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LAMPIRAN 1

Penamaan sampel
ZnO : ZnO tanpa doping
ZNi5 : ZnO dengan doping nikel 5% ($Zn_{0.95}Ni_{0.05}O$)
ZNi6 : ZnO dengan doping nikel 6% ($Zn_{0.94}Ni_{0.06}O$)
ZNi7 : ZnO dengan doping nikel 7% ($Zn_{0.93}Ni_{0.07}O$)
ZNi9 : ZnO dengan doping nikel 9% ($Zn_{0.91}Ni_{0.09}O$)
ZNi11: ZnO dengan doping nikel 11% ($Zn_{0.81}Ni_{0.11}O$)

Tabel 1.1 Data hasil pengujian FTIR setiap sampel

Bilangan gelombang (cm^{-1})	ZnO	ZNi5	ZNi6	ZNi7	ZNi9	ZNi11
339,4716	80,63206	91,34076	69,7627	82,31167	70,97911	69,89859
341,4004	100,0764	100,7677	99,60563	100,4915	101,2512	100,9443
343,3293	97,98985	99,00624	97,84204	98,76805	99,19375	97,84164
345,2581	95,7342	97,36711	95,77552	97,07654	97,09929	94,3101
347,1869	93,01666	95,34948	93,0128	95,05538	94,45321	89,97486
349,1157	90,29826	93,42237	90,0431	93,16683	91,69441	85,54331
351,0445	88,02372	91,9063	87,14897	91,54718	89,09189	81,27575
352,9733	86,08232	90,72798	84,36143	90,07328	86,61403	77,35218
354,9021	84,84379	90,18011	81,88108	89,01338	84,50487	74,01157
356,831	82,37524	88,16728	78,39144	86,95953	81,16129	70,06337
358,7598	79,83535	85,9322	74,87609	84,52797	77,50249	65,85938
360,6886	75,96689	82,75574	70,77779	81,21417	73,04268	61,18724
362,6174	72,10419	79,38792	66,73353	77,73996	68,39523	56,26976
364,5462	68,76117	76,22883	62,59297	74,51027	63,6641	51,63538
366,475	67,1402	74,17099	58,88144	72,3418	59,67377	47,93371
368,4039	65,5658	72,31869	54,78965	70,31599	55,59076	44,60146
370,3327	63,97019	70,42584	50,35993	68,2711	51,43415	41,19843
372,2615	61,93686	68,15765	45,40735	65,93139	47,06652	37,88614
374,1903	59,42511	65,2078	39,75806	63,07754	42,16482	34,42307
376,1191	56,85955	62,18129	34,21504	60,18724	37,4875	31,58348
378,0479	54,13148	58,92817	28,79408	56,97365	32,99237	29,05314
379,9768	50,87999	55,26548	23,57216	53,33	28,66562	26,79788
381,9056	47,46318	51,47456	18,82393	49,55679	24,77763	24,78882
383,8344	44,1112	47,82045	14,82867	45,93796	21,60201	23,21545
385,7632	40,85404	44,14348	11,44684	42,37029	18,82383	21,61777
387,692	37,4969	40,38364	8,88828	38,8681	16,62618	20,19326
389,6208	34,46792	36,81994	7,13662	35,63816	14,98737	18,8026
391,5497	31,30763	33,17021	5,66583	32,4441	13,46302	17,39608
393,4785	28,02551	29,4993	4,65969	29,35871	12,19939	16,08528
395,4073	24,7777	25,98694	4,12288	26,49645	11,24653	15,00498

