISCUSSION

From STM data obtained for 2 Å Co deposited on the thin aluminum oxide an average particle size of 190 atoms can be estimated corresponding diameter of $\approx$16 Å assuming spherical particles.[9] Particles of this size have to be considered superparamagnetic, however, due to the particle size distribution, not all of them are in the isotropic limit of FMR spectroscopy giving rise to a size dependence of the resonance position within the ensemble. It was shown previously that this effect is responsible for the asymmetry of the linewidth observed in the spectra.[12] The pristine 2 Å Co deposit exhibits an easy axis of magnetization in the surface plane

TABLE II. Difference of resonance position measured in parallel and perpendicular orientations with respect to the surface and g-value determined by the analysis of the angular dependent resonance position.

	ΔH_{res} (mT)	g-Value
2 Å Co	9.3	2.22 ± 0.02
+1 Å Pd	12.6	2.23 ± 0.02
+3 Å Pd	17.0	2.24 ± 0.02

and small uniaxial out of plane anisotropy which is deduced from angular dependent measurements. A rather small shift in resonance position of 9.3 mT is observed (data not shown) consistent with the expected superparamagnetic behavior for the 2 Å Co particles. An analysis of the angular dependence, assuming superparamagnetic particles with a uniaxial anisotropy, results in a g-value of 2.22 ± 0.015 which is in a good agreement with previously obtained data and indicates that the structure of the clusters is perturbed as compared to bulk-like situations where a smaller g-value is expected.[12] With increasing amount of Co three-dimensional particles of increasing size are formed ranging from about 190 atoms for 2 Å Co to about 10 000 atoms for the 10 Å deposit.[16,17] Based on STM results no indication for a change in the shape of the particles can be found, which renders the size of the particle the most important aspect for the observed change in the FMR spectra of the particle ensembles.

Upon addition of Pd to 2 Å Co deposits the FMR intensity doubles after addition of 2 Å or more Pd. This increase in FMR intensity is due to an increase in the projection of the magnetization along the static magnetic field for these superparamagnetic particles. In principle this increase could either be governed by an increase in the magnetic anisotropy or by an increase in the magnetic moments of the metal particles. The observed change in the resonance positions is small (see Table II) which renders it unlikely that the effect is dominated by an increase in the anisotropy constants. This is further corroborated by the results found for the annealed system. In this case similar changes in the resonance positions as compared to the pristine deposits were observed, however, the intensity changes are small. Thus, it is concluded that the increase in the FMR intensity is mostly determined by an increase in the magnetic moment of metal particles. However, this does not rule out that changes in the magnetic anisotropy take place. The experiments of the pristine and annealed system suggest that such changes occur. However, a quantification of the effect is hampered by the size distribution of the particles which results in a mixture of dynamic (fluctuations of the magnetic moment) and static (differences in the anisotropy constants) which is difficult to disentangle. The analysis of the angular dependent measurements shows that apart from the increase in magnetization also the g-value of the particles changes slightly toward higher values from $g = 2.22 \pm 0.015$ for the pristine deposits to 2.24 ± 0.015 after addition of 3 Å Pd.

What is the microscopic origin for this increase in magnetic moment? Temperature dependent measurements have shown that this increase in the magnetization is not just due to a change of the Curie temperature; the pristine particles

have a Curie temperature well above 500 K.[12] Thus, the addition of Pd onto Co particles is connected to an enhanced magnetic moment of the particles. A similar increase in the magnetic moment has been observed for larger Co clusters on sapphire single crystal surfaces upon annealing to moderate temperatures which is explained by temperature induces structural changes of the kinetically controlled structure of the pristine deposits.[12] In the present case of a bimetallic system the situation is more complicated because of the potential interplay between structural and electronic effects of the Pd on the Co particles. One possible source would be a polarization of the Pd which has been observed, e.g., on Ni (Ref. [18]) and Fe (Ref. [19]) surfaces, and there are also reports of ferromagnetic ordering of isolated Pd nanoparticles.[20] However, in all cases the magnetic moment on Pd was restricted to a few tenth of μ_B/atom which is too small to account for the observed effect. Furthermore, the absolute change in the FMR intensity for the larger particles is about three orders of magnitude larger than for the small particles while the amount of Pd necessary to achieve this increase differs only by a factor of 2 which renders this explanation even more unrealistic for the bigger particles.