LAMPIRAN 2

Tabel 2.1. Data hasil pengujian XRD setiap sampel

2θ	**ZnO**	**ZNi5**	**ZNi6**	**ZNi7**	**ZNi9**	**ZNi11**
10	70	83	88	103	85	91
10,02	59	101	86	83	79	107
10,04	50	100	82	85	66	100
10,06	59	83	88	90	59	108
10,08	59	95	105	91	70	93
10,1	51	100	56	90	70	89
10,12	46	92	68	78	78	89
10,14	53	84	83	89	71	105
10,16	75	110	90	96	82	113
10,18	53	114	92	95	76	89
10,2	48	90	78	84	65	111
10,22	63	105	85	75	68	101
10,24	70	87	78	78	80	98
10,26	65	101	77	89	71	106
10,28	62	103	85	87	82	99
10,3	44	84	91	78	74	102
10,32	55	124	76	96	51	102
10,34	55	110	75	92	71	109
10,36	77	92	90	92	68	108
10,38	55	118	94	83	83	102
10,4	67	86	102	74	77	114
10,42	64	77	71	85	60	112
10,44	55	97	95	83	71	102
10,46	65	104	88	98	84	121
10,48	42	105	72	108	77	98
10,5	64	107	100	105	84	103
10,52	54	95	71	85	69	86
10,54	62	103	97	90	63	85
10,56	45	94	76	94	65	117
10,58	60	94	86	87	53	90
10,6	71	102	91	91	70	99
10,62	55	102	94	103	77	102
10,64	60	123	74	89	85	133
10,66	58	98	87	91	79	108
10,68	52	102	99	95	72	103
10,7	49	88	89	87	89	103
10,72	62	116	107	93	86	121

LAMPIRAN 3

Analisis Data XRD untuk mengetahui ukuran kristal dan regangan kisi

Untuk sampel $Zn_{0,95}Ni_{0,05}$

A. Menggunakan persamaan Debye Scherrer

Ukuran kristal menggunakan persamaan (4.1)

$$D = \frac{k\,\lambda}{\beta \cos\theta}$$

$$D = \frac{0,98\;(0,154)}{(0,00444)\cos(0,277041697)}$$

$$D = \frac{0,15092}{(0,004269467)}$$

$$D = 35,34867467 \text{ nm}$$

Regangan kisi menggunakan persamaan (4.2)

$$\varepsilon = \frac{\beta}{4\,tan\theta}$$

$$\varepsilon = \frac{0,004438721}{4\,tan\,(0,277041697)}$$

$$\varepsilon = 0,003902459$$

Tabel 3.1. Analisis data XRD menggunakan metode Debye Scherrer

2 theta (deg)	2 theta (rad)	cos theta	FWHM (deg)	FWHM (rad)	k	λ	D (nm)	Regangan
31,76	0,554298768	0,961868775	0,25069	0,00444	0,98	0,154	35,34867075	0,003902459
34,43	0,600863454	0,955230558	0,25524	0,00473	0,98	0,154	33,37271002	0,00382125
36,25	0,632623734	0,950424189	0,27588	0,00492	0,98	0,154	32,25142157	0,003762171
47,56	0,830058521	0,915150682	0,31087	0,00559	0,98	0,154	29,52382071	0,003170214
56,62	0,988250452	0,880446571	0,35264	0,00618	0,98	0,154	27,74675735	0,002867894
62,90	1,097892036	0,853149711	0,38607	0,00733	0,98	0,154	24,12347194	0,002998157
67,99	1,186661576	0,836690719	0,4231	0,00672	0,98	0,154	26,82915068	0,002567772
69,13	1,206627793	0,829130816	0,44631	0,00757	0,98	0,154	24,05399122	0,002805727
66,44	1,159515597	0,823532796	0,3974	0,00762	0,98	0,154	24,03951969	0,002766765
Rata-rata							**28,58772377**	**0,003184712**

B. Menggunakan metode Williamson Hall (UDM)

Ukuran kristal sebagai berikut :

$$D = \frac{k\,\lambda}{(intercept)}$$

$$D = \frac{0{,}98\ (0{,}154)}{0{,}00236}$$

$$D = 63{,}949152542$$

Untuk nilai regangan (ε) diperoleh dengan memplot $\beta \cos \theta$ terhadap 4 tan θ. Dimana berdasarkan persamaan garis nilai slope diperoleh yaitu 0,00166.

Tabel 3.2. Analisis data XRD menggunakan metode Williamson Hall

2 theta (deg)	**2 theta (rad)**	**cos theta (rad)**	**sin theta (rad)**	**FWHM (deg)**	**FWHM (rad)**	**k**	$\boldsymbol{\lambda}$	$\boldsymbol{x = 4\ sin\theta}$	$\boldsymbol{y = \beta\ cos\theta}$
31,76	0,554298768	0,961868775	0,27351135	0,25069	0,00444	0,98	0,154	1,094045402	0,004269467
34,43	0,600863454	0,955230558	0,295862436	0,25524	0,00473	0,98	0,154	1,183449743	0,004522258
36,25	0,632623734	0,950424189	0,310956366	0,27588	0,00492	0,98	0,154	1,243825465	0,004679484
47,56	0,830058521	0,915150682	0,403111931	0,31087	0,00559	0,98	0,154	1,612447723	0,005111805
56,62	0,988250452	0,880446571	0,474145374	0,35264	0,00618	0,98	0,154	1,896581497	0,005439194
62,90	1,097892036	0,853149711	0,521666149	0,38607	0,00733	0,98	0,154	2,086664597	0,006256148
67,99	1,186661576	0,836690719	0,547675672	0,4231	0,00672	0,98	0,154	2,190702686	0,005625225
69,13	1,206627793	0,829130816	0,55905464	0,44631	0,00757	0,98	0,154	2,236218561	0,006274219
66,44	1,159515597	0,823532796	0,567268662	0,3974	0,00762	0,98	0,154	2,269074647	0,006277996

LAMPIRAN 4

Tabel 4.1. Data hasil pengujian bandgap untuk setiap sampel

λ	ZnO		ZNi5		Zni6		ZNi7		ZNi9		ZNi11	
	$h\upsilon$	$\alpha h\upsilon^2$	$h\upsilon$	$\alpha h\upsilon^2$	$h\upsilon$	$\alpha h\upsilon^2$	$h\upsilon$	$\alpha h\upsilon^2$	$h\upsilon$	$\alpha h\upsilon^2$	$h\upsilon$	$\alpha h\upsilon^2$
300	0,932	4,0343	0,28	4,13333	0,934	3,93437	0,089	4,13333	0,02	4,13333	0,956	4,12774
301	0,857	4,02056	0,29	4,1196	0,859	3,92064	0,089	4,1196	0,019	4,1196	0,885	4,11401
302	0,788	4,00692	0,28	4,10596	0,79	3,907	0,088	4,10596	0,018	4,10596	0,811	4,10037
303	0,725	3,99337	0,27	4,09241	0,729	3,89345	0,087	4,09241	0,018	4,09241	0,75	4,08682
304	0,667	3,97991	0,27	4,07895	0,67	3,87999	0,087	4,07895	0,019	4,07895	0,691	4,07335
305	0,611	3,96654	0,25	4,06557	0,614	3,86661	0,086	4,06557	0,018	4,06557	0,634	4,05998
306	0,56	3,95325	0,25	4,05229	0,567	3,85333	0,086	4,05229	0,019	4,05229	0,586	4,0467
307	0,516	3,94005	0,23	4,03909	0,518	3,84013	0,085	4,03909	0,019	4,03909	0,54	4,0335
308	0,472	3,92694	0,21	4,02597	0,472	3,82701	0,084	4,02597	0,017	4,02597	0,495	4,02038
309	0,43	3,91391	0,21	4,01294	0,434	3,81398	0,082	4,01294	0,017	4,01294	0,455	4,00735
310	0,394	3,90096	0,19	4	0,396	3,80104	0,082	4	0,018	4	0,417	3,99441
311	0,361	3,8881	0,19	3,98714	0,363	3,78818	0,083	3,98714	0,018	3,98714	0,383	3,98155
312	0,332	3,87532	0,19	3,97436	0,334	3,7754	0,082	3,97436	0,017	3,97436	0,353	3,96877
313	0,305	3,86262	0,17	3,96166	0,306	3,7627	0,082	3,96166	0,017	3,96166	0,325	3,95607
314	0,277	3,85001	0,15	3,94904	0,278	3,75008	0,08	3,94904	0,016	3,94904	0,296	3,94345
315	0,253	3,83747	0,16	3,93651	0,256	3,73755	0,081	3,93651	0,017	3,93651	0,274	3,93092
316	0,233	3,82501	0,14	3,92405	0,234	3,72509	0,08	3,92405	0,016	3,92405	0,254	3,91846
317	0,214	3,81263	0,15	3,91167	0,214	3,71271	0,081	3,91167	0,016	3,91167	0,233	3,90608
318	0,195	3,80033	0,14	3,89937	0,196	3,70041	0,08	3,89937	0,017	3,89937	0,215	3,89378
319	0,177	3,78811	0,12	3,88715	0,179	3,68819	0,079	3,88715	0,015	3,88715	0,197	3,88155
320	0,162	3,77596	0,11	3,875	0,163	3,67604	0,079	3,875	0,015	3,875	0,181	3,86941