Structurally it was shown by STM that the size of the Co core remains constant when Pd is added to it.[9] As inferred from IR spectroscopy Pd tends to stay on the surface of Co particles and readily forms a core shell structure.[8] However, TPD investigations show that the binding energy of CO molecules and thus the valence band structure of Pd deposited on top of 2 Å Co are perturbed up to 3–4 Å Pd.[7] The Pd 3d XPS signal for the above mentioned system shows a significant change toward higher binding energy for the addition of small amount of Pd and shifts toward the value observed for pure Pd particles after addition of about 3–5 Å Pd. On the other hand the corresponding Co 2p signal remains virtually constant.[7] At first glance the lack of a change in the XPS signal seems to contradict an intermixture of the metal components. However, in the case of a reversed deposition of Co on Pd and a Co content of less than 50% virtually no shift of the Co 2p XPS binding energy is observed while IR spectroscopy reveals a substantial intermixture of the metal clearly showing that the XPS binding energy is not a good reporter for the presence of metal intermixing.[7,8] Additional evidence for a Pd induced change in the Co particles comes from the observed g-value. The increase in the g-value observed after addition of Pd on 2 Å Co particles indicates that Pd has not only an impact on the magnetic moment but also effects its orbital contribution. From the well known Kittel formula $(\mu_l/\mu_s=(g-2)/2)$ this increase can be associated with an enhanced orbital contribution which can be interpreted by a localization of the Co 3d states.[21] An increase in the g-value and thus the orbital contribution is in line with expectations for an intermixing of Co and Pd.[22]

Therefore, the FMR results can be understood as a Pd induced restructuring of the Co which involves some intermixing of the Pd into the Co particles, in line with the previous STM, IR, XPS, and TPD experiments. This argument is further corroborated by the comparison with the annealed sample which exhibits a more crystalline structure of the Co particles as indicated by the reduced g-value. In this situation, where the particles are thermally relaxed toward the equilibrium structure, the addition of Pd has very little impact on the FMR intensity. This can be interpreted by the formation of a Pd shell on top of the Co particles as expected based on the surface energies of the materials and corroborated by the observed change in linewidth and magnetic anisotropy, but no significant structural modifications of the Co particles. This is in line with the analysis of angular dependent spectra (data not shown) showing a constant g-value within the experimental accuracy.

The structural rearrangement of the Co particles induced by Pd will be effective for all particle sizes investigated here. For the larger particles it is important to consider the possibility of interparticle dipole-dipole interaction which will influence the FMR intensity as well as the magnetic anisotropy. After deposition of 10 Å Co the particle density is about $(1-2)\times 10^{12}$ cm^{-2}.[17] This leads to an average particle size of about 40 Å. This is about twice the average interparticle distances. Taking the Co bulk magnetization of 145 mT this results in a dipole-dipole interaction of about 20 mT. This value is of the same order of magnitude than the bulk magnetocrystalline anisotropy of Co. The addition of Pd increases the magnetization of the particles roughly by a factor of 2, thus, the dipole-dipole interaction will increase proportionally. The case of 10 Å Co is also at the edge where percolation of particles takes place. In case a Pd layer completes the percolation of ferromagnetic Co particles the coupling between the particles should increase significantly as it is observed for Co/Pd multilayered structures. However, the situation is rather complex due to the geometry of the system characterized by spherical or hemispherical particles. Some accounts of the effects of the particle shape and the corresponding thickness dependences, etc., are described in a recent paper on Co/Pd multilayers grown on spherical particles.[23]

For smaller Co particles deposition of a small amount of Pd leads to a broadening of the linewidth which in the course of further deposition decreases again. The change in linewidth is also associated with a change of the line shape which was previously shown to be a superposition of resonances for particles of different sizes.[12] The fact that the linewidth decrease after the first addition of 1 Å Pd while the apparent magnetic anisotropy increases points to the fact that the initial decoration of the Co particles with Pd leads to structurally and hence magnetically inhomogeneous particles which causes a line broadening, e.g., by enhanced damping. In this respect it is interesting to have a closer look at the role of the surface of the Co particles which are known to exhibit a substantial amount of low coordinated Co atoms. These sites were identified by their ability to form Co carbonyls upon CO adsorption.[24] It was further shown that Pd preferentially nucleates at these sites, and as little as 0.1 Å Pd on top of 2 Å Co is sufficient to reduce the formation of these carbonyl species by more than 50%. Low coordinated sites are thought to exhibit larger anisotropies as well as magnetic moments as compared to their bulk counterparts which was verified experimentally by a several groups using different techniques (e.g., Ref. [25]). The nucleation of Pd atoms to these low coordinated sites changes their coordination and