321	0,147	3,76389	0,09	3,86293	0,149	3,66397	0,078	3,86293	0,015	3,86293	0,167	3,85734
322	0,135	3,75189	0,08	3,85093	0,135	3,65197	0,077	3,85093	0,013	3,85093	0,154	3,84534
323	0,122	3,73997	0,07	3,83901	0,123	3,64005	0,078	3,83901	0,015	3,83901	0,141	3,83342
324	0,11	3,72812	0,07	3,82716	0,112	3,6282	0,077	3,82716	0,015	3,82716	0,13	3,82157
325	0,099	3,71635	0,06	3,81538	0,101	3,61642	0,076	3,81538	0,013	3,81538	0,118	3,80979
326	0,09	3,70464	0,06	3,80368	0,091	3,60472	0,076	3,80368	0,012	3,80368	0,108	3,79809
327	0,08	3,69301	0,06	3,79205	0,082	3,59309	0,075	3,79205	0,012	3,79205	0,1	3,78646
328	0,072	3,68145	0,04	3,78049	0,073	3,58153	0,076	3,78049	0,012	3,78049	0,091	3,7749
329	0,066	3,66996	0,05	3,769	0,067	3,57003	0,075	3,769	0,012	3,769	0,084	3,7634
330	0,06	3,65854	0,04	3,75758	0,061	3,55861	0,076	3,75758	0,012	3,75758	0,077	3,75198

LAMPIRAN 5

Tabel 5.1. Data hasil pengujian spektrofotometer UV-VIS pada sampel ZnO doping Ni 5%

Panjang Gelombang (nm)	Absorbansi				
	0 menit	**15 menit**	**30 menit**	**45 menit**	**60 menit**
300	1,557	0,042	1,28	0,057	1,039
301	1,498	0,04	0,962	0,056	0,966
302	1,425	0,041	0,89	0,056	0,898
303	1,382	0,04	0,83	0,055	0,833
304	1,328	0,04	0,77	0,055	0,778
305	1,288	0,04	0,715	0,055	0,719
306	1,248	0,039	0,666	0,054	0,674
307	1,22	0,039	0,621	0,054	0,627
308	1,183	0,04	0,58	0,054	0,585
309	1,155	0,039	0,539	0,053	0,542
310	1,119	0,039	0,503	0,052	0,508
311	1,102	0,038	0,47	0,052	0,473
312	1,077	0,038	0,44	0,051	0,441
313	1,06	0,038	0,413	0,05	0,413
314	1,046	0,038	0,386	0,051	0,388
315	1,024	0,038	0,363	0,05	0,363
316	1,011	0,037	0,343	0,05	0,341
317	0,998	0,037	0,321	0,049	0,32
318	0,989	0,037	0,303	0,049	0,303
319	0,98	0,036	0,286	0,048	0,285
320	0,975	0,036	0,271	0,047	0,268
321	0,966	0,035	0,256	0,046	0,253
322	0,96	0,035	0,244	0,047	0,24
323	0,95	0,034	0,23	0,045	0,225
324	0,945	0,034	0,218	0,044	0,213
325	0,946	0,034	0,208	0,044	0,203
326	0,941	0,033	0,198	0,043	0,192
327	0,941	0,033	0,19	0,044	0,182
328	0,941	0,033	0,182	0,043	0,174
329	0,94	0,033	0,174	0,042	0,166
330	0,938	0,031	0,167	0,04	0,158
331	0,94	0,031	0,161	0,04	0,152
332	0,945	0,03	0,153	0,04	0,144
333	0,94	0,03	0,148	0,039	0,138
334	0,937	0,03	0,142	0,039	0,132
335	0,942	0,028	0,136	0,037	0,127

336	0,949	0,028	0,133	0,037	0,122
337	0,945	0,027	0,127	0,035	0,116
338	0,949	0,027	0,124	0,035	0,113
339	0,948	0,027	0,121	0,034	0,109
340	0,945	0,026	0,117	0,033	0,104
341	0,941	0,025	0,113	0,033	0,1
342	0,939	0,025	0,11	0,033	0,097
343	0,936	0,025	0,108	0,032	0,093
344	0,933	0,025	0,105	0,032	0,092
345	0,933	0,024	0,102	0,03	0,088
346	0,927	0,023	0,099	0,03	0,085
347	0,925	0,023	0,098	0,029	0,083
348	0,921	0,022	0,095	0,029	0,081
349	0,915	0,022	0,094	0,028	0,079
350	0,91	0,021	0,092	0,027	0,076
351	0,902	0,021	0,091	0,027	0,075
352	0,896	0,02	0,089	0,027	0,073
353	0,889	0,02	0,088	0,026	0,072
354	0,879	0,02	0,087	0,026	0,07
355	0,869	0,019	0,086	0,025	0,069
356	0,86	0,019	0,085	0,025	0,067
357	0,851	0,019	0,084	0,025	0,066
358	0,842	0,018	0,083	0,024	0,066
359	0,831	0,019	0,082	0,023	0,064
360	0,821	0,018	0,081	0,023	0,062
361	0,806	0,018	0,081	0,023	0,062
362	0,796	0,017	0,08	0,023	0,061
363	0,788	0,017	0,079	0,022	0,059
364	0,774	0,017	0,078	0,021	0,059
365	0,761	0,018	0,079	0,021	0,058
366	0,749	0,017	0,078	0,021	0,057
367	0,736	0,017	0,078	0,021	0,055
368	0,725	0,016	0,078	0,02	0,055
369	0,713	0,016	0,078	0,019	0,053
370	0,702	0,016	0,078	0,019	0,053
371	0,691	0,016	0,078	0,019	0,052
372	0,679	0,015	0,078	0,019	0,052
373	0,668	0,016	0,079	0,018	0,051
374	0,657	0,015	0,079	0,018	0,05
375	0,646	0,014	0,079	0,018	0,049
376	0,636	0,015	0,079	0,017	0,048
377	0,626	0,014	0,078	0,018	0,048
378	0,615	0,014	0,078	0,017	0,048

LAMPIRAN 6

A. Analisis persentase degradasi limbah Congo red untuk sampel ZnO doping nikel 5%

Persentasi degradasi dapat dihitungan dengan persamaan sebagai berikut:

$$Persentasi\ degradasi\ (\%) = \frac{Co - Ct}{Co} \times 100\%$$

Persentasi degradasi untuk sampel $Zn_{0,95}Ni_{0,05}$ pada menit ke 15 dengan konsentrasi awal (Co) 1,295 dan konsentrasi pengukuran (Ct) 0,022 maka berdasarkan hasil perhitungan diperoleh :

$$Persentasi\ degradasi\ (\%) = \frac{1,295 - 0,022}{1,295} \times 100\%$$

$$Persentasi\ degradasi\ (\%) = \frac{1,273}{1,295} \times 100\%$$

$$Persentasi\ degradasi\ (\%) = 98,301\%$$

Tabel 6.1. Persentasi degradasi Congo red yang ditambangkan Ni 5%

Nama Sampel	**Co**	**Ct1 (15 menit)**	**Ct2 (30 menit)**	**Ct3 (45 menit)**	**Ct4 (60 menit)**	**% Degradasi (15 menit)**	**% Degradasi (30 menit)**	**% Degradasi (45 menit)**	**% Degradasi (60 menit)**
ZNi1	1,295	0,16	0,155	0,154	0,152	87,645	88,031	88,108	88,26255
ZNi2	1,295	0,022	0,048	0,012	0,04	98,301	96,293	99,073	96,9112
ZNi3	1,295	0,104	0,059	0,016	0,048	91,969	95,444	98,764	96,29344
ZNi4	1,295	0,03	0,092	0,111	0,11	97,683	92,896	91,429	91,50579
ZNi5	1,295	0,02	0,042	0,035	0,065	98,456	96,757	97,297	94,98069
ZNi6	1,295	0,039	0,079	0,069	0,077	96,988	93,899	94,672	94,05405