may therefore influence the magnetic properties of the particles. However, the FMR intensity as well as the line position and shape of 0.2 Å Pd grown on top of 2 Å Co shows no peculiarity as compared to the other depositions discussed before. The intensity increase slightly and the behavior fits smoothly into the curve shown in Fig. 3. Thus, these low coordinated sites do not play a prominent role in the magnetic behavior of the Co particles investigated here. This is in line with the observations for annealed particles which show a qualitatively similar behavior of the linewidth, but exhibit a significantly reduced number of low coordinated sites. On the other hand the similarity of the change in resonance position and linewidth between the pristine and the annealed samples indicates that the Pd/Co interface plays an important role for the magnetic anisotropy of the particles, despite the fact that the FMR intensity is hardly affected in the annealed case.

For the reversed deposition order IR spectroscopy proves a substantial tendency of Pd to segregate to the surface. For 2 Å Pd grown at 100 K more than 10 Å Co are needed to suppress IR signals associated with CO bound on top of Pd sites.[8] This tendency to segregate is further corroborated by XPS results.[7] Investigations on Co/Pd multilayers and Co on Pd single crystal surfaces [(100) and (111)] show that the interfacial structure plays an important role for the magnetic properties of the systems. Meyerheim *et al.* found that Co deposition on Pd(100) at 300 K leads to a fact structure of Co on the Pd surface which can be transformed into a Pd/Co/Pd(100) multilayer upon annealing to 600 K. In turn the easy axis of magnetization switches from in plane to out of plane.[3] For Co on Pd(111) an intermixing was found at the interface of the two metals.[2,26] For the particle systems investigated here, a reversed deposition order leads to a drastic change in the spectral response (see Fig. 5). Namely, a reduction of the signal intensity as well as a shift of the resonance position toward lower fields is due to an increase in the magnetic anisotropy as readily confirmed by angular dependent measurements (data not shown). The spectra are also consistent with an increase in the g-value of the system as expected for Co/Pd alloys.[22] However, a reliable determination of the g-value is not possible for systems with large magnetic anisotropies using FMR spectroscopy at a single frequency.[27] The increased asymmetry and linewidth of the spectra can be understood by an incoherent superposition of resonances caused by the distribution of size as well as chemical composition within the ensemble due to the statistical growth process. In addition structural aspects of the particles will play an important role, too. The structure of the Pd particles grown at 115 K is only metastable at 300 K and thus prone to structural changes. To this end it is interesting to compare the spectra of 2 Å Co on top of 2 Å Pd(300 K) to those of 7 Å Pd deposited on top of 6 Å Co which are characterized by the same average number of atoms and Co/Pd ratio per particle. It is clearly seen that the intensity of the FMR signal is again higher for the system with the Co core, indicating that the magnetic moment for the strongly intermixed systems is significantly smaller than for particles with a Co core containing only small amounts of Pd.

V. CONCLUSION

In conclusion we have shown that Pd deposited on top of Co particles grown at 300 K changes the magnetic properties of the Co particles considerably, in particular, with respect to the magnetic moment of the particles. This increase in the magnetic moment could be correlated to structural rearrangements within the pristine Co particles which are induced by Pd and it is likely that a smaller fraction of the Pd is not used to build a shell on top of the Co particles as inferred from XPS, STM, TPD, and IR results, but is incorporated into the Co particles to facilitate this structural rearrangements. This is corroborated by comparing the abovementioned pristine particles to structurally relaxed systems created by thermal annealing. In this case no increase in the magnetic moment was observed, however, similar changes in the resonance position and the linewidth were observed in both cases, indicating the importance of the Co/Pd interface for the magnetic anisotropy of the system. For a reversed deposition order previous experiments had already shown that a substantial intermixing of Co and Pd takes place. This intermixture of Pd and Co leads to systems with a considerably smaller magnetization. On the other hand the linewidth characterized by an inhomogeneous superposition of resonance lines indicates that the magnetic properties differ considerably within the ensemble which is due to the spread in the chemical composition and the structural inhomogeneities of these systems grown under kinetically controlled situations.

ACKNOWLEDGMENTS

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