B. Kinerja fotokatalis sampel ZnO doping Ni terhadap waktu degradasi limbah Congo red diperoleh dari persamaan sebagai berikut:

$$Efisiensi\ degradasi\ = \frac{Ct}{Co}$$

Kinerja fotokatalis untuk sampel $Zn_{0,95}Ni_{0,05}$ pada menit ke 15 dengan konsentrasi awal (Co) 1,295 dan konsentrasi pengukuran (Ct) 0,022. Dimana nilai Ct dan Co diperoleh dari tabel sebelumnya, maka berdasarkan hasil perhitungan diperoleh :

$$Efisiensi\ degradasi\ = \frac{0{,}022}{1{,}295}$$

$$Efisiensi\ degradasi\ = 0{,}016988417$$

C. Laju kinetik fotokatalis terhadap waktu degradasi limbah Congo red diperoleh dari persamaan sebagai berikut:

$$Laju\ Kinetik\ sampel\ =\ (kt) = ln\frac{Co}{Ct}$$

Laju kinetik fotokatalis untuk sampel $Zn_{0,95}Ni_{0,05}$ pada menit ke 15 dengan konsentrasi awal (Co) 1,295 dan konsentrasi pengukuran (Ct) 0,022. Dimana nilai Ct dan Co diperoleh dari tabel sebelumnya, maka berdasarkan hasil perhitungan diperoleh :

$$Laju\ Kinetik\ sampel\ =\ (kt) = ln\frac{1{,}295}{0{,}022}$$

$$Laju\ Kinetik\ sampel\ =\ (kt) = 4.07522352$$

Tabel 6.1. Efisiensi degradasi dan laju kinetic fotokatalis untuk setiap sampel

Nama Sampel	Co	Ct/Co				ln Co/Ct			
		15 menit	**30 menit**	**45 menit**	**60 menit**	**15 menit**	**30 menit**	**45 menit**	**60 menit**
ZNi1	1,295	0,123552	0,119691	0,118919	0,117375	2,09109216	2,12284086	2,12931337	2,142385
ZNi2	1,295	0,016988	0,037066	0,009266	0,030888	4,07522352	3,29506496	4,68135932	3,477387
ZNi3	1,295	0,080309	0,04556	0,012355	0,037066	2,52187507	3,08872853	4,39367725	3,295065
ZNi4	1,295	0,023166	0,071042	0,085714	0,084942	3,76506859	2,6444774	2,45673577	2,465786
ZNi5	1,295	0,015444	0,032432	0,027027	0,050193	4,1705337	3,42859636	3,61091791	2,991879
ZNi6	1,295	0,030116	0,061004	0,053282	0,059459	3,50270433	2,79681812	2,93215947	2,822461

LAMPIRAN 7

Tabel. 7.1. Persentasi degradasi terhadap waktu siklus 45 menit dengan variasi konsentrasi *Congo Red*

Variasi *Congo Red*	Co	Ct1	Ct2	Ct3	Ct4	Ct5	% Degradasi 1	% Degradasi 2	% Degradasi 3	% Degradasi 4	% Degradasi 5
0,04 gr	1,095	0,039	0,051	0,151	0,165	0,432	96,438	95,342	86,210	84,932	60,548
0,06 gr	2,143	0,066	0,122	0,193	0,28	0,449	96,920	94,307	90,994	86,934	79,048
0,08 gr	2,555	0,21	0,447	0,511	0,534	1,007	91,781	82,505	80,000	79,100	60,587
0,10 gr	2,954	0,088	0,524	0,551	0,572	0,576	97,021	82,261	81,347	80,636	80,